Soils and Fertilizers for Public Schools

CHARLES L. QUEAR

SOILS AND FERTILIZERS

FOR PUBLIC SCHOOLS

A Discussion Upon the Nature and Treatment of Soils and the Value of Fertilizers

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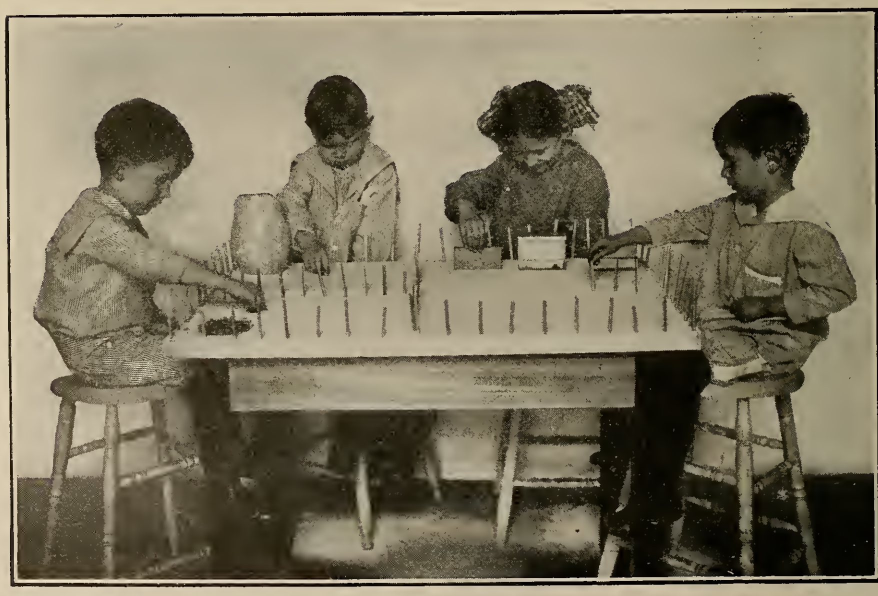
UNDIRECTED PLAY



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INTRODUCTION.

There has been much objection to the teaching of Agriculture in our District Schools, because teachers claim they do not have time to take up an additional subject, when they have so many subjects that are already required, and which must be taught. However, in recent years Agriculture has been coming into its own, and is being taught more and more in the schools. Teachers have begun to realize that any subject which holds the interest and attention of the pupils is worth while, and that any subject which does not hold their attention is not worthy of a place in our already crowded school course.

In order to make Agriculture interesting to the pupil, we must base the work upon real practical problems which he can understand and appreciate. To do this is no small task, and it is a thing which demands a great deal of perseverance and initiative, on the part of teachers in such schools.

The more ideas which an author attempts to incorporate into a text book, the more complex his text becomes, and the more difficult it is to follow. Therefore, in this text book we have taken only a few of the most important conditions and have tried to incorporate them in such a manner that they can be used by the average district or graded school. We have tried further to make the book correct—theoretically and practically. The entire text has been written for boys and girls of the country schools, with these two things in mind, and the success which attends its use presupposes a proper presentation of many minor details, which it would be impossible to include under this cover.

Many teachers get the idea that the subject of Agriculture as taught in our public schools is a Vocational Subject. This is a mistaken idea, and the teachers should above all bear in mind that we are not making better farmers so much as we are making better men and women who are farmers. Naturally the teaching of Agriculture will make better farmers, and will serve to keep more of our boys on the farm.

FOR THE TEACHER.

The contents of the following pages give only a small portion of the great facts which can be brought to bear upon the subjects under discussion. Neither space, nor purpose permits more elaboration in this book, but the teacher in adjusting its contents to his immediate needs, can condense or elaborate the topics at will.

The author has attempted to give the most vital facts and to present them in a logical order. It remains largely with the teacher, however, to demonstrate the value of the following pages, and this requires enthusiasm. This text presupposes that it will fall into the hands of willing people who have unbounded enthusiasm. If such persons use the following lessons as directed, supplementing them with their own judgment, much good will result.

It is presumed that the interested teacher desires to do and know more than he is expected to teach, and for that reason we are furnishing a list of references which may be used for the personal benefit of the teacher, or class, or both. These references are valuable merely as an index to more elaborate stores of knowledge upon the subjects at hand. They are worth the time of both the teacher and student, if it is possible for either to study them.

The experiments and questions at the end of each chapter should be worked by the teacher, before they are presented to the class.

There are given pictures and specifications of many handy devices, which the pupils may make either at home or at school. This work will furnish a method of correlating actual hand work with the Agricultural Principles. If possible, pupils should be encouraged to make the things mentioned, or, at least, some of them.

Other handy devices may be designed by the pupils and teacher at their option. The work given in this phase of the subject is merely a beginning, and can be made as elaborate and extensive as the teacher desires. The devices given here do not demand expensive or uncommon material, or large shops, and as many teachers' difficulties as possible have been avoided in their designing.

There will be difficulties peculiar to each community, which must be overcome, but it is hoped that the ingenuity of the teacher will prevail over all such inconveniences. A course would not be a success, unless difficulties were encountered. It will not be a success, unless these handicaps are, at least, partially mastered.

One of the greatest aids to a successful course is a good note-book properly kept. *Properly kept* means written in a clear, legible hand, in ink, and at all times up to the last assigned lesson. Keep an accurate check on all note-books, and do not let students get behind in this phase of the work. Nothing destroys interest so quickly as getting behind. Have the pupils put the results of all experiments and observations in their note-books; also drawings of apparatus will help such a book. Link your drawing work with Agriculture and both subjects will be improved by the union. Do not make note-book work copy work. Copying a line here and there from a text book does not make a note-book. Have the note-books always ready for inspection, and inspection will seldom be necessary.

One of the greatest aids in note-book work is a camera, if it can be had. The use of a camera in a course on soils registers accurately many conditions that can not be described in words. A few photographs placed in a note-book, showing the things under discussion, are an invaluable asset to every student.

Know just where you are, and what you are going to do next, and your laboratory work will be the feature of the course. Do not skip the questions. They are the clinchers which hold the fabric together. Leave them out and your structure can not be well built, pedagogically or scientifically.

Let your pupils be participants rather than spectators. If you make them feel that they have a part to play their respect for the work will never lag.

To learn to know by doing is to see, to know, and to do.

For a number of very valuable illustrations used in this text, the Editor is indebted to the following: Purdue Experiment Station, Lafayette, Indiana; Independent Harvester Co., Plano, Illinois; Cornell Experiment Station, Ithaca, New York; International Harvester Co., Chicago, Illinois.

CHAPTER I

CONDITIONS NECESSARY FOR PLANT LIFE.

Introduction: A little plant is a wonderful thing. It comes as you know, from a little seed which seems as dead as a grain of sand. It grows, produces flowers and fruit and becomes a thing of both beauty and value.

Fairy stories are interesting, but they are less interesting and certainly not so true as the history of the most humble plant. In your story books your characters are able to run about and to do great and marvelous things, but in your Agricultural work, you will find while plants can not move about they can do many things that no man has ever yet been able to do.

The Conditions Necessary for Plant Growth: Plants grow in practically every part of the world, from the torrid regions at the equator to the frigid zone of the arctic circle. The conditions, as far as climate is concerned, are very different. However, in a small degree, the same conditions exist at one place as at the other. All plants must have moisture, warmth, air, plant food and some sort of mechanical support.

The plants at the equator you know have plenty of warmth. Strange as it may seem those at the arctic circle also have warmth, although not so much.

The plants which grow in our own fields have a great deal of moisture; also the cactus which grows on the dry and barren desert has moisture, although we usually think of it as growing without this necessary element. It has adapted itself to such a degree that it needs only a little moisture, but moisture it must have, for that is one of the conditions necessary for life.

The leaves of most all plants are fortunately blessed with air, but the mechanical support of plants differs greatly. We usually give the mechanical support of plants small consideration, but at one time—as you will learn in a later paragraph—it was possibly the most important function the soil performed.

We will take up each condition necessary for plant growth and discuss briefly its value.

Work Required to Produce a Rain: We think very little of a rain or shower, as we watch it fall, but did you ever stop to think what a great task has been performed when even a little rain falls? The rain which falls on an acre of ground during a gentle shower weighs thousands and thousands of pounds. The farmer says he is very busy in the spring, getting ready to till his ground and plant his crops, but the water which Nature brings in one day is more than he could haul and put on his ground in one whole spring. In some places Nature does not bring the water for the crops, and put it on the soil in the form of rain. Men have to dig ditches and turn the water from streams into them to water the crops. This is called Irrigation, and costs the farmers thousands and thousands of dollars. So when we see the rain we must remember that by means of sunshine and air Nature is doing a great and good work for the farmer by supplying the little plants with water.

Moisture and Warmth: A little seed dropped into the soil without the knowledge of any human being—it was neither planted nor sown by mankind, but was distributed by one of Nature's agencies. There it lay in the soil all winter; it did not change, and appeared to be no different from the soil grains with which it mixed. You could not have found it, unless you had examined the soil very, very carefully, and you would even then have needed a microscope. But let us see what happens when Spring comes.

What Happens to the Seed: When Spring comes, this little seed, lying so quietly in the soil, becomes warm, and begins to take up the moisture. Both of these conditions—moisture and heat—come with the Spring. The seed requires heat before it will absorb moisture, and it requires moisture as soon as it becomes warm. As the seed becomes warm it drinks very greedily.

The soil is so warm and comfortable in the Spring after a long and cold winter that the seed drinks very much, and since it can not stretch the seed covering, it bursts. This accident, however, is not so very unfortunate, for although it destroys the seed it liberates the little plant which has been locked up, so it at once begins to grow. We see now that warmth and water have unlocked the door which kept the little plant imprisoned. Before the little plant can reach the sunshine, or can be seen by man, it must grow to a much larger plant than it is at this time. Of course, it can not grow without food, and being so small, it is unable to get food for itself.

Where the Little Plant Gets Food: In searching for food this infant plant finds that the mother plant has filled its cradle home entirely full of the best food imaginable. The parent has furnished the food, so that all the plant has to do is to eat and grow. While it is growing and living on the food already furnished, it begins to send out little rootlets and a little stem with small leaves on it. The stem and leaves push upwards towards the sunlight while the roots seek to bury themselves deeper and deeper in the warm moist soil in search of water and food.

It seems that a plant would not send its leaves toward the light and the roots into the ground if the seed were planted up side down. However, the plant, as we have said, is a wonderful thing, and no difference which way we turn the seed, the little plant will push its leaves and stem upward towards the light and the roots downward into the ground. This is shown in Fig. 1.

Use of the Parts of a Plant: Not only does the little plant send each of its parts on its own special way, but it sends each to do certain things for the life of the plant. The little plant sends its leaves towards the sun to get light, heat and air, for air is usually present where there is plenty of light. It sends the little roots into the ground to get food and water, and to give the plant support, so that it can stand up strong and straight.

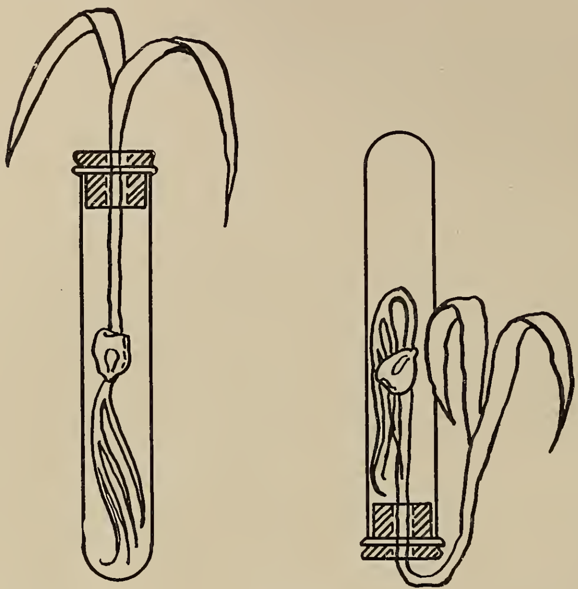


FIG. 1.
The above shows that regardless of the position in which a plant is placed, its roots will grow downward and its stem and leaves upward.

The plant must have all of these conditions — heat, light, water, air and mechanical support—to grow and live, so it has good reason for developing roots and leaves while it is living on the food provided by the mother. When this food is gone, it will have to live upon its own resources and to do this it will have to have the roots and leaves; the roots to gather food and water; and the leaves to gather air and to manufacture food, by the aid of sunlight.

Air in Relation to Plant Life: It seems strange that leaves are put forth to obtain food from the air, yet that is what they do. As a man could not live without lungs, so a plant could not live without leaves. The leaves breathe just as animals breathe, but they do not use the same foods from the air that animals do. The leaves take carbon out of air in the form of carbon dioxide, and build it into their plant body.

Carbon: Carbon in the air is a gas and is found united with oxygen. This carbon and oxygen gas, called carbon dioxide, is taken into the plant through the leaves. The leaves use the carbon and throw off the oxygen.

The carbon is built into the plant and makes about one-half of the dry or woody portion of the plant. A good example of the carbon found in plants is coal. Coal is almost pure carbon which is left when plants die. When this coal is burned most of it, in the form of gas, passes into the air from whence it came.

Although this seems impossible, with a little study you can see that carbon as gas goes into a plant and is formed into a solid, which can be burned as wood or coal when the plant dies and becomes dry. When burned the carbon in the plant goes back into the air as carbon dioxide gas, and is again ready to be used by a growing plant.

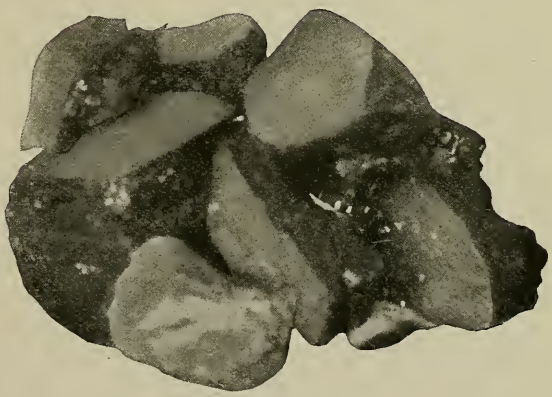


FIG. 2.
The principal part of this coal, the carbon, was taken from the air by the growing plant, and will be returned to the air when the coal is burned.

Do not forget the fact, that through all of its changes, none of the carbon is really destroyed. From the time it enters the plant until it escapes there is no loss and no change except in its form. Any substance may be changed but no substance can ever be destroyed.

Relationship Between Plants and Animals: Another valuable thing that we should know is that while plant leaves absorb carbon dioxide gas (carbon and oxygen mixed) and throw off oxygen, animals breathe oxygen and throw off carbon dioxide. Thus plants throw off a gas which animals use, while animals give off the proper gas for plants.

Don't you think that Nature has been very wise in covering the earth with both plants and animals?

Did you ever regard plants as your friends, in the respect that they are working all of the time to furnish you not only substances to eat but air to breathe?

Also the air carries the great amount of water which falls upon the soil and feeds the plants. Water always exists as a part of the atmosphere. Water may be seen passing into the atmosphere by noticing the spout of a tea-kettle while the water is boiling.

The Amount of a Plant That Comes From the Air: When we sum up all the parts of a plant that come from the air, we find that about 97% of a plant has existed at some time as air. The picture below shows you how much this amount really is. The white corner shows what part of the plant comes from the soil particles. The large black portion of the square shows the amount that comes from the air.

FIG. 3.
Percentage of mineral matter in plants.

The air is a very complex and interesting substance, and contains many gases each of which plays its important part in the life processes of plants and animals. To fully understand the air and the part it plays in Agriculture, we would be compelled to study separately each of the gases, of which it is composed.

It is like the large black locomotive; very interesting, but to be fully understood, so that we may appreciate it, each part must be studied so that we may see what will happen when any one part is disturbed.

Water in the Air: If we were to separate the atmosphere into its various parts we would find water vapor to be one of the principal compounds which is present. This water is obtained by the roots of the plants after it has fallen as rain. Of the substances existing in the air only two are used directly by the plant. One is Carbon Dioxide, which is Carbon and Oxygen, and the other is Nitrogen. We will give special attention to these when we study Plant Foods.

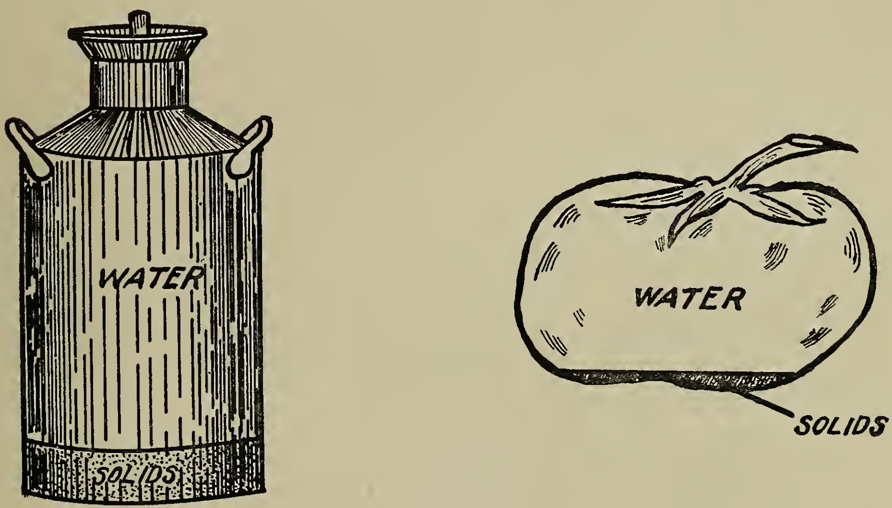


FIG. 4.
The percentage of water in a tomato is larger than in milk.

Water in Relation to Plant Life: Although the water which a plant uses comes from the soil, it is made up of two gases and was, therefore, a part of the atmosphere. These gases which make water are Hydrogen and Oxygen. They unite in the form of water, and are taken into the plant in this united form.

Water as a Food: Plants use water as a food just the same as animals do. They build water into their cells until finally the largest part of the plant is water; in fact, over seven-tenths of the average growing plant is water. Think of cutting a hundred pounds of hay to find that you had seventy or more pounds of water, the same as you get from the well.

There is more water in a large ripe tomato than there is in an equal weight of milk, yet we drink the milk and eat the tomato. The solid material is in solution in the milk, while in the tomato it forms a network of peeling and fibre, which holds the mass in a solid form. The preceding picture shows you the percentage of water in a ripe tomato and in a can of milk.

Water as the Blood of the Plant: Not only is water used as food for the plant, but it is the thing that carries all of the other foods to the plant. It performs the same tasks for the plants that our blood performs for us. Since plants can not eat solid food, the water must dissolve the food from the soil and take this food with it into the plant so that the plant can live. Since each drop of water will carry only a very little food, a great deal of water must pass through the plant to furnish all of the food that the plant needs. From three to five hundred pounds of water must pass through the plant to produce one pound of plant. This gives an idea what a large amount of water is required to produce even an ordinary crop. Since a plant needs so much water, and since it does most of its growing during the warm summer months, when very little rain is falling, we can at once see that the problem of how to keep the water that falls as rain on the soil is as great as any problem in all Agriculture.

How Water Gets Into the Plant: Since water is found in the air we sometimes think that it gets into the plants through the leaves, but this is not correct. All water must enter the plant through its little roots. If you will carefully sprout some kernels of corn, according to an experiment at the close of another chapter, you will be able to see the little roots called root hairs which absorb the water from the soil. These little root hairs are the mouths of the plant and they are at work all of the time taking the water that is brought to them.

Plants Resemble Animals: We find that a plant is very much like an animal in many respects. It has leaves for lungs and takes food out of the air by breathing just as animals do. A plant must have this air just as an animal must.

A plant has water for blood and it serves this purpose for the plant just as well as the blood of an animal serves the animal.

A plant has roots for a mouth, and they are busy all of the time getting the food for the whole plant. The plant can not run about as a boy can to hunt the food that he likes. It must take the food that is brought to it and do the best that it can. Now, if the food is not in the soil the water can not dissolve it and take it to the plant, therefore the plant will starve. In order that we may see to it that the proper foods are in the soil and where the plants can get them, we must know what plant foods are necessary.

Plant Foods: Although the air is composed of several substances we have found that there are possibly only two of these substances that the plant can take directly into its body from the air. In a like manner, although there are many substances in the soil, there are only a very few that are necessary to the plant. At present there are ten plant food substances found in the soil, all of which are thought to be necessary for the growth of plants. Of these ten, only four are of great interest to us, for there is so much of each of the others in the soil, that there is no need for us to wonder about them.

The four most important elements that are oft-times wanting in the soil are: Nitrogen, Phosphorus, Potash, and Lime. We will take up each one of these substances under the chapter on fertilizers, for if one of these substances is absent in the soil, plants cannot grow at all. It is by placing on the soil the plant foods that are deficient that we hope to increase our crops in the future.

Elements and Compounds: We have referred to Nitrogen, Phosphorus, Potash, etc., as plant food elements, but before we can understand exactly what they are, we must know as definitely as we can what an element is.

All substances are divided into two classes. They are either classed as elements or as compounds. When an object is composed of only one kind of substance it is said to be an element. There are only a few elements in existence, but they are combined in a great number of ways to make compounds.

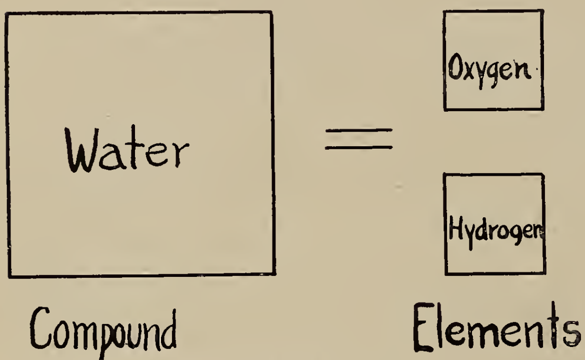


FIG. 5.
A compound may always be divided into two or more elements.

Any object which is composed of more than one kind of substance is called a compound. For example, water while apparently an element is in reality a compound. It is not an element because it is composed of two different substances. When we divide water into the two substances Hydrogen and Oxygen, of which it is composed, we cannot divide it further. Neither the Hydrogen nor the Oxygen will divide into other substances, so we call them elements.

Thus the two simple elements Hydrogen and Oxygen when put together form a compound called water. The complete classification of elements and compounds is very difficult and belongs to the study of Chemistry. We cannot discuss the subject more fully in this chapter. See Fig. 5.

Organic and Mineral Substances: It is rather difficult to get a clear understanding of the difference between organic and mineral substances, but a simple and yet sufficiently accurate way of expressing it is to say that all substances which contain carbon are called organic substances, while all of those which do not contain carbon are called mineral substances. By a simple experiment we can easily divide a plant into these two classes. See Experiment No. 5.

Mechanical Support: A long time ago the earth was covered with water, and plants were compelled to live entirely in water.

B A

FIG. 6.
A, Organic and mineral substance; B, mineral substance alone, after burning "A," which is a pile of straw.

They floated around getting sunshine, moisture and air in abundance. We imagine that it was then very pleasant for plants, for they could move from place to place. Finally some plants drifted into shallow water and the bottom of the plants became covered with mud. At that time water held the plants up and the mud at the bottom only kept them from drifting away. Gradually however, the water left parts of the earth, and the plants that were growing there had to depend on the soil both to feed them and to hold them up. So now while the soil is a place where the plants can get food, it is probable that its first use was merely to hold or support the plants. Fig. 7 shows a plant that gets all of its food from the air. It is merely tied to the tree.

FIG. 7.
A plant that requires no soil.

EXPERIMENT NO. 1.

The Effect of Heat Upon Plant Growth.

Obtain two flower pots, or two tin cans, and plant 5 or 6 large healthy seeds in each. Either corn or beans will be good seeds to plant. Be sure to plant them all the same depth so that they will have an even chance to grow. Place one pot of seeds in a warm place and the other in a very cool place. Water both alike, and examine at the end of a week. What does this show you? Dig up the seeds that were in the cold soil. What has happened to them? What happens when a farmer plants his corn before the ground is warm? Examine the seeds that were planted in the warm soil. What has become of them? What does this show you about the value of planting large seeds?

Below you will find a picture showing how the seeds will be apt to appear. Make a drawing in your note book to show the results of your experiment.

EXPERIMENT NO. 2.

The Effect of Light Upon Plant Growth.

If you have no flower pots for this experiment, bring two tin cans from home and with a nail, punch a few holes in the bottom of each.

The cans may not look as nice, but they will work just as well as flower pots.

You could also use small boxes, such as chalk boxes, if you care to do so. Start some beans to growing in each of the two receptacles. After they are up nicely, that is, above ground three or four days, cover one pot with something that will keep out as much of the light as possible. You can easily shut out the light by putting a large can or light tight box over the plant. At the end of a week remove the covering and compare the plants. Explain what happens when a plant does not get sufficient light.

Write the results of the experiment in your note book.

FIG. 8.

Seeds kept moist without enough heat on the left. Notice that they have decayed.

The seeds on the right have produced plants. The plants have eaten the food, leaving only a seed covering.

EXPERIMENT NO. 3.

The Effect of Moisture Upon Plant Growth.

Plant some seeds in dry soil, some in the same kind of soil kept moist, and some in the same kind kept very wet. Examine often and see what effect moisture has on the growth of plants. What effect does too much moisture have on the growth of plants? On a farm how may we get rid of any over supply of moisture? Write in your note book the results of this experiment.

EXPERIMENT NO. 4.

To Show That There Is Air in the Soil.

You would be surprised to know how much air space there is in the soil a foot deep on an acre of ground. You can get an idea of the amount of space in a soil which is occupied by the air by taking a very little dry soil, and putting water in the place of air.

To do this, take two glass vessels of the same size, such as beakers. Fill one beaker one-half full of clay soil, and jar slightly to settle it. Fill the other beaker to the same height with water. Pour the water from the beaker into the soil, and let stand until all of the soil is wet. Note the height to which the soil and water come in the beaker.

The difference between the height of the soil and water combined, and the sum of their heights, when separate, is the amount of air contained by the soil.

For example: Suppose one beaker contained two inches of water, and the other two inches of soil, and when poured together, their combined height was three inches. Four inches the sum of the height of the water and soil minus three inches, their height when combined, leaves one inch, the amount of the soil occupied by air spaces. The amount of air spaces divided by the total amount of soil gives the percentage of the soil that is composed of air spaces. In this case, one divided by two equals fifty one-hundredths; the per cent. of the soil which was air space.

Write the results of this experiment in your note book.

Repeat this experiment using different kinds of soils.

Compare the air spaces in each.

Write a discussion, telling what you have found out about air spaces in coarse and fine soils.

EXPERIMENT NO. 5.

Mineral Substance and Organic Substance.

Let us take a potato and wash it clean. Weigh it and then burn it in an oven until all that will burn has been removed. This will require a very high temperature to burn out all of the carbon.

All that has been removed by the burning came from the air and is called organic substance. This includes the water, for it came originally from the air.

Weigh that which remains. It is called plant ash; it came from the soil. It is also called mineral substance. Can you figure what part of the potato came from the soil? What part came from the air?

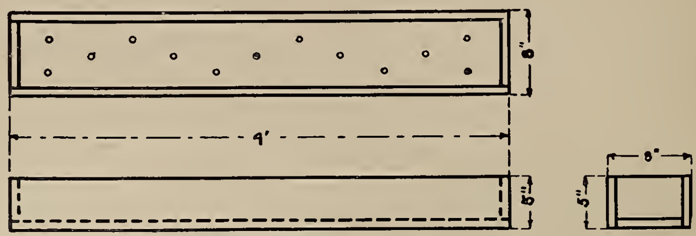


Fig. 1, Window Box.

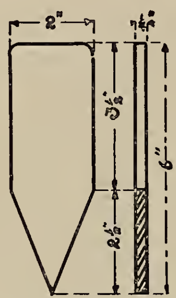


Fig. 2, Plant Label.

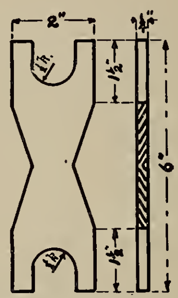


Fig. 3, Line Winder

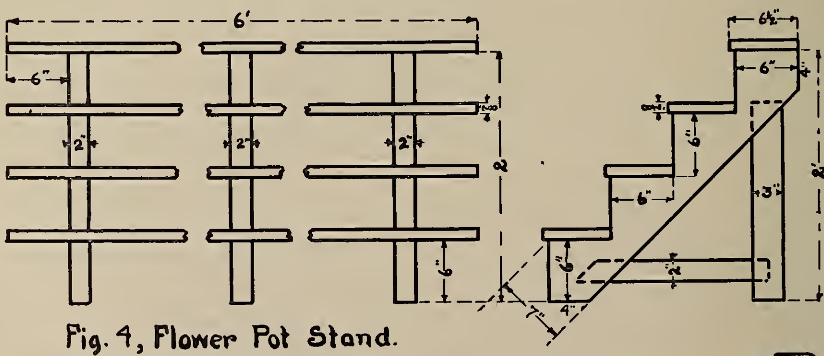


Fig. 4, Flower Pot Stand.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Window Box.

Window boxes are very handy in the school room, and may be so made that they can be taken out of doors when spring comes. Almost any kind of wood can be used in making your box. Figure 1 of plate 2 on the opposite page gives a complete working drawing of such a box.

The box can vary in size, but four inches deep and eight inches wide makes a very good size. The box should be about the length of the apron board under the window. The box may be fastened to the window by screws extending into the casing, or it may be placed upon brackets. If placed upon brackets, the pupils may make the brackets out of wood. Cast iron brackets could be purchased if desired. They give your box a more finished appearance. Small holes should be made in the bottom of the box to let out surplus water. There should be several holes at various places in the box. One-eighth inch holes are large enough for this. It would be well to have each student make out a bill of lumber and a drawing of this article before beginning to work. Six penny or eight penny nails should be used to fasten the box together, and 2-inch screws to fasten it to the window casing. In painting this box, a coat of dark green paint will make it look very attractive. Paint will not only make your work look attractive, but it will preserve it. The paint stops up the openings or pores in the wood and this keeps out air and moisture. This almost entirely stops decay. Since the inside of your box will be moist most of the time, you should paint it inside as well as outside. It is advisable to use at least two coats of paint on any wood material which is to be exposed to air and moisture.

Flower Pot Stand.

If you have flower pots in which to grow your plants, or if you use tin cans, you will have difficulty in finding places where they will all have equal chances at light and heat. Also, if you have many pots of plants at the same time, and you should have, you will be at a loss to know where to put all of them. A flower pot stand will solve this difficulty, besides the fact that it will be very attractive. Figure 4 of plate 2 will give you a complete idea of how to make this stand. The dimensions may be altered to suit the person making the stand. If made smaller than the dimensions given the three supports may be made from one-inch material instead of two-inch, as shown.

When completed, finish with one or two coats of dark red or green paint, and you will have a very nice and handy arrangement for your plant experiments.

Plant Label.

In order that you may know what is planted in each pot and who is performing the experiment, it is necessary that you have some form of a plant label. The one shown in Plate 2, Figure 2, is very desirable and can be made with very little trouble. You will find all dimensions given on the drawing. Use any kind of soft wood, and when completed give it one or two coats of paint, both to preserve it and to add to its appearance.

QUESTIONS AND PROBLEMS.

1. A quart of water weighs two pounds. What is the weight of thirty-one and one-half gallons?

2. If light travels at the rate of 186,000 miles per second, how far will it travel in one minute?

3. It requires five hundred pounds of water to produce one pound of plant. How many gallons does it require?

4. If two leaves on a tree give off eight ounces of water in a day, how many leaves will a plant require to throw off six hundred pounds in a day?

5. How many cubic inches of water are there on a square yard of soil if the water is two inches deep?

6. If three hundred bushels of tomatoes are grown on an acre, and they are nine-tenths water, how much water is there in the ripened fruit?

7. How many square feet in one square yard? In one acre?

8. If a board is one inch thick, twelve inches wide and six feet long, how much would it be worth at 8c per board foot? (A board foot means one foot square, one inch thick.)

9. It requires the following material for your window box:
   1 pc. 1 in. thick, 6 in. wide and 14 ft. long at.... 8c per board foot
   1 pc. 1 in. thick, 10 in. wide and 6 ft. long at.... 8c per board foot
   1 pound 8d nails at........................... 5c per pound
   How much will the material cost for your box?

10. At the end of seven days your corn plants kept where it was cold were one-half inch tall. Those kept where it was warm were four inches tall. How much more did the warm plants grow than the cold ones per day? At the above rate, how tall would the warm plants be at the end of 110 days? How tall would the cold plants be?

11. If the temperature of the cold plants was kept at 52° and the warm ones at 70°, what was the difference in temperature?

12. If eighteen degrees difference in temperature makes two feet difference in the height of a stalk of corn during the growing season, how many inches will one degree affect the height?

Read all of the following references obtainable and any others at hand. Do field experiments and as much supplementary laboratory work as possible. Every community has its peculiar soil conditions which should be studied.

REFERENCES.

Treating Soil in the Laboratory and Field, State College of Agriculture, Ames, Iowa.

Soil Conservation; United States Dept. of Agriculture. Farmers' Bulletin 406.

39 Experiments in Soils; Published by Chas. L. Quear, Muncie, Indiana.

Warren's Elements of Agriculture; Published by Orange Judd Co.

First Principles of Soil Fertility; Published by Orange Judd Co.

CHAPTER II

HOW SOILS ARE FORMED.

What Soil Is: Soil is that part of the earth's surface which can be tilled and in which plants can grow. We sometimes think of soil as being composed of fine rock particles and nothing more. This is a wrong idea for a soil is not only composed of rock particles, but it contains organic matter, moisture, and air. It must contain all of these things in order that plants may grow. That part of the earth upon which plants cannot grow should not be called soil.

Mineral Matter: Mineral matter is that part of the soil which is made up of rock particles. These rock particles vary in size from very large boulders, to dust so fine that it feels perfectly smooth to the sense of touch. As a usual rule the finer the mineral particles of a soil are divided, the more easily they are soluble and the better soil they make.

Organic Matter: The death and decay of plants and animals furnish most of the organic matter. Organic matter is a very complex substance and will be given special attention in a chapter on fertilizers.

Soil Moisture: Although there is always moisture present in the air in the form of vapor, most plants get their water supply from the soil. So until water vapor in the air condenses, and falls as water, thus moistening the ground, we cannot have true soil.

Soil Air: All plants must have air to live and this air must be present in the ground as well as above it. No plant roots can remain alive where there is no air to be had.

Necessary Soil Conditions: You have already learned that in order for plants to grow, the mineral matter and the organic matter in the soil must be soluble in water. Also, soil cannot well be tilled unless the rock particles are finely divided. There are several agencies that are at work all of the time breaking down the soil materials, and changing them so that they may be used as food by plants.

How Soils Are Formed: At one time the earth was not covered with the fine layer of soil which we find now. It was heaped with great boulders and masses of rock, but as years passed on, the water, air, heat and cold crumbled the rocks into fine particles, so that the roots of plants were able to gain a foothold. Then the roots of plants together with animals that live under the ground, began to help break these small particles of rock into smaller and smaller particles. These plants and animals in the course of time died and their decayed bodies were added to the finely divided rock particles, until now we have a thick covering of soil over almost the entire surface of the earth. This mixture of mineral and organic matter holds moisture and air, so plants are able to find in it all of the soil conditions necessary for life.

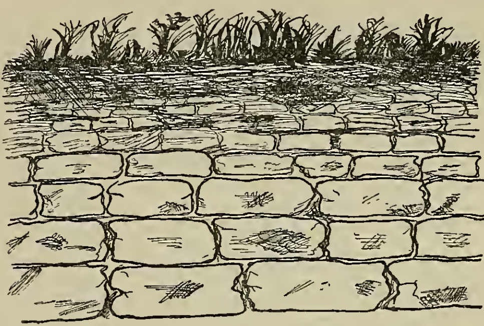


FIG. 9.
How soil is formed.

The forces which have made this valuable layer of soil are at work all of the time breaking down rock particles into soil. If you will examine some large rocks out in the fields, you can find where one or more of these agencies is at work even now breaking down the rock particles into smaller and smaller bits, so that at last they can be dissolved by water and taken into a plant as food.

The air also performs such an important part in this never ending work that we must not fail to think of it.

Air As An Agent of Soil Formation: Small particles of soil are caught up by the wind and are ground against other objects until they become very fine. You can see what the wind is doing in forming soils if you will look on top of the snow along the side of a field that has been plowed in the fall, and across which the wind has been blowing. You will find here great quantities of soil that have been ground up and carried off of the field by the wind.

Chemical Action of Air: There is also a greater action of the air which is called chemical action. In a chemical action certain elements of the air unite with substances in the soil to decompose them. Thus the air is constantly at work changing both mineral and organic substances. As soon as life is gone from any of nature's creatures, whether they are animals or plants, the air begins changing their lifeless bodies back into soil elements to furnish food for another generation of plants. We are all familiar with this process of decay for anywhere that we look about us we can see bits of fruit, vegetables, meat and other substances beginning to rot. Isn't this a wonderful plan which nature has of saving every particle of her building material, and using the air, which is always present, to change the things which we consider worthless back into valuable elements for her great storehouse, the soil.

This is certainly a beautiful way to think of the decomposition which is brought about by the air. The common expression is to say that things rot. A chemist would call this process oxidation.

Oxidation: Oxidation is slow combustion and this is what happens to substances exposed to the air. They burn very slowly, but just as truly as the wood burns in the stove. A stick of wood that is left lying out of doors for a long time disappears, and we say that it has rotted. In fact it has decomposed by slow oxidation. Another good example of oxidation is the rusting of an iron pipe when exposed to the air. The red rust which forms is very different from the iron itself and contains oxygen from the atmosphere. If we keep the air away from the pipe by painting it, or by covering it with grease, no rust will form. This goes to show you that it is the air that is destroying the pipe. In view of this fact how will you keep air from rusting the plow when not in use? How would you prevent air from rotting a house?

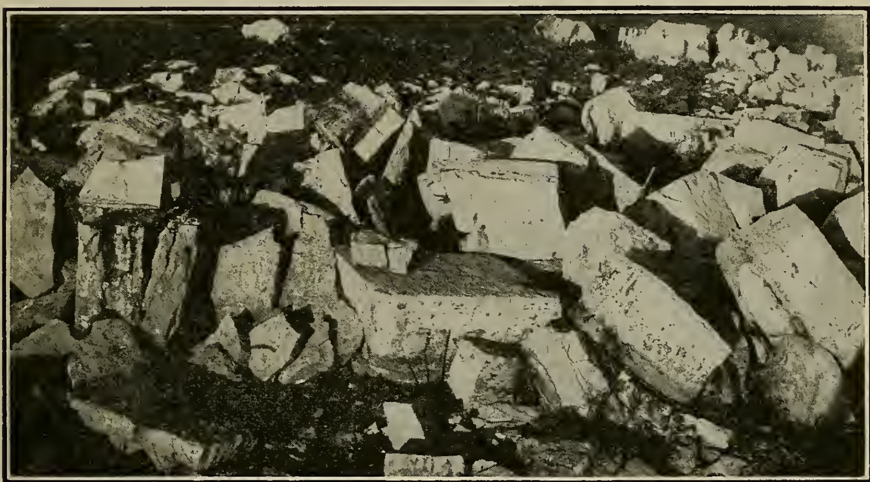


FIG. 10.
The results of weathering upon stone.

Temperature As An Agent of Soil Formation: On a warm and sunny day the heat of the atmosphere warms the soil and causes it to expand. Some of the particles that go to make up a rock do not expand as rapidly as others, so the rock breaks, and pieces scale off of its surface. During the night the soil becomes cold and contracts, again breaking the rock particles into smaller and smaller parts. This action is going on all of the time and is very important in the formation of soils.

Water As An Agent of Soil Formation: Water and temperature combined is a powerful agent in soil formation. The water gets into cracks in the rocks and freezes. When it freezes it bursts apart the little particles of rock. Solid rocks are in this manner broken to pieces. You can understand how freezing water will burst a rock, if you have ever noticed what happens when water freezes in a bottle or a pitcher. The rock particles are forced apart in the same manner that the pitcher is broken. Water is also very active in dissolving rocks. Indeed, if water did not dissolve rocks the plants would never obtain mineral food. Water dissolves some rocks more rapidly than others. Under certain conditions limestone, for example, is dissolved by water. If you will look inside of the tea-kettle you will find a deposit of limestone which has been dissolved by the water and left in the tea-kettle when the water evaporated. When you get home examine the tea-kettle to see if it contains lime.

Plants As An Agent of Soil Formation: Plants aid in the formation of soil in three ways.

1. They take substances from the air and build them into their bodies. When the plants die, this substance goes into the soil. Carbon is an example of an element which thus gets into the soil.

2. The roots grow in crevices between the rock particles and force them apart. The picture below shows the force exerted by a tree which lifted and broke a concrete walk. (Fig. 11.) See if you can find where a little root of a climbing plant has forced its way between the brick of a wall or building.

3. Plants give off acid which dissolves rock. They give off this acid both while they are living and when they die. You can easily see where the acid given off by a growing plant has eaten by pulling the moss off a rock. See Experiment No. 6.

Animals As An Agent of Soil Formation: Burrowing animals, such as prairie dogs, moles, earthworms and insects, dig in the soil and break it into finer and finer particles. Indeed the earthworm eats the soil, and in passing through its body, the soil particles become very finely divided. Also soil is more open where burrowing animals are numerous. This allows water and air to pass through the soil and dissolve it freely. The soil is thus better fitted to supply plant life.

Cultivation As An Agent of Soil Formation: We oft-times think of cultivation as a powerful agent in soil formation. However, cultivation plays only a very small part in making soils. In order to understand the difference between what cultivation, and the other agencies do towards forming soil, we will have to know the difference between texture and structure of soils.

FIG. 11.
Tree breaking a concrete walk.

Texture and Structure: In order that you may thoroughly understand the meaning of soil structure and soil texture you must keep in mind the fact that all soil is composed of tiny particles, which we usually call soil grains. In different soils the size of these soil grains varies greatly, some soils having extremely fine grains while other soils are composed of much coarser grains. If the soil grains are coarse we say the soil has a coarse texture. Sandy soil is a good example of a coarse textured soil. If the soil grains are very, very small, we say that this particular soil is fine in texture. Clay is a good example of a fine textured soil.

Soil structure refers not to the size of soil grains, but to their form of arrangement. Thus we may say that a soil is loose, packed, or cloddy in its structure without considering at all whether its texture is fine or coarse. Cultivation may break up the clods and change the way in which the tiny soil grains are bound together, thus changing the structure, but not affecting the size of the soil grains, therefore not affecting the texture.

To illustrate, a box of shelled popcorn might be considered of fine texture because of its small grains, while a box of shelled dent corn would be considered coarse in texture. If you should pour either box of corn into a basket or different shaped box you would change the structure. The size of the grains, however, would remain the same, so you see the texture would not be affected.

Cultivation which deals only with structure, cannot therefore, be said to be a direct agent of soil formation. However, cultivation helps the other agencies to work and is called an Indirect Agent of Soil Formation.

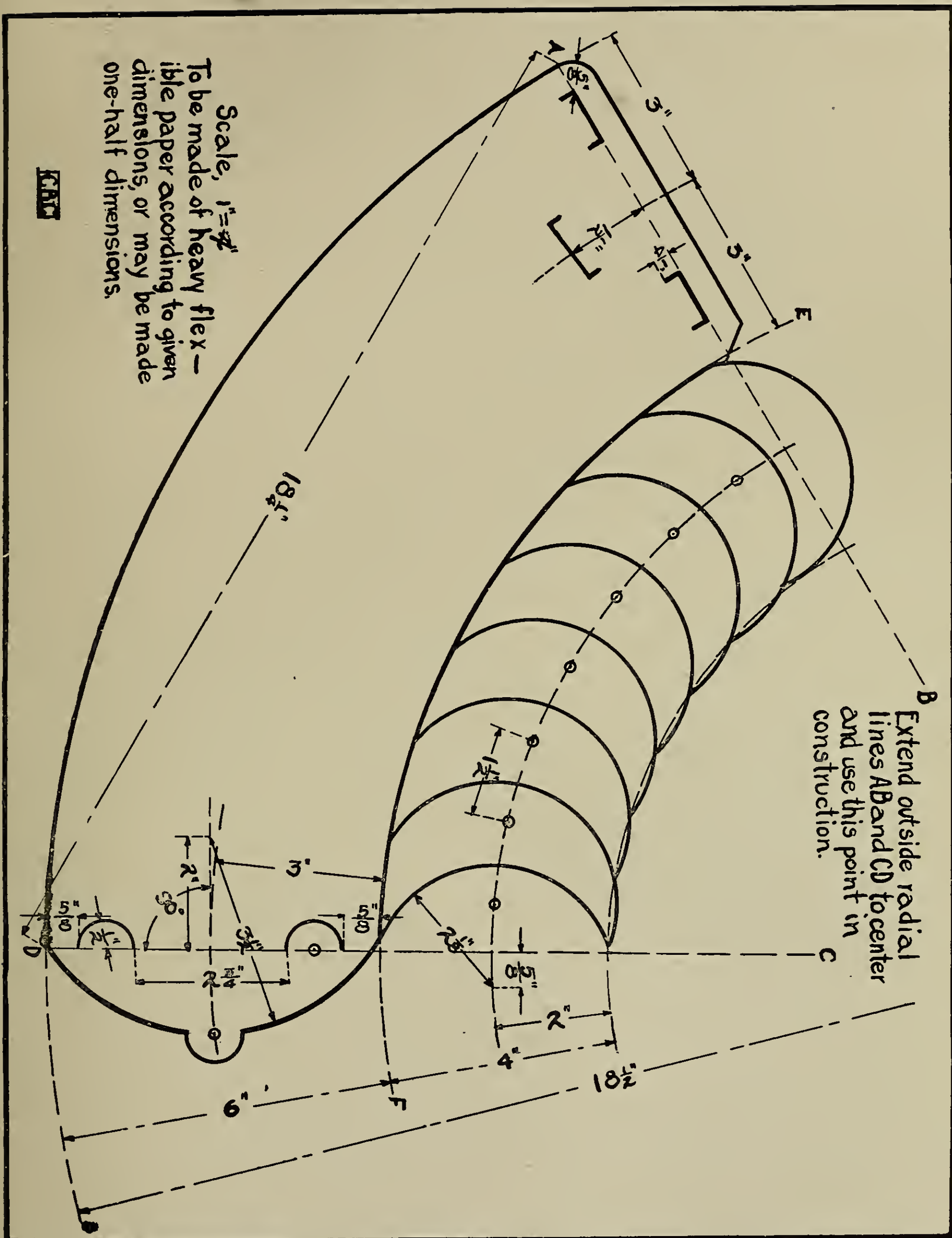

To be made of heavy flex-
ible paper according to given
dimensions, or may be made
one-half dimensions.
Extend outside radial
lines AB and CD to center
and use this point in
construction.
A
B
C
D
E
F

PLATE 3.

EXPERIMENT NO. 6.

To Show That the Roots of a Plant Give Off Acid.

Take a piece of smooth stone, such as marble, or if such a stone is not to be had, pick up a smooth stone along the roadside. Germinate (sprout) a kernel of corn in a pot of clean sand, and as soon as it is above the ground dig it up carefully, so as not to injure the little roots. Lay the roots of this plant against the smooth side of the stone and cover them with soil. Let the plant grow for a week or ten days. Remove the rock and see if you can trace the outline of the roots on the rock. What does the outline of the roots show you?

NOTE: It is well to place the rock at an angle directly underneath the roots so that they cannot grow downward without following its surface. See Fig. 12.

EXPERIMENT NO. 7.

To Determine How a Soil Becomes Acid.

If we once put lime enough on the soil to make it sweet (free from acid), there seems to be no reason why it should not remain so forever. In other words, we might think that a soil once made sweet with any substance should remain that way indefinitely. However, we find this is not the case. In seeking to find an explanation for this, we have decided that the roots of plants give off an acid. To prove this the following experiment has been devised.

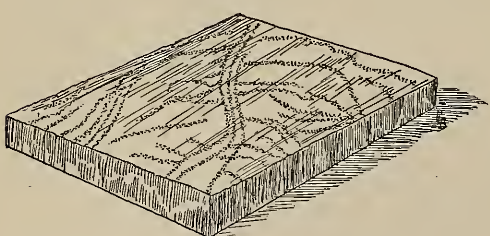


FIG. 12.
Showing that the roots of a plant give off acid.

In making tests to detect the presence of acids we use a substance called litmus. It has a very dark blue color, and looks much like indigo, or the bluing which you have seen used in the laundry. Whenever even a small amount of acid comes in contact with litmus the solution turns pink or red in color. It is therefore used in all kinds of tests to find whether or not acid is present. Sometimes paper is soaked in litmus sclution, producing what is known as litmus paper. It is used for the same purpose of making acid tests.

Obtain a small amount of gelatine that has no flavor. Dissolve it in a small quantity of boiling water. Color this while it is hot with blue litmus solution. Do not get the gelatine too deep a blue color. Use only enough litmus to give a definite tinge.

Carefully dig up a healthy growing plant which is four or five days old—that is, one which has been above the ground four or five days. Be careful not to injure the roots of the little plant, for you want it to continue growing. A corn plant would be a very excellent plant to use for this experiment. Insert the roots of the plant into a small vessel, such as a test tube, and when the gelatine is rather cool, but not yet solidified, pour it around the roots of the plant as if it were soil; in other words, you will have a plant growing in a test tube with gelatine as a substitute for soil.

Note the plant and the gelatine every half day for several days, or until the plant dies. What changes do you note in the color of the gelatine? If the gelatine changes from the blue color to a pink or red color, you will know that acid has been given off by the growing plant. In the small plant which you have used there are only a few roots, and only a little acid will be given off at best, so you will have to observe very carefully any changes that may take place. In a large plant there are thousands of rootlets, and consequently much more acid would be given off.

Write the results of this experiment in your note-book.

Make a drawing to show your experiment.

EXPERIMENT NO. 8.

Rain Water and Soil Water.

Take about one-half pint of clean water from the well and evaporate it in a clean white dish or a beaker. In another similar vessel evaporate some water which you have caught as rain. It is best to catch this water directly into a pan or pail. If it runs from a roof it will contain impurities and will not do. Use the same amount of this water as you did of the well water. Do you find anything left when the well or soil water disappears? Will it burn? What kind of matter is it? Where did it come from? Did you find anything remaining from the rain water? Why?

EXPERIMENT NO. 9.

To Show That Water Dissolves Mineral Matter from Soil.

If we take rain water before it touches the earth, a roof or anything unclean, it will contain no mineral matter, except that which is collected as dust.

Water which has soaked into the ground always contains more or less mineral matter. We know that plants must have mineral matter to live and thrive, so by growing plants in both kinds of water we can tell which contains the more mineral plant food.

Take a dozen or more kernels of wheat and plant them. After they have grown an inch or so above the surface carefully dig them up. Take two small pieces of screen wire and carefully push the roots of five plants through each piece of wire. Put one piece of wire in each kind of water (one in clean pure rain water and the other in water which has come from a well), so that the water just covers the kernels and the roots. Keep the amount of water in the pans as near the same height as you can, and note the plants at the close of the week. What difference do you find? If there is no apparent difference and both samples are growing, leave alone until results appear. What did the soil water have which the rain water did not have? Why do we call water the blood of the plant? See Fig. 13.

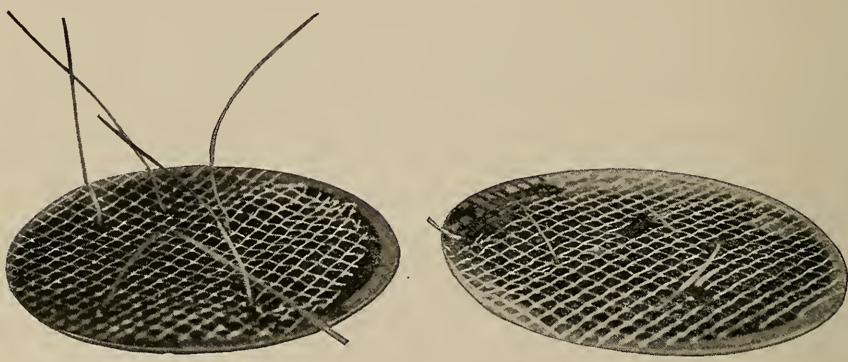


FIG. 13.
(A) Plants grown in soil water; (B) plants grown in rain water.

EXPERIMENT NO. 10.

Oxidation.

Take two pieces of bright tin, or two pieces of iron and file them bright. (Any scrap of iron such as a piece of a hinge, an iron pipe, an old knife-blade or even a nail will do.) Coat one piece with vaseline or oil and leave the other just as it is. Expose the two alike to the outdoor air for a few days. Examine and note the changes. What is the change in the one piece called? What caused it? Why do people paint houses and machinery?

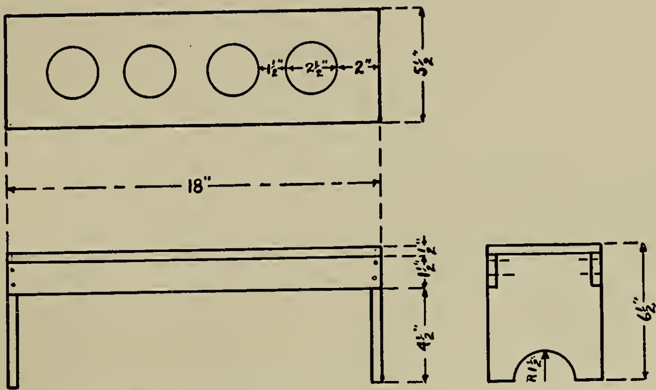


Fig. 1, Percolation Rack.

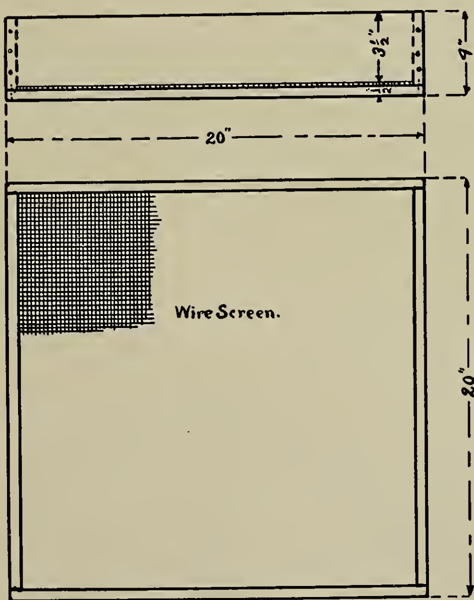


Fig. 2, Soil Screen.

PLATE 4.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Percolation Rack.

A rack for percolation bottles is a very desirable piece of apparatus to make. It is very useful in the study of soils and also presents some good Manual Training principles. A design is furnished in Fig. 14 which is very good, but the student can change his design to suit himself. Any kind of wood may be used for this rack, but it is better for the young student to use soft wood. One-half inch basswood is excellent. The finish may be of any nature; it may be painted, or stained and varnished, at the option of the student. Plate 4 gives dimensions and a complete design of a very serviceable percolation rack.

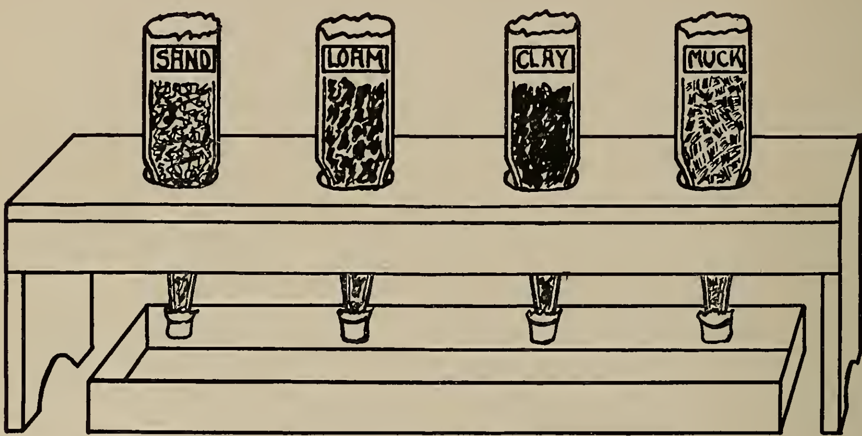


FIG. 14.
Percolation rack in use.

Percolation Bottles.

Lamp chimneys make excellent percolation tubes, but they are expensive and cannot always be had. Bottles may be used just as well, as they can usually be had for the asking. The large, long-necked round bottles of the beer bottle type are best. Before a bottle can be used as a percolation bottle it must have the bottom removed. The best way that this can be done is to tie a string which has been soaked in kerosene or turpentine around the bottle near the bottom and set it on fire. When the string has burned immerse the bottle suddenly in cold water. When tapped gently the bottom will usually break off smoothly. Now, plug the mouth of the bottle with cotton, or cover it with cheese-cloth and the bottle is ready for use.

Flower Pot.

In your experiments you oft-times have need for a flower pot. Tin cans with holes in the bottom may be substituted and will work just as well. However, they do not present a very neat appearance as a rule. You can make a very nice flower pot out of paper which will be serviceable for some time. Take heavy building paper, or any heavy tough paper, and lay out the design for the flower pot as shown in Plate 3. Cut out your design and fold together. Cut all of the heavy lines, except E. F. Fasten the center pieces at the bottom, one over the other. Fasten the sides together and your flower pot is ready for use. If you will handle it carefully and not put too much water on the soil in it at any one time the pot will look nice for some time. Heavy waxed paper is the best to use if it can be obtained. Paraffined bristol board can usually be had at the book store or print shop and is very good for this piece of work. Fig. 15 shows such a flower pot before and after putting it together.

FIG. 15.

Fire Kindlers.

It is very disagreeable to make a fire in a cold room when you have to depend upon shavings, bark and kerosene for kindling. A very excellent remedy for this is to make a bunch of kindlers that are always ready and which will start the fire. This may be done as follows:

Take one quart of tar and three pounds of resin; melt them together, and before they are cool mix with as much sawdust as they will hold. Usually an old tin pail or cast away kettle can be used to do the melting. It is well to add a little powdered charcoal to the sawdust. After you have worked in all of the sawdust that you can, spread the mixture on a board to dry.

When it is dry break into small pieces, and you will have enough kindling to last a long time. A match will light the kindlers and they will burn long enough to start almost any wood. Be careful in heating this mixture not to get it on fire. In case the material caught fire you would have difficulty in putting it out.

How to Make a Still Out of Cake Tins.

Rain water contains very little solid material, and can be used in experiments where pure water is required. Sometimes, however, pure rain water is not to be had and then we must prepare some water by distilling well water (that is, by boiling it, collecting the steam and changing it back into water by cooling it).

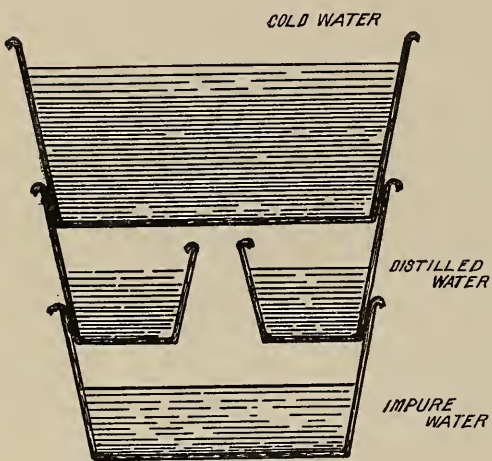


FIG. 16.

The apparatus used to distill water is usually rather expensive, but the accompanying drawing shows an inexpensive method by which we may obtain comparatively pure water. This water still consists of two pans and a cake tin. The central cone of the cake tin must be cut down until its top is a little below the bottom of the upper pan. Water is placed in the top and bottom pan. When heated below, steam forms, passes up into the second pan and, striking the bottom of the top pan, is cooled and falls as water into the cake tin. The water in the upper pan will have to be changed frequently as it becomes hot.

QUESTIONS AND PROBLEMS.

1. What is the boiling point of water, Fahrenheit? Centigrade?
2. How fast does a ray of sunshine travel?
3. What happens to water left in the sunshine?
4. If air presses down with a force of 15 lbs. to the square inch, what is the pressure per square foot?
5. Loam weighs 92 lbs. per cubic foot; sandy soil weighs 100 lbs. per cubic foot. How much would a cubic foot of sandy loam weigh if the two were mixed equally? How much would a cubic foot weigh if they were mixed two parts sand to one part loam? How much would a cubic foot weigh if they were mixed two parts loam to one part sand?
6. If ninety-seven onc hundredths of a plant comes from the air, how many pounds of material in a bushel of corn comes from the soil? What is this substance called?
7. If a pound of soil water contains one-tenth ounce of phosphorus, one-tenth ounce of potash and two-tenths ounce of lime, how many ounces of pure water is there in a pound of soil water? How much lime would there be in 14 lbs. of water? How much potash?
8. How many pounds of soil water like the above would have to pass through a plant to leave a pound of mineral matter?
9. How many pounds are there in a ton?
10. If three one-hundredths part of hay comes from the mineral matter of the soil, how many pounds of mineral matter must be furnished to the plant to produce one ton of hay?
11. If one cubic foot of soil contains four-tenths cubic foot of air space, how many pounds of water would it hold if water weighs 62.8 lbs. per cubic foot?
12. If a rock has one and one-half pounds of its surface broken into soil particles each year, how much soil would be formed from it in twelve years?
13. If a cubic foot of water weighs nine-tenths as much as a cubic foot of loam, how much does a cubic foot of loam weigh?
14. What does qt. mean? pk.? pkg.? gal.? bu.?
    How many pks. in a bu.? How many qts. in a bu.?
15. How many hours in three and one-fourth days?
16. If the water in a ditch carries 100 lbs. of plant food an hour, how many pounds will it carry away in one and one-half days?

17. If flower pots cost 20c apiece for six-inch pots, 25c apiece for seven-inch pots, and 30c apiece for eight-inch pots, make an order for the following: One-half dozen six-inch, eight seven-inch, and one dozen eight-inch flower pots. Write out the order as if you were going to mail it to some firm. Show the total cost on the order.

REFERENCES.

Unproductive Black Soils; State Experiment Station, Lafayette, Ind., Bulletin 157.

Halligan's Fundamentals of Agriculture; published by D. C. Heath Co.

Experimental Botany, by Payne; published by the American Book Co.

Encyclopedia of American Agriculture; by L. H. Bailey. Published by the American Book Co.

CHAPTER III

CLASSES OF SOILS.

How Soils Are Classified: You very well know that the soil of one field is seldom like the soil of another field. Even in different parts of the same field, the soil is different. It would be hard to learn very much about soils if we had to study each field separately, so men have divided soils into different classes, and the soil of every field is described under these classes. Some people speak of all soils as being either heavy or light; others divide them into warm and cold soils.

A very good method of classification and the one most commonly used, is to divide soils into groups depending on the size of the soil particles, and the amount of humus which is present. When we classify soils on this basis, we have four types: clay, loam, muck and sand. Gravel is not ordinarily classified as a soil. If a soil contains clay and loam it is called a sandy loam, etc.

So although we have four distinct types of soils, they are divided into several divisions, the following being the most common: Clay, heavy clay loam, loam, sandy loam, light sandy loam, fine sand, medium sand, and coarse sand. Students should collect as many of these as possible.

Clay: If the soil does not contain much organic matter, or humus, and is very finely divided it is called clay. The most important difference between clay and any other soil is the size of the soil particles. This difference produces many other conditions peculiar to a clay soil. Coarse soil allows water to pass through it readily, but fine soil as clay, holds a great deal of this water. After a rain a fine soil stays wet for a long time, and this keeps out the air which makes such a soil undesirable for many crops.

Clay a Cold Soil: Large amounts of water leave a soil of this kind by evaporating from the surface and as long as evaporation is taking place, the soil will remain cold. A good way to show that evaporation produces coolness is to moisten the finger a little and then wave it through the air. You will notice that the finger will become cool where the moisture has been applied, and will remain so until the moisture is all evaporated.

FIG. 17.
(1) Puddled Clay. (2) Puddled Clay exposed to the action of freezing and thawing.

Why Clay Is Called "Heavy": The finer the soil particles are in the soil, the stickier the soil is when moist, and, therefore, a clay soil is usually very sticky. This fact and the fact that it is usually very hard when dry makes it hard to work and farmers for this reason call it a "heavy" soil. Although clay weighs only 80 pounds per cubic foot and sand weighs 110 pounds per cubic foot, clay is called heavy soil and sand light soil, for clay is hard to work, while sand works very readily.

In dividing soils into the classes warm and cold soils, we call clay a cold soil, for the reason that we have shown previously, and for the further reason that light colored soils do not absorb heat as well as dark soils. Organic matter gives soils their dark color and since clay contains very little organic matter, it is almost always light in color. The reddish or yellowish color which clay usually shows is due to the iron present.

Plant Food in a Clay Soil: Although the above characteristic makes clay undesirable for a number of crops, there are many ways to improve it, and these methods will be mentioned under Improvement of Soils. One of the greatest advantages of a clay soil is the fact that the plant food is very readily soluble. The finer the soil particles the easier it is for water to dissolve the food, and for this reason clay soil is the richest of all soils in mineral plant foods.

Grasses will grow on cold soils when other crops will not live, and since clay is a cold soil it is usually called grass land. Name some crops that will grow well in cool weather. Do such crops grow well on clay ground? Which is the better suited to clay ground, wheat or corn? Bring some clay from home and examine it carefully. Various experiments at the close of each chapter will help you to learn several important things about clay.

Loam: As a general purpose soil, (for growing different kinds of crops) a loam soil is the best soil that we have. Its texture is neither so fine as clay, nor so coarse as sand. Loam soil will hold a large amount of water and yet does not hold so much as to keep out the air. This soil is finely enough divided to supply the average crop with mineral plant foods although the food is not so readily soluble as it is in the clay.

Since a loam soil contains organic matter it is easy to work and does not become hard when dry, or sticky when wet. Also the organic matter makes the soil black, and a black soil absorbs heat better than a light soil, as has been mentioned.

For this reason a loam soil becomes warm early in the spring and is called a warm soil. That a white color will not absorb heat as well as black is shown by the fact that we wear white garments in the summer to turn off the heat from the sun.

Loam is a good soil in which to plant garden vegetables since it is warmer than most soils. It is also a good soil for corn. Loam is very easy to till and is called a light soil although by weight it is as heavy as clay. Bring some loam from home to school and experiment with it as with the clay. Weight equal volumes of dry loam and clay. Compare their weights.

Muck: A soil which contains large amounts of partially decayed organic matter is called a muck soil. Such a soil is usually found around old swamps where ponds have been and on low level ground. It is found in such places, because water is one of the chief agencies that helps to produce muck soils.

To understand fully how such soils are formed we must understand decay. When a plant dies it at once begins to decay and to go back into its former state. This decay is called oxidation, as mentioned previously. If in any manner air is kept away from the plant it will not decay and it is this principle that produces a muck soil.

The plant when it dies is covered with water, or submerged in a wet soil and decay cannot continue with much rapidity on account of lack of air.

Also heat makes decay take place more rapidly, and since a wet soil is a cold soil this helps to prevent the dead plant from decaying. After dead plants have accumulated on such a soil for a number of years we say that the soil is a muck soil. The dead plant is principally carbon and makes the soil black and sticky. A muck soil has a very undesirable structure and this must be changed before the soil can become very valuable. Also it is very cold on account of the moisture which it contains. This too must be remedied. A muck soil is most always unable to produce a crop because it is acid. You should examine some muck soil very carefully for acid. A later paragraph will tell you how to do this.

When organic matter, which is the main substance in a muck soil, is present only in small amounts and mixed with other mineral matter, the soil is called a loam soil. If a large amount of organic matter is mixed with clay, the soil is called a clay loam, or gumbo soil. Gumbo soil is found in small sections of most states, as Iowa, Illinois, Indiana, etc., but in greater amounts in the Southern States, Alabama and Louisiana being good examples.

Peat: A large quantity of pure organic matter well decayed is spongy black and sticky. You can easily find some of this kind of soil if you will scrape some of the dead leaves from the soil in the woods. You will be apt to find a soil composed of dead trees, plants and leaves, and containing very little mineral matter. Such a muck soil is called peat. In cool countries, where it is always moist, the peat soils become very thick. In some of these countries, such as Ireland, the people dry this peat and use it for fuel. In other words, they complete the oxidation which is not completed by the air. Why is it that a rotten piece of wood if thoroughly dry will burn quicker than a solid piece of dry wood? Get your teacher to explain to you how coal is formed.

Humus: Humus is usually defined as decayed vegetable matter. This definition often causes humus to be confused with muck and peat. There is very little difference between the three terms, but they do not refer to the same things. Muck is undecayed, or only slightly decayed organic matter, usually wet. It is found in low undrained areas. Peat is almost pure organic matter, and when dry can be used as fuel. Peat usually contains less inorganic, or mineral matter than muck. Humus exists as a portion of a peat, muck, or loam soil, and, indeed, is found in all soils that produce crops naturally. It will be discussed in the following paragraphs.

Fertility and Humus: Plant and animal matter partly decayed is termed humus, and its presence in a soil gives the dark color characteristic of highly productive land. The close relation between the color of a soil and its productivity is so general, that many farmers judge a soil entirely by the depth of the color. The most apparent change in the soil as it becomes exhausted is the gradual loss of color until the dark color has entirely disappeared. At this state a soil is no longer capable of producing paying crops. In nine cases out of ten, the loss of soil fertility is in direct relation to the loss of humus, and in no case can a soil lacking in humus be naturally productive. The maintenance of humus, therefore, is the very foundation of increased soil productivity and good farm management.

Nature of Humus: Any organic substance, when completely decayed, is changed into the gases and mineral substances from which it came. During the process of decay, we designate the substance as humus. The term humus is used as a general term. Humus proper is a very complex substance, partly soluble, dark in color and gummy or sticky in its nature. This gummy nature, together with the other properties, is well shown in a muck soil.

Humus, while very complex, contains two classes of substances. One class includes all substances which contain nitrogen, the most important factor in its composition, although possibly not the most important factor in its value. The other class of substances which goes to make humus is mineral elements. The mineral elements, however, are not so important or valuable as the nitrogenous substances.

Supply of Humus: Most humus in a soil is supplied directly by the plants which grow on the fields. When the tops are removed from the plants in harvesting, only the roots go to furnish humus. In some cases, the entire plant is plowed under to increase this supply. Oft-times the plants are removed and later returned to the soil in the form of barnyard manure. Sometimes fertilizers derived directly from plants and animals are applied to the soil to supply humus, such as cottonseed meal, and dried blood. Also there are in the soil great numbers of microscopic plants called bacteria, which by their death and decay produce humus. Although the forms of life that may furnish humus are many, the one great fact remains, that our entire source of humus is the result of the death and decay of living things. It is the farmer's duty to see to it that humus which can only be obtained by the loss of life, is returned to the soil to the best possible advantage. It should be remembered that if the humus content of a soil is retained, its fertility will last for a very long time.

Conditions Favorable For the Formation of Humus: Since all humus is the product of decay, the rate at which decay can take place largely determines the humus present. Decay will take place only in the presence of air, heat and moisture. Therefore, if a soil is undrained, or is very compact, decay takes place very slowly, on account of the lack of air, and thus the production of humus is hindered. If, on the other hand, the soil is too well drained, as in a sandy soil, very much air passes through it and decay takes place too rapidly. In this case the organic matter is entirely destroyed, much of it going back to its original form of gases and mineral matter.

Therefore, we may conclude that the drainage of a soil has much to do with the formation of humus. Also, a soil that is warm and well tilled, forms humus from vegetable matter very rapidly.

Relation of Mineral Substances to Decay: A soil must have certain mineral substances present before humus will become abundant, for without these substances the organisms which produce decay can not live. One of these substances, and, indeed, the most important one is lime. The subject of lime on the soil will be fully discussed in later paragraphs.

Value of Humus On a Soil: As has been said, humus is gelatinous or gummy in its nature, and very porous. When it is applied to a soil, it makes a better structure, and reduces the tendency of the soil to bake, or puddle. By making the soil crumbly in structure tillage is much easier accomplished, and in such a soil plants can root much more freely.

Humus will absorb great quantities of water, and when present in a soil prevents the loss of large amounts of soil water. The water which humus absorbs dissolves from it large quantities of readily available plant food which the plant can use directly. The humus, besides furnishing plant food, helps also to liberate plant food from the mineral part of the soil.

FIG. 18.
(A) Plants in sand with humus added; (B) Plants in pure sand.

Finally, humus in a soil permits plants to grow more vigorously and makes them better able to withstand disease or drought. It is usually considered that from one-third to one-fifth of the organic matter found in a soil is available (useable) in the form of humus.

Sand: Pure sand would be a very poor soil for several reasons. It is so porous that it will not hold enough moisture to support a plant through the dry seasons. It is so coarse and insoluble, that the water which a plant obtains from it contains very little mineral foods. It is not compact enough for plants to get a very firm foothold and consequently winds oft-times blow the plants over.

On the other hand sand is a very warm soil, and when modified with other substances a very early crop can be obtained, for plants will grow in such a soil in the spring before they will start to grow in other soils.

Gardeners always like to have a sandy soil for the above reason. We can take a sandy soil, and if it is not too coarse, we can make a very excellent soil of it. We are to learn in the next chapter how to do this, as well as how to improve the other soils which have been discussed. Sand is the best soil we can use for germinating seeds. The sand is warm and admits air. It is also clean and can be handled without inconvenience. If you test any seeds for germination at this time use sand in the seed tester. It will not furnish food for the plants, but they will not need it so long as there is food in the seed from which they grow.

The Subsoil: That part of a field which is called soil usually occupies the surface six to twelve inches. Sometimes, however, this surface soil is many feet thick and sometimes it is less than six inches in depth. There are several differences between subsoil and surface soil. The subsoil is usually harder to work than the surface soil and can generally be told from the surface soil by its color. The surface soil is darker in color on account of the organic matter which it contains. Also, the plant food in the surface soil is more readily dissolved than the plant food in the subsoil. As subsoils decay they become more and more like surface soils. The nature of the subsoil has much to do with the value of a surface soil. It determines in a large measure the fertility, drainage and texture of the surface soil. Dig down into a field at home. Notice the difference between the surface and the subsoil. About how deep is the surface soil? What kind of a subsoil do you find under the surface soil?

EXPERIMENT NO. 11.

Difference in Soils Demonstrated.

Obtain three small jars or bottles which can be sealed tightly for collecting soil samples. Pint fruit jars are about as good as anything readily found. Go to the field and scrape away the plants and surface soil to about the depth of an inch. Take a sample of this soil and put it into one of the small jars. Seal it tightly so that none of the moisture can escape. Dig down 6 inches and take another sample of soil. Place this sample in another bottle and seal. Likewise secure another sample at a depth of 12 inches from the surface.

When you return to the schoolroom weigh out equal amounts (about four ounces) of each soil. Spread each sample in a shallow pan and let it dry for two or three days. Weigh each sample again at the end of this time. The difference between these weights and the first weight is the amount of water which each soil contained, that could be removed by evaporation. Note the color of each sample of soil. If you have a microscope, examine each soil with it.

Heat each sample in an iron spoon until everything that will burn has been burned. Weigh each one again. The difference between these weights and the previous ones shows the amount of organic matter in each sample. The final weights show the amount of mineral matter which each soil contains. Write the results in your note-book in the following form:

Depth of soil	Total amount of soil	Amount of moisture present	Amount of organic matter present	Amount of mineral matter present	Color of the soil	Size of the soil grains
1 inch						
6 inches						
12 inches						
Average						

EXPERIMENT NO. 12.

Physical Composition of Soils.

To say that a soil contains clay, silt (a coarser form of clay) or humus does not mean anything very definite to a student. To let him find the clay, or silt, in a soil for himself is a different proposition. This experiment is arranged to permit a student to determine for himself the substances in a soil.

To perform this experiment, obtain a glass tumbler, two quart fruit jars, or similar glass vessels, some soil of each kind to be tested, and a microscope, if there is one to be had.

Put a tablespoonful of soil in a tumbler and fill full of water. Stir thoroughly. Let stand a moment and then pour off the muddy water into one of the larger vessels. Put on more water, stir and pour off again. Repeat this operation four times in all, pouring the muddy water each time into the same vessel. Add water, stir, and pour off four more times, as above, except pour the water into the other large vessel.

Let the two vessels stand for a short time and compare sediments. That which remains in suspension is real clay and very fine silt. The sediment is loam and granulated particles of clay. The material which remains in the tumbler is principally sand.

If you have a microscope examine the different soil grains and describe each. Proceed in this way with each of the soils to be tested.

Heat a teaspoonful of soil in a large spoon until it is red hot. Which kind of soil burns? What do you have left?

What difference does the composition of a soil make as to the agricultural value of the soil?

Write a discussion explaining the results of this experiment.

Estimate the percentage of each kind of soil constituent in the soils which you have examined.

Name the soils that you have examined according to the substances which they contain.

EXPERIMENT NO. 13.

Temperature of Light and Dark Soils.

Take some loam soil and put about equal amounts in two pans. Place the bulb of a thermometer in each soil. Be sure that the bulb is covered with soil. Cover the surface of one pan of the soil with a thin layer of salt, sugar, flour or any similar white substance. Set the two pans in the sunshine and read the thermometers every ten minutes for an hour. Do not remove the thermometers to read them. What difference do you note in temperature? What does this show you about light colored soils?

EXPERIMENT NO. 14.

Why a Soil Becomes Cloddy.

Take a small sample of all the kinds of soil which you can obtain and place each in a shallow pan. Cover them with water and stir until each is mixed thoroughly. Use equal amounts of soil and pour over each the same amount of water. Set the pans away to dry. Which kind of soil dries first? Why? Which last? Why? After they are all dry, examine them. Which one is the hardest? Which one is the softest? Why? What happens when we plow soil which is too wet? Do you think that it pays to start the plow a little early in order to gain a few days of time?

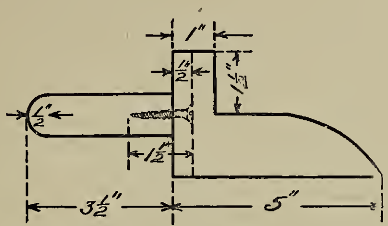


FIG 1 SOIL SCOOP

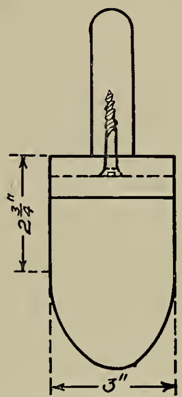
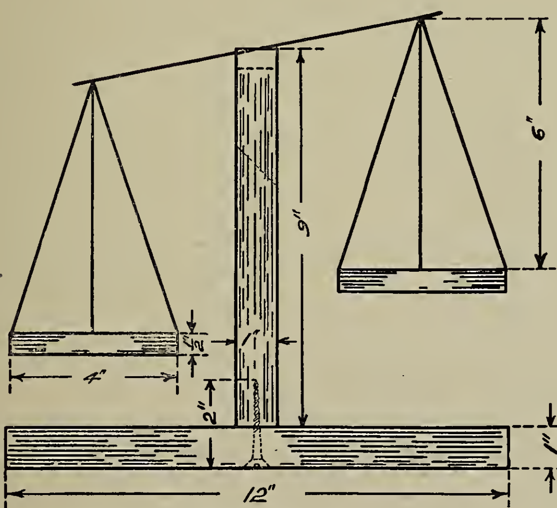


FIG 2



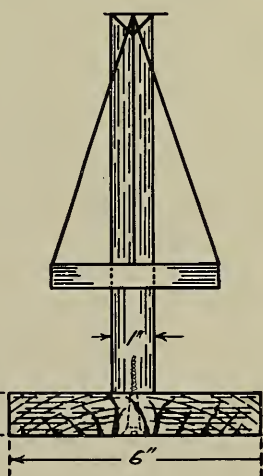


FIG 3 HOME MADE BALANCES

FIG 4

PLATE 5.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

A Soil Screen.

There should always be a supply of soil kept in the laboratory, and this can be prepared by use of a soil screen. A neat method of storing soil for school experiments is discussed in another chapter.

In order to remove all large particles, clods, rocks, etc., from the soil it should be screened into the soil bins. To prepare a soil screen for this purpose obtain any soft wood of the dimensions given in Fig. 2, Plate 4. The fastening together of this frame for your soil screen can be accomplished by merely using 8d nails. If you cut your pieces for opposite sides exactly the same length your corners will be square. The bottom strips to hold the screen in place should be put on with one inch flat head bright screws. You can strengthen the soil screen if you desire by fastening three cornered blocks in each of the corners; this can be done with glue and nails. This is not shown on the plate. Ordinary galvanized screen wire is a very serviceable form of wire to use and is fine enough for most soil work. Put dry soil into the sieve that you have made and, by shaking it over the soil bin, fine, clean soil will be obtained. Nothing adds interest to soil work so much as nice, fine soil with which to work.

Home-Made Scales.

Balances are very necessary in many experiments, but they are rather expensive. A pair of balances, which will do for all ordinary purposes, can be made at school. Take a 1-inch square upright and fasten it to a base, as shown in Figs. 3 and 4, Plate 5. Cut a V-shaped groove in the top of the upright. Obtain an umbrella rib and through the hole where the short stay was attached put a darning needle. Cut the umbrella stay so that it is the same distance from either end to the darning needle. Fasten pans to the arms of the balance as shown in the drawing. Lids from baking powder cans make good pans. Suspend the needle across the V-shaped groove in the upright and balance the pans by sticking gum or wax to the lighter pan. When the pans balance you have a very serviceable pair of scales which will weigh accurately enough for your use in the laboratory or schoolroom.

Scoops from Tin Cans.

In working with soils it is very convenient to have soil scoops. One which will serve very well can be made out of the material found around the home. Such a scoop can be used around the barn in the ground feed, salt, etc. If neatly fashioned, smaller scoops may be made to use in the sugar and flour bins, etc., of the kitchen.

Take a tin can and either cut or melt off the top. Now, beginning at the open end and one-fourth way round each way from the seam, split the side of the can to within one-half inch of the bottom. You will need a heavy pair of shears to do this. Tinners' snips are best if you can obtain a pair. Then cut off one-half even with the splits which you have made in the sides. Round the corners of the open end and the body of your scoop is finished. See Plate 5, Fig. 2. Cut a piece of one-half inch wood to fit the bottom of the can. Place it as shown in the cut, Plate 5, Fig. 1.

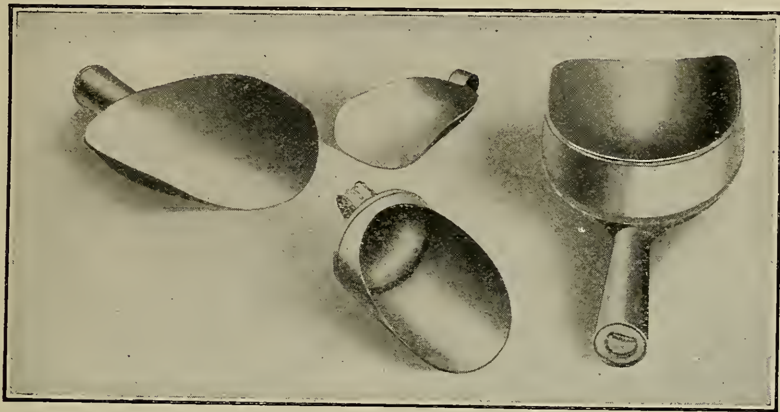


FIG. 19.

Secure an old broom handle and cut a piece about three inches long for a handle. Put a screw through the board at the bottom of the can into the handle and your scoop is complete. You can make a hole through the tin for the screw with a nail if you have no metal drills. A one-inch or one and one-half-inch Number 8 screw is about the right size. When completed compare your scoop with the picture of the ones above. You might use any of the above styles you desire in making your scoop.

How to Sharpen Scissors.

It is very easy to sharpen a pair of scissors or shears even if you do not have a whetstone. If you use a pair of shears in making your soil scoop as above mentioned they will need sharpening. To sharpen them take a bottle or glass jar and put one blade inside the jar and the other outside. Act just as if you were trying to cut the jar. Repeat this cutting motion several times and your shears will be sharp. Do not use too much pressure.

QUESTIONS AND PROBLEMS.

1. If a sample of soil which weighed 6 oz. weighed 5 oz. after being exposed to the air for two days, what fractional part of the 6 oz. was water?
2. If a sample of soil which weighed 6 oz. weighed $2\frac{1}{2}$ oz. after being burned, what fractional part of the 6 oz. remained?
3. How many ounces in $12\frac{1}{2}$ pounds? In one-eighth pound? In two and one-sixth pounds? In three and one-fifth pounds?
4. How many pounds and ounces in 28 oz.? In 56 oz.? In 80 oz.?
5. How many square inches in a piece of screen wire 15 in. by 24 in.? How many square feet? What would it be worth at 8c per square foot?
6. Your experiments require 7 cu. ft. of clay weighing 80 lbs. per cubic foot; 9 cu. ft. of sandy loam weighing 98 lbs. per cubic foot, and 6 cu. ft. of clay loam weighing 92 lbs. per cubic foot, and 12 cu. ft. of humus weighing 50 lbs. per cubic foot. How many pounds would this be altogether?
7. A man has 12 A. of clay land worth $70 an acre; 22 A. of loam soil worth $120 per acre. What is the average price of his land per acre?
8. Loam yields $5\frac{1}{8}$ bu. more corn per acre than clay soil. How much more is the corn crop from a forty-acre loam field worth than the crop from a forty-acre clay field, if the corn is worth 40c a bushel and the loam soil yields 40 bu. per acre?
9. Forty-five gallons make a barrel. How many gallons in 603 bbls.?
10. How much would a 45-gal. barrel of water weigh if 1 qt. of water weighs 2 lbs. and the barrel weighed 80 lbs.?
11. A cubic foot of clay soil will hold 32 lbs. of water. How many gallons, quarts and pints is this?
12. Write an order to some one for the following:

One-half bushel yellow corn	at $5.00 per bu.
One peck Red Clover seed	at 8.00 per bu.
Twelve packages Assorted Flower Seed	at .10 per pkg.
Three quarts Winter Onion sets	at 1.20 per gal.

How much money would you have to enclose for such an order?

CHAPTER IV

SOIL IMPROVEMENT.

The Problem of the Farmer: Most farmers know quite well how to feed animals, and when to market them, how to manage a farm, and what kind of farming they are best prepared to do. But the number of farmers who are acquainted with their soils, and who know how to improve them are very few indeed. The problem of soil fertility is the greatest problem confronting the farmer today. This includes the problem of soil moisture, for soil moisture composes the greatest portion of all crops.

Every student must realize that each field is a separate problem, and its case must be considered individually. No two fields respond exactly alike to the same treatment, for they are never lacking in exactly the same substances in the same amounts. No general rules can be used to cure a soil any more than a few general facts will cure all sick people.

The person who attempts to cure or benefit the productive power of a soil must know how to find out what the soil needs, how best to apply this needed material, and when and what to apply.

A doctor of medicine examines a sick person and after finding out what is wrong proceeds to correct that ailment. He does not give every sick person the same kind of medicine. Neither should you give every soil the same treatment. You as a soil doctor, should do more than the doctor of medicine. You should not only be interested in making poor sick soils well, but in making good healthy soils better. It is a very difficult study, and the problems are large ones. There are a few rules for improving the various classes of soils that we should know and be able to apply, just as there are a few rules for maintaining good health. The special needs of soils we will have to learn by observation, practice and study.

Improvement of a Clay Soil: One of the things that causes a great deal of trouble for the farmer is the fact that a clay soil puddles very easily. Soil particles arranging themselves very

B Fig. 20 A
(A) Treated soil; (B) Part of same field untreated.

close together so that they become very hard in structure when dry is called puddling. (See Fig. 17.) Puddling is caused in most cases by plowing or cultivating the soil while it is too wet. Farmers say of such a soil that it bakes. Puddled soil may always be seen in the bottom of a hog wallow after the water has evaporated. The soil while wet has been stirred by the hogs, and the soil grains have been able to get as close together as possible.

When such a soil dries, it becomes almost as hard as cement. Indeed, a long time ago people used to make brick this same way. They would stir a clay soil while it was very wet and then make it into the shape of bricks. They would leave these bricks to dry in the sun and after they were dry, they called them sun dried bricks. You might try making a brick like the people a long time ago used. Get your teacher to tell you how bricks are made today. If there is a brickyard near your school go see how bricks are made.

Soil Plowed Wet: When soil is plowed too wet it behaves just as if it had been made into sun dried bricks. Plants will starve in such a soil, for all of the plant food is locked up. A clay soil plowed too wet will not recover from the injury it receives for two or three years. Therefore, one of the most important rules to follow regarding clay is *don't plow while the soil is too wet.* Soil is too wet to plow when a handful of it worked in the hand and made into a ball will pack and become slick on the outside.

Acid In a Clay Soil: Another thing that sometimes causes a clay soil to puddle is the acid which it contains. Acid in a soil tends to cement the soil grains together, making a very hard compact mass. It should therefore be removed. This is best done by removing surplus water and by the addition of soil amendments. By soil amendments we mean anything which will help to correct an improper condition of the soil. This subject will be discussed under the chapter on Fertilizers. The only way to remove surplus water successfully is by drainage, so remember that *clay should always be well drained.*

Effect of Drainage On Clay Soil: In a clay soil the texture is too fine to permit air to penetrate, or to permit water to pass through as it should. We cannot change its texture much, but we can change its structure. Plowing while the soil is wet should change its structure, but this method would ruin the soil. It would make the clay soil very lumpy and hard.

The drainage of a clay soil allows air to penetrate more freely and air acting on the lime which is present sticks little groups of the soil grains together, which makes the clay coarser in structure. These little groups of soil grains are not stuck together so tightly as to make them worthless. This permits the air and moisture to pass freely and is a very beneficial change in the soil structure. It is in fact the main reason why we should drain a clay soil. On some soils drainage does not have this effect, because there is no lime in the soil. Such a soil needs lime applied to change its structure.

Effect of Humus On Clay: Humus applied to a clay soil is one of the best methods of modifying its structure. Humus makes the soil more porous and allows air to enter freely. It not only admits the air, but also helps to prevent the soil from washing by rain, or drifting by wind.

A clay soil containing humus is not ordinarily easy to puddle. It does not become hard when dry. Clay soil alone contains mineral plant foods in abundance, but since plants can not live on mineral matter alone, we must apply humus so the plant may have all of the food material that it needs.

Remember that a clay soil needs humus more than any other soil both as food for the plant, and as an agent to modify the structure of the soil. Commercial fertilizers are usually of little value to clay soil. This will be discussed further under the chapter on Fertilizers.

Improvement of a Loam Soil: The structure of a loam soil is usually very good. It contains both organic and mineral plant foods. It is classed as a warm soil. If, as sometimes happens, a loam soil is cold, it is because the soil needs drainage. This is one thing that loam soils need in many cases.

While both mineral and organic plant foods are present in a loam soil, some of the essential ones may not be present in large amounts. The ones which we need apply as fertilizers must be largely determined by the crop that is to be grown on such a soil, as well as the manner in which the soil has been cropped for the past several years.

Crops For Loam Soil: Rapid growing crops, as corn, are usually grown on loam soils. Such crops require large amounts of moisture in a short growing season. Therefore, the moisture supply of a loam soil must be looked after by proper drainage and tillage. A loam soil usually becomes poor rapidly, because it is most likely to be abused. Air can pass through it readily, and as a result the organic matter oxidizes rapidly. If we continue to raise large crops on such a soil, and take away the crops in a few years the supply of organic matter is almost gone, and as a result the structure, tilth and fertility is destroyed. A loam soil is a good soil, but it requires care or it will not remain fertile and productive.

Improvement of Muck Soils: Muck soils are quite variable and no rules for improving such soils will apply generally. Some muck soils contain more organic matter than others and again this organic matter is more completely decayed in some cases than in others. However, the one condition common to all muck soils is the large amount of organic matter which is present. This condition is favorable for a very fertile soil. Organic matter in large quantities makes a soil that does not drain naturally, and further such a soil is almost invariably acid. Artificial drainage is one method of improving such a soil, and the addition of fertilizers, or substances to correct the acidity of the soil is another. It is not hard to correct the acidity of soil if you know how to go about it.

Some people try to improve muck or humus soils by burning the top layer of soil. This is a poor way of improvement and should not be practiced except in very rare cases. When this is done but very little acid is neutralized, while a great deal of organic matter is destroyed. Drainage and soil amendments are the secret of success in handling muck soils.

Improvement of Sandy Soils: A sandy soil may be made a very excellent soil by proper treatment. A sandy soil is loose and open in structure, which condition permits the roots of a growing plant to pass freely in all directions. In such a soil the resistance offered to the roots is not sufficient to check their lateral growth, and the water is usually far enough below the surface to permit a plant to root deeply. Plants must have their roots scattered over a large area to obtain the moisture which they require, particularly through the summer months. When you stop to think that a corn plant on a warm day in July or August will consume as much as two and one-half lbs. of water and that the soil from which this must be obtained is so dry that by no possible means could we squeeze a single drop from it, you will see why it is necessary that the roots cover a larger area.

Humus On Sandy Soils: If we add humus to a sandy soil we increase the power of the soil to hold water, for humus is like a sponge. It soaks up large amounts of soil water, yet it does not prevent the roots from growing freely in all directions.

If we drain a sandy soil and put the drains rather close to the surface, the water can supply the plants for a longer period of time. By putting a shallow drain in sandy soil, we raise the level of the soil moisture which permits the plants to use water which they would not otherwise obtain. This will be discussed further under drainage.

Plowing At the Same Depth: By plowing at the same depth each year we may improve the water holding power of a sandy soil. Plowing at the same depth year after year has a tendency to firm the soil below the plow, and this allows the moisture to be brought up from below more readily.

Sandy soil has a great advantage over clay soil in the respect that it neither bakes when it becomes dry, nor becomes saturated with water after every rain. Also a plant can obtain what moisture there is present from a sandy soil easier than it can from a clay soil, for a sandy soil yields its water readily while a clay soil retains it vigorously. A sandy soil is from 5 degrees to 10 degrees warmer in the spring than a clay soil and will warm up to a greater depth early in the season. The warm spring rains soak into a sandy soil and warm it by forcing out the cold water that is already present. In a clay soil the cold water that is present remains and the spring rains run off as surface water. This fact makes a sandy soil an earlier soil for planting crops.

However, the water that passes through a sandy soil takes plant foods with it and these must be replaced by the addition of fertilizers. Humus will replace some of these plant foods.

How Plants Live In Different Soils: Plants adapt themselves to all kinds of soils, and this fact has helped many plants to become used to certain kinds of soils, and has permitted them to thrive there although they formerly preferred another kind of soil. We associate certain crops with certain soils and it is always best to plant the desired crop on the soil suitable for that crop, rather than to modify the soil to suit the crop. It is perfectly correct to study methods of modifying the soil, but we must not disregard the nature of the plants we are raising.

The crops which we are attempting to raise, by careful selection can be so chosen, as to fit the particular kind of soil which we are tilling. By this means we can avoid needless expense in a vain effort to change the nature of the soil. As a rule, fit the crop to your soil, rather than your soil to the crop.

EXPERIMENT NO. 15.

Planning a Rotation.

Have each pupil bring samples of surface soil and of subsoil from the fields at home. Classify each and compare the value of the different subsoils. These soil samples can be brought to school in small tin cans or boxes.

Have pupils make drawings of the farm at home, showing each field. Write in the drawing of each field the kind of crop grown, the kind of surface soil, and the kind of subsoil.

On this farm plan a four years' rotation. Write the name of the crop to be planted in each field, and the time the same should be planted.

Note how many times each field must be plowed in four years.

Note how many months each field will lie idle during this time.

Upon which fields would you place the barnyard manure in your rotation? Why?

By using colored crayons and letting different colors denote different crops a very interesting map may be made.

EXPERIMENT NO. 16.

The Value of Organic Plant Food.

Clean sand contains all of the mineral plant foods, but does not contain organic matter. We will test the plant-producing value of organic matter by growing some plants in pure sand and some others in sand to which organic matter has been added.

Obtain two flower pots which are near the same size. Fill one with clean sand, which you have burned at a high temperature for an hour or more. Fill the other about one-half full of the same kind of sand. Fill it the remainder of the way with organic matter. Mix the two kinds of soil in this pot thoroughly. The organic matter which you add should be well rotted manure or decayed leaves, from the woods. Use whichever is the more convenient.

Plant five or six seeds of some common plant, as corn, in each and subject both to the same conditions. Water as often as necessary with clean rain water and observe the results at the end of each week for four weeks. Write in your note-book the results which this experiment shows. At the close of the experiment write a brief paragraph telling the value of barnyard manure.

EXPERIMENT NO. 17.

Water-Holding Power of Soils.

Let us compare the water-holding power of the four main types of soils in the following manner: Take four percolation bottles which will hold a quart each and stuff cotton in the necks of them, or, if it is more convenient, tie cheese-cloth around each. See Fig. 14.

Fill each bottle one-half full of soil as follows. Into one put sand; into another clay; into another loam, and into the last humus. Jar each bottle slightly to settle the soil. Now place the bottles in the percolation rack and into each bottle pour one pint of water. Observe the amount of water which passes from the soil as free water. Which soil retains the most water? Which one the least? Can you explain the results of your experiment and its value? Make a drawing of the apparatus.

EXPERIMENT NO. 18.

Rapidity of Percolation in Different Soils.

The purpose of this experiment is to demonstrate the rapidity with which water escapes through the different types of soils.

Obtain four bottles with the bottoms removed and tie a piece of cheese-cloth over the mouth of each. Fill each bottle two-thirds full of soil, using a different soil for each bottle. Place the bottles in a percolation rack, mouths downward. Pour water on each soil, a little at a time, until it begins to drip from the mouth of each bottle. After water is dripping from all of the bottles, note the amount of water which drips through in a given time, say four periods of five minutes each. Keep a supply of water above the soil in the bottles all of the time. Which soil loses the most water? Which one the least?

Ask yourself five questions about this exercise and write the answers. Show them to your teacher. Make a sketch of the apparatus and put it in your note-book.

EXPERIMENT NO. 19.

The Effect of Organic Matter on the Tenacity of Soils.

Take two small pans and put some clay in each. Pour equal amounts of water over the clay in both pans and stir until you have a stiff batter in each pan. Into one pan put a small amount of very fine and well rotted humus, and stir until it is thoroughly mixed with the clay. Set the pans away for the soil to dry. When thoroughly dry break or crush the soil in each pan. Note the hardness of each soil. What effect does humus seem to have on clay? Write one sentence on the Value of Humus to Clay.

REFERENCES.

Call and Schafer's Laboratory Manual; published by the MacMillan Co.

First Principles of Agriculture; by Goff and Mayne. Published by the American Book Co.

Utilization of Muck Land; Regular Bulletin 273 State Agricultural College, Lansing, Michigan.

Use of Fertilizers on Indiana Soils; Cir. 10, State Experiment Station, Lafayette, Ind.

Mayne and Hatch, High School Agriculture; published by the American Book Co.

Nolan's 100 Lessons in Agriculture; published by Row Peterson and Co.

Plant Food in Relation to Soil Fertility; State Experiment Station, Urbana, Illinois, Cir. 157.

Soil Fertility in Iowa; Bulletin 150, State Experiment Station, Ames, Iowa.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Soil Bins.

It is very unhandy to keep soils in the schoolroom unless you have something especially made for holding them. When soils are kept in the schoolroom they are often placed in boxes of all sizes and shapes which makes the room look untidy. Also this takes up a great amount of unnecessary space. It is much more desirable to have a row of soil bins.

Take four boxes which are the same size and bolt them together. Be sure that they are good, tight boxes, so that when they are filled, soil will not constantly leak from them. Put legs on the boxes to hold them the desired height. It is well to bolt the legs to the boxes, for they will have to support considerable weight. Put a lid on the boxes, as shown in Fig. 21. Then paint the whole thing some desirable color.

Using a different colored paint from that which you used on the boxes, paint on the front of each box the name of the soil which you expect to place in it. This will make a very attractive and useful soil box, and will prevent a lot of untidiness otherwise unavoidable. A box like the above, having only one section, makes a very good waste box.

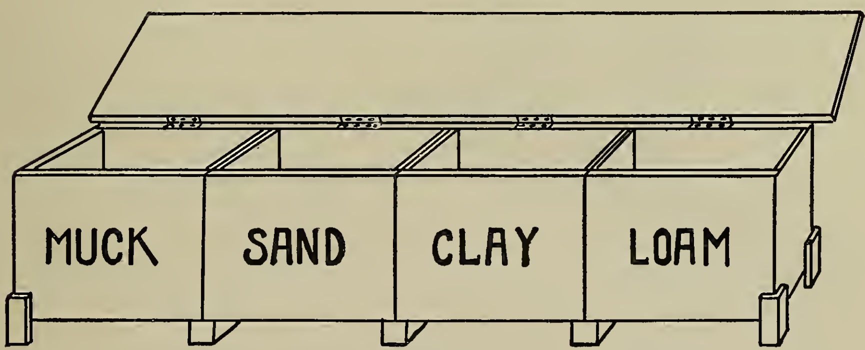


FIG. 21.
Soil bin.

A Rope or a Monkey Wrench Substituted for a Pipe Wrench.

Oft-times the farmer has to uncouple a pipe and, without a pipe wrench, this presents a serious problem. However, this task can usually be accomplished by the aid of a piece of rope and a short stick for a lever. Wrap the rope around the pipe, as shown in the illustration, Fig. 22, and it will not slip, but will grip the pipe very tightly. Now insert a stick as shown and unscrew the pipe.

A monkey wrench may be used for a pipe wrench by inserting a bolt under the upper jaw of the wrench. The method of doing this is shown in Fig. 22-B.

A Straight Edge.

A straight edge is a very desirable thing to have around a shop, and one can be made very easily. Select a clear piece of pine (five or six feet long) and plane one edge as straight as possible, testing it with the eye. In order to test it more accurately, lay it upon a smooth surface and mark with a pencil against the edge which you have planed. Then turn it over and with the same edge on the line which you have already made, mark again. These two lines show every defect in the straight edge, just twice as bad as it really is. In this manner defects can easily be found. Work the high places down with a sharp plane and test occasionally as explained above. In this manner make the edge perfectly straight. Such a straight edge will be valuable in marking boards to be ripped, or in testing work for straightness in the shop.

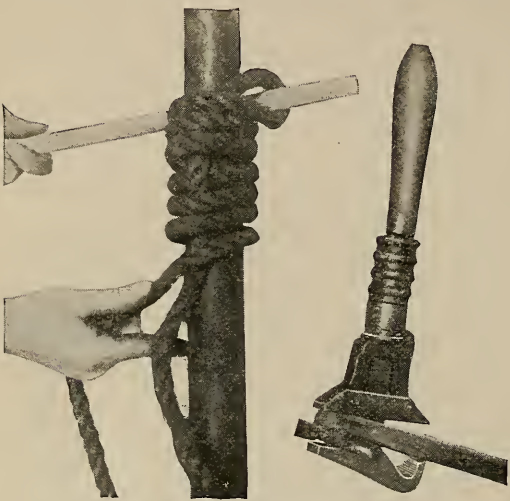


FIG. 22.
(A) Rope for pipe wrench; (B) Monkey wrench for pipe wrench.

QUESTIONS AND PROBLEMS.

1. If draining a field increased the corn crop by 12 bu., worth 40c per bushel, how much would the increased yield on a forty-acre field be worth? On how much money would this amount pay interest at 6 per cent?
2. A person bought 20 acres of land which was planted in corn. He paid $150 an acre for the land and corn. How much did the land alone cost him if the corn yielded 60 bu. per acre and he sold it for 40c per bu.?
3. A soil weighing 80 lbs. per cubic foot absorbs five-eighths of its weight of water. How much water does it hold?
4. A soil weighing 92 lbs. per cubic foot is five-eighths water. How much dry soil is there in a cubic foot?
5. If 275 lbs. of moisture are required to produce 1 lb. of a corn plant, how much will one hill of corn require if it weighs 7¼ lbs.?
6. There are 43,560 sq. ft. in an acre. If we place one ton of manure on an acre, how much is that per square foot?
7. One cubic foot of soil admits ⅜ cu. ft. of air. How many cubic feet of soil are required to contain 1 cu. ft. of air?
8. What makes a soil hard if it is plowed too wet?
9. Explain puddling of a soil.
10. Why can not plants grow well in a cloddy soil?
11. Under what condition is a soil too wet to plow?
12. What is the value of drainage to clay soil?
13. What is the value of humus to clay soil?
14. What is the use of air in the soil?
15. Why does a loam soil need care?
16. Why is burning a humus soil a bad method of improvement?
17. What is the advantage of giving plants plenty of room for their roots?
18. How may we increase the water-holding power of a sandy soil?
19. What is meant by surplus water?

CHAPTER V

SOIL MOISTURE.

Plants take water from the soil through their roots. This water passes directly to the leaves, and that which is not required by the plant is evaporated from the leaves into the air. One ton of dry corn crop will use during its growing period about three hundred tons of water. This water is obtained by the plant in three conditions: (1) as free water; (2) as capillary water; (3) as hygroscopic water.

Free Water: Free water is that water which flows along beneath the surface of the soil, and is not retained by the soil grains. The passage of this moisture, due to its weight down through the soil is called percolation. (See A Fig. 23.) The water which flows from a tile ditch, or into a post hole is free water. It is oft-times called underground water. The free water in some soils is very close to the surface, while in others it is very deep. Plants can not send their roots below the level at which the free water is found, and this place in soils is called the water table. (See B Fig. 23.)

If the water table or level of the free water is very near the surface, the plant has very little soil from which to get its food and cannot grow well. We drain soils, therefore, to lower the level of the free water. This gives the roots of the plants more soil from which to obtain food. We do not want the level of the free water to be too deep, for if it is too far down to the free water, the capillary water can not supply the surface soil as it should.

Capillary water depends upon the free water in the subsoil for its source of supply. The depth at which the free water or water table should be located in well managed soils depends upon the nature of the subsoil; six feet being a maximum depth.

Capillary Water: The water which creeps from soil grain to soil grain through the soil is called capillary water. The power by which this water is lifted from soil grain to soil grain is called capillary action, or capillarity. In capillary action the water moves just as the oil moves in a lamp wick. (C Fig. 23 shows capillary action.) You have no doubt observed this thing many times in the lamp. The oil which goes up through the wick corresponds to the capillary water in the soil, while the oil in the lamp corresponds to the free water. If the free water in the soil is too far below the surface, it would be a difficult task for the water to climb to the surface as capillary water. The pull that the soil grains would exert upon the water would not be great enough to bring sufficient water to the surface soil to supply the needs of a growing plant. Near the free water the layer of moisture around each soil grain is very thick. But as we approach the surface of the soil, the layers of moisture are less and less thick.

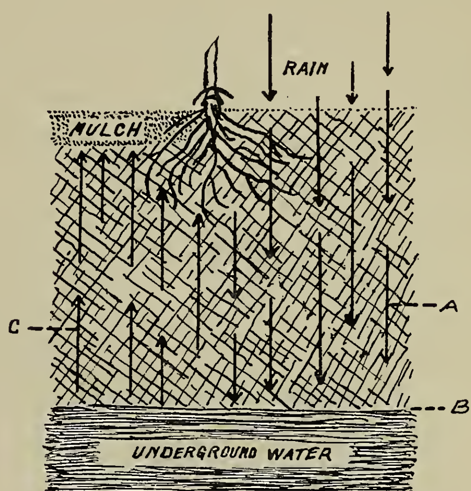


FIG. 23.
Soil water.

Where Capillarity Is Greatest: The moisture moves upward in fine soils, such as clay, in much larger amounts than in coarse soils like sand. This is on account of the pore spaces in the soil.

Pore space is the name given to the openings between the soil grains. When the pore spaces are large the water can not climb so high, for the layers of water, or films, become so heavy that the force of capillarity is soon overcome. The fact that in a fine soil the moisture may be lifted much farther than in a coarse soil accounts in part for the reason that a clay soil gives off moisture so much longer than a sandy soil.

Method Of Showing Capillary Action: If you will heap up a pile of loose, dry soil in a pan, and pour water around the base of the pile, in a little while the water will have moistened all of the soil. The water passes from soil grain to soil grain until it reaches the top and moistens every grain. This capillary water is the water which the plant uses. The plant uses very little free water.

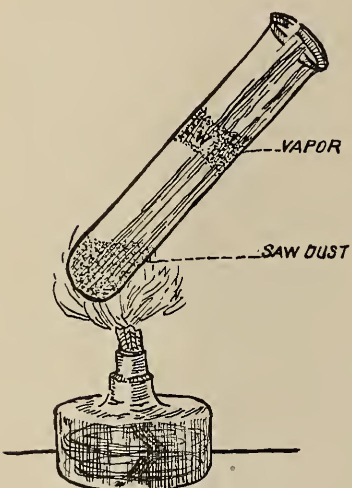


FIG. 24.
Hygroscopic water.

The water which evaporates from a soil is also capillary water. As fast as capillary water is removed from soil by plants, or by evaporation, more water is supplied, drawing upon the supply of free water below. Therefore as long as we keep the supply of free water deep enough that the roots of the plants can have sufficient room, and near enough to the surface to allow capillarity to bring the water up as fast as it is used, our water supply is well taken care of.

Hygroscopic Water: When soil seems very dry it still contains some moisture. Even when it is so dry that plants can not live for want of moisture, there is some water present. This water exists as very fine films around each soil grain. You can easily show that hygroscopic moisture exists in the most thoroughly air dried soils. To do this, take some dry soil from a field, or some dust from the road. Put a little of it in a test tube or vial and heat it gently over a flame. You will soon notice particles of moisture collecting near the mouth of the tube. This shows moisture to have been present in the soil. Hygroscopic moisture is of very little use to the farmer since the plants can obtain only a very small amount of moisture in this form.

Fig. 24 shows sawdust that was obtained from a well seasoned board, giving off moisture. This sawdust would have seemed perfectly dry to the touch, yet the experiment shows that it contained some moisture.

Soil Mulches To Conserve Water: A soil mulch is a layer of loose soil over the more compact soil. (See Fig. 23.) The more compact the soil is, the better it conducts water to the surface. If we break up and pulverize a few inches of top soil capillarity is checked in its upward movement when it reaches this point. Since the moisture must get in contact with the air before it evaporates, and since a mulch prevents this, the moisture evaporates but slowly. Producing a mulch is the most valuable thing we can do after each rain in order to keep the moisture in the ground where the plants can use it. This should be done as soon as the soil is fit to work.

Most farmers pay no regard to weather conditions when cultivating their crops. They go over their corn one or four times, whichever their standard of excellence is, paying no attention to whether their mulch has been destroyed or not. As long as the soil mulch is not destroyed in a cultivated field plowing is of very little value. Cultivating a field of growing crops at the correct time to save the moisture which falls or is present, is of as much importance as any of the other operations which the farmer performs. Later you will have some experiments which show you how well a soil mulch checks the loss of capillary water.

The Water Holding Capacity of Soils: The amount of water which a soil can hold is determined by the amount of surface area in that soil. The finer the particles of which a soil is composed the more surface area there will be. (See Fig. 25.)

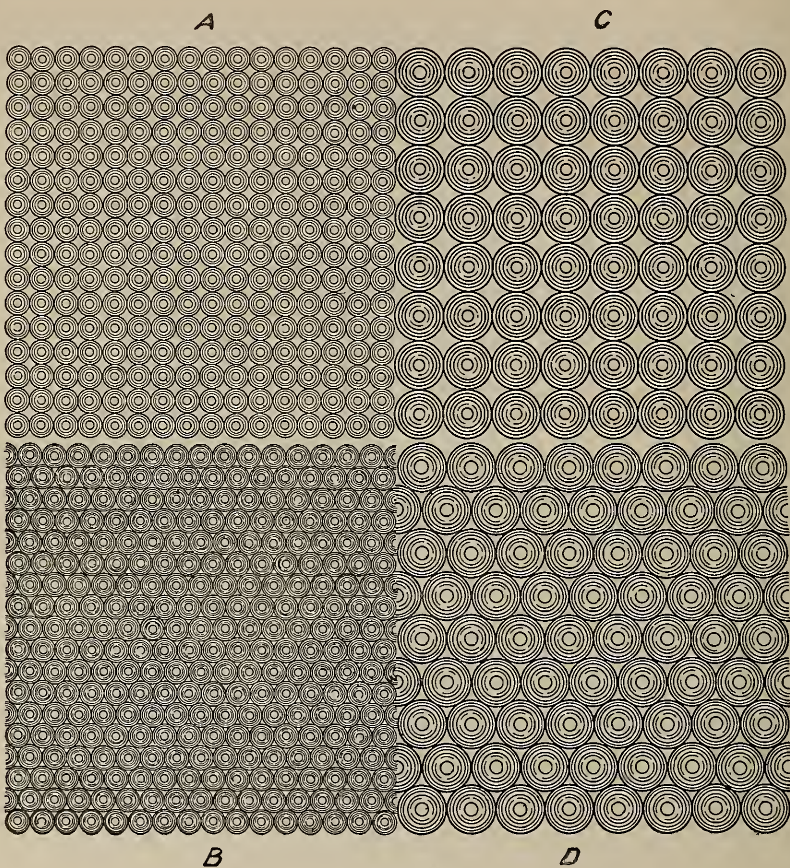


FIG. 25.
Pore space and water holding power of soils.

Therefore a coarse sandy soil will not have as much surface area as a fine soil, and consequently will not hold as much water. In fact, a sandy soil when saturated (filled with water) will hold only about 16 lbs. of water per cu. ft., while a pure humus soil will hold 26 lbs. per cu. ft.; the other soils hold amounts varying between these extremes. Fig. 25 shows different arrangements of soil grains.

But we do not want our soils to be saturated with water, for this keeps out the air. We are not interested so much in the amount of water a cu. ft. of soil will hold when saturated, as we are interested in the amount of capillary water it will retain. All the water which remains after percolation has ceased is called capillary water. This includes hygroscopic water. As capillary water is found on the surface of the soil grains the greater the amount of surface in a soil the greater amount of capillary water it will hold. A fine soil not only has more soil particles, but more surface than a coarse soil, therefore, we may say that a fine soil will retain more capillary moisture than a coarse one. Obviously then a soil which will contain a great deal of capillary moisture, and with a water table that will permit of a constant supply of water, is a very desirable soil.

The Conservation Of Soil Moisture: The saving of soil moisture is a very important problem to the farmer, for possibly no one thing limits the average crop so often as the shortage of water. It is estimated that for each ton of mature crop produced on an acre four inches of rain has been consumed. If five tons of material is harvested from an acre, twenty inches of rain has been required by that crop. In many localities very little more than this amount falls during an entire year, and in many places there is much less than this amount.

When we remember that the greatest amount of our moisture is received during the seasons when the plants are not growing, and that a large part of the water which the soil receives is lost by evaporation, we begin to see the importance of saving all of the water we can.

The best means of saving moisture are cultivation and drainage. Most of the moisture that is lost from the soil is lost by evaporation. The water is brought to the surface by capillarity, and is then evaporated into the air and lost. If after the rain falls the surface of the soil is stirred so that capillarity is stopped the water remains in the soil and is not lost.

REFERENCES.

Simple Exercise Illustrating Some Applications of Chemistry to Agriculture. United States Department of Agriculture, Farmers' Bulletin 195.

Practical Agriculture, by Wilkinson. Published by the American Book Co.

Davis, Productive Farming; published by the Lippincott Publishing Co.

EXPERIMENT NO. 20.

Effect of Soils on the Absorption of Substances from Solution.

We have learned that clay soils are richer in plant food than sandy soils. When water dissolves the plant foods as it passes through the soil it takes this plant food away unless something retains it. Fine particles of soil absorb this plant food from the water and retain it for the use of the plants.

Let us prove by an experiment that a fine soil does retain more of this plant food than a coarse soil. To do this we will have to pour water over the soils and have in this water a substance which we can see. Color some water red by adding red ink or by adding some aniline dye. You can obtain this at any drug store in packages as Diamond Dyes, etc. Do not make the water too red. Add only enough dye to color the water distinctly. Take two percolation bottles and tie cloth over the mouths of each or plug them with cotton. Put them in the percolation rack and pour a little sand in one and a little clay in the other. Now pour a quantity of the colored solution into each bottle and collect the water which drips through. Use as many more soils as you care to in this test.

Which soil permits the most color to pass through? As rain water passes through different kinds of soil, from which will it carry the most plant food? Would it be a good plan to apply fertilizers to a sandy soil? What would happen to the fertilizers if it rained?

Make a drawing of the apparatus in your note-book. Use colored crayons to show the difference in the color of the water as it comes from the different soils. In your drawing label each bottle to show what kind of soil it contained.

EXPERIMENT NO. 21.

Capillarity.

The capillary rise of water, as has been explained, depends upon the number and size of the pore spaces in the soil. In the following experiment you will expect the clay to lift more water than the sand. It will at first not appear to do so, although this is in fact what it does. The water which passes upward through the clay soil is covering more surface area than the water which passes through the sand. It moves upward slower at first, because the soil grains are so much closer together. In the sand the soil grains are far apart, and the water climbs rapidly. If you were to take long steps you would travel more rapidly than if you took the same number of short steps. The water in the clay takes short steps while that in the sand takes long ones. If your columns of clay and sand are high enough at the end of a day or two you will find that the moisture has traveled farther in the clay than in the sand, although the sand was ahead at first. Try to bring out the above facts in your experiment. (See Fig. 26.)

Take four percolation bottles and cover the mouth of each with cheesecloth, or plug them with cotton. Fill each with a different kind of soil. Clay, sand, loam and humus are good ones to use. Place the bottles in the percolation rack so that the mouth of each bottle almost touches the bottom of a tumbler. Pour the same amount of water into each tumbler and keep the level of the water above the mouth of each bottle.

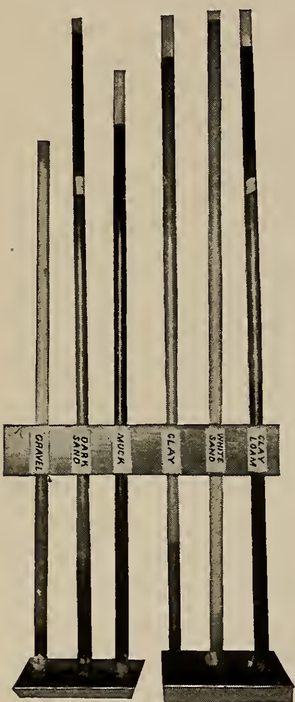


FIG. 26.
Capillary tubes in use.

Measure the height to which the water rises in the bottles at intervals of ten minutes each. Write the results in your note-book and explain why the moisture behaves as it does in each soil. Note how much water is removed from each tumbler and tell which soil takes up the most water in a given length of time.

EXPERIMENT NO. 22.

Distance Capillarity Will Lift Water.

We have shown in a previous experiment how water passes up through a soil by means of capillarity. You will find, however, that capillarity will not lift water a very great distance.

In order to see how far water may sink in a soil before it is lost to the plants—that is, so capillarity cannot bring it back again—we will perform the following experiment:

Obtain a glass tube of large bore about 1 inch in diameter and 6 or 7 feet long. If this is not to be had, ordinary glass tubing connected with pieces of rubber tubing will serve. Tie a piece of cheese-cloth over one end of the tube and fill the tube with finely pulverized dry clay soil. This soil must be well packed if it represents ordinary field conditions. Immerse one end of the tube in a pan of water and let the apparatus stand from 8 to 10 days.

Record the height to which water rises in the tube at the end of this time. This will show you how high capillarity will lift water in a clay soil. Any water which sinks below this depth is lost to the plants. In a clay soil this depth will reach to about 6 feet. If you have the apparatus it would be well to test loam, sand, etc., for capillarity.

This experiment will help you to understand drainage, which will be taken up in another chapter. It will also help you to understand how plants live during the dry summer months. Find out all you can about the depth of the water table in your locality at various seasons of the year.

Write a discussion, "The Underground Supply of Plant Moisture."

EXPERIMENT NO. 23.

The Three Kinds of Moisture in the Soil.

The purpose of this experiment is to classify the various kinds of moisture in the soil, so that we may know what we are trying to save by tillage. To perform this experiment, obtain a percolation bottle, a pint of loam soil, some cheese-cloth and a pair of balances.

Tie a cloth over the mouth of the percolation bottle. Put into it about a pint of loam soil, and jar slightly to settle it. Now add water until it begins to drip from the mouth of the bottle. This water is free water.

After the water stops dripping, remove the soil from the bottle. Weigh it. Spread it out and let dry until there seems to be no more moisture present. Weigh again. The loss in weight is capillary water. Put the dry soil in a dish and heat it in an oven for an hour or two. The heat should not be above the boiling point of water. Cool and weigh again. The loss of weight is hygroscopic moisture.

What kind of water is most valuable to crops?

Can the farmer control any of these forms of soil water?

Take 2 small bottles of the same size and put in one the amount of capillary water which was in your pint of soil. In the other place the amount of hygroscopic water that was present.

Make a drawing of the two bottles in your note-book, and show by comparison the amount of each kind of water in the sample of soil tested.

Hygroscopic water may also be shown by taking a dry piece of wood and heating it in a test tube as shown previously, Fig. 24. The moisture which collects at the mouth of the test tube is hygroscopic water. In your note-book write a definition of hygroscopic water; of free water; of capillary water.

EXPERIMENT NO. 24.

Water Consumed by a Plant.

We have mentioned the fact that plants consume large quantities of water, so let us perform a simple experiment to demonstrate this fact. Take two clean glass tumblers or fruit jars, and pour exactly the same amount of water in each. Carefully dig up a healthy bunch of red clover or some other hardy plant so as not to injure its roots. Wash the soil from the roots and then immerse them in one of the tumblers of water. See Fig. 27. Mark the

FIG. 27.
Water consumed by a plant.

height of the water in each tumbler by pasting a piece of paper on the outside, even with the surface of the water. Place the tumblers in the window side by side.

When the plant begins to wilt, possibly at the end of two or three days, remove and notice the water lost. What has become of the water that has left the tumbler which contained no plant? How much more has gone from the tumbler which contained the plant? Account for the difference in the amounts removed from the two tumblers.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Dirt Band.

In removing plants from a hotbed to outdoor beds the sudden change of conditions is likely to kill them. In order to make this change a little more gradual, a cold frame, which is very similar to a hotbed, but kept at a much lower temperature, is often used. When we place plants in such a cold frame, it is well to place each in a separate receptacle, so that when they are to be transplanted for the last time no roots will be torn or removed and the

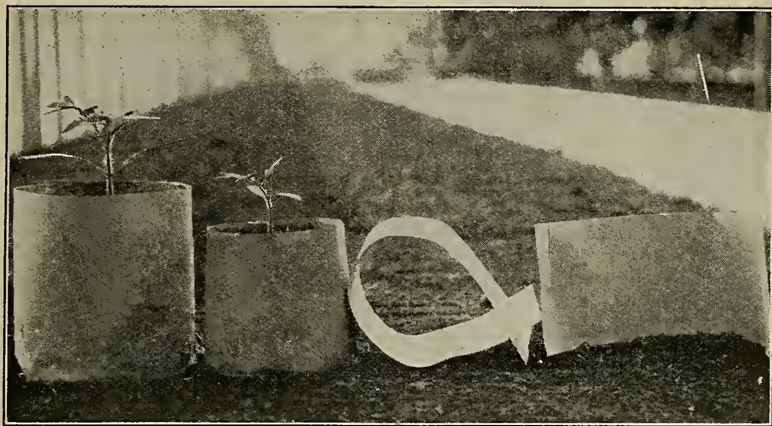


FIG. 28.
A Dirt Band.

plant will receive no setback. The most convenient way to do this is by means of dirt bands. The dirt bands should be made of heavy paper and of any desired size. Fig. 28 shows one 3 inches in diameter. This is a very good size, but a smaller one will serve as well.

A double thickness of newspaper serves as a bottom, the band being filled with soil and placed on the newspaper. One plant is set in each band, and when removed to the garden the soil and band are both taken and set. The paper soon decays and the plant has been transplanted without the loss of a single root. To make this dirt band, lay out a figure on heavy paper the same as shown in Plate 3, except the part below line E. F. This part is left out entirely. Put it together and your work is complete. You might make one as shown in Fig. 28 if you prefer it.

Flat for Growing Plants.

When plants are transplanted from the hotbed they are usually planted in flats. Oft-times the seeds are sown directly in the flats. A flat is a box 3 inches deep, 15 inches wide and 20 inches long, inside measurements. Such a flat may be made as follows:

Use soft wood one inch thick for the sides of the flat. Cut and put together as shown in Fig. 29, using 6d nails. Use one-half inch material for the bottom. This material should be narrow. Wide boards warp until the soil leaks out at the bottom. When nailing on the bottom boards do not put them against one another too tight. If you do, when they become wet they will swell and bulge away from the frame.

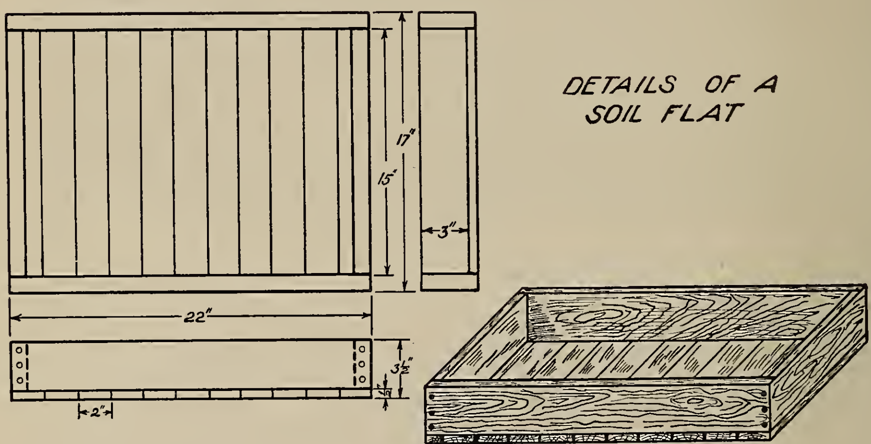


FIG. 29.
A soil flat.

Use the flat in your experiments in growing plants. It would be very interesting and profitable if. you could grow some early cabbage or tomato plants to be taken home and planted when the weather becomes warm. Place a layer of paper in the bottom of the flat before putting in the soil. This will prevent any soil from leaking from the box.

Line Winder.

A line winder is a very valuable little article around the farm garden where laying off the rows across the garden is accomplished by means of string. The drawing shown on Fig. 30 makes a very good winder. Use any

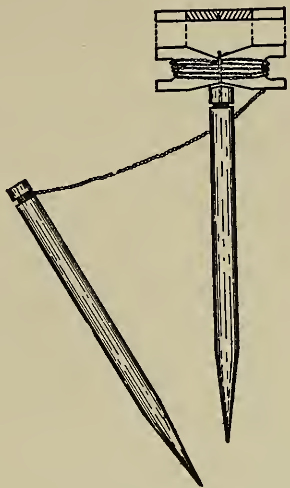


FIG. 30.
A line winder.

kind of wood for this work. Soft wood given a coat of varnish when completed is very good. This line winder may be fastened on a stake as shown, if it is to be used a great deal in the garden. Fig. 2, Plate 2 shows a neat line winder.

QUESTIONS AND PROBLEMS.

1. A cubic foot of soil contains 30 lbs. of moisture; 18% of it is free water and the remainder is capillary water. How many pounds of capillary water does it contain?
2. If water dissolves 10,000 lbs. of plant food from the surface foot of a soil in one week, how much would it dissolve per day? How much would it dissolve in an hour?
3. At the above rate, how much plant food would water dissolve from the first 6 inches of a soil in one day? In one hour?
4. Eighty-four per cent of the substance in a soil will not be dissolved by water. How many pounds of soluble material in a cubic foot of clay weighing 80 lbs.?
5. If $2\frac{1}{8}$ inches of rainfall dissolves 260 lbs. of a plant food from the garden soil, how much rainfall will be required to dissolve 600 lbs. of plant food?
6. If 309.8 tons of water in a crop denoted a rainfall of 2.6 inches, how much rainfall would 452.8 tons of water in a crop denote?
7. A sandy soil having a water-holding power of 18% weighs 110 lbs. per cubic foot when dry. How many pounds of water will it hold?
8. A clay soil weighing 80 lbs. per cubic foot when dry has a water-holding capacity of 26%. How many pounds of water does it hold?
9. If a corn crop is able to reduce the water in a soil from 18% to 4%, how many pounds will it remove from a cubic foot of soil?
10. If a corn crop is able to reduce the amount of moisture in a clay soil from 26% to 12%, how much water will it remove from a cubic foot of soil?
11. Name the different forms of water in a soil.
12. Which form of water is used most by the growing plant?
13. What becomes of the moisture taken up by a plant?
14. What effect does compacting a soil have upon capillarity?
15. What kind of soil holds the most capillary moisture?
16. What is capillary water?
17. What is meant by "Water Table?"
18. How may we test soil for hygroscopic water?

CHAPTER VI

DRAINAGE.

A Plant's Problem: A plant on an undrained soil has a very hard time trying to obtain the correct moisture conditions for its growth. Early in the spring the rainfall is usually so great that the plant is surrounded by too much water. Later in the season the soil becomes very dry. In order to live, the plant must adapt itself to each of these conditions which it does only with great effort and usually with a small amount of growth. Moisture conditions may be made much more desirable for the plants, as well as more convenient for the farmer by proper drainage.

A Wet Soil: A wet soil in the spring makes the farmer late with his spring plowing, thus causing his crops to get a late start. Such a soil is always cold so that when the plants are started, they do not grow well. Before a farmer can cultivate a wet soil, the weeds get a start and are then very hard to overcome.

The roots of a plant in a wet soil have a small chance to obtain the air which they need, and oft-times can be seen growing above the ground, trying to escape the extra water. Therefore, unless we drain the soil so that it will rid itself of this extra moisture, our ordinary plants will have a very poor chance to grow successfully.

The Value of Drainage: The only way to remove surplus water from a field that is practically level is by drainage. The drainage of such a soil admits air to the roots of the plants. It deepens the layer of soil from which the roots can obtain food. In time of drought, plants growing in a well drained soil do not suffer for moisture as much as plants growing in an undrained soil.

Good drainage permits of early tillage and increases the plant food in the soil.

Another important point to be considered in draining the soil is that a well drained soil becomes warm earlier in the spring, giving the plants a better chance to grow.

Drainage Gives Roots More Room: If a soil is undrained the water usually sinks only a short distance below the surface.

FIG. 31.
A wet soil.

If we dig down a few feet we find that the soil is completely filled with water. This water level, as we have learned, is called the water table and in an undrained soil it lies very near the surface, especially in the spring and fall. Since the roots of a plant will not grow below this water table, they have only a very little room for growth in such a soil. By draining this same soil the roots will penetrate deeply, and when the dry days of summer come the great network of roots is able to obtain water by capillarity. Therefore the plants do not suffer so much for moisture as they would have suffered if the soil had not been drained.

Fig. 31 shows an undrained field.

Drainage Increases Weathering Action: To show what water does in a soil let us notice what happens to a solid lump of sugar if placed in a tumbler of water. The sugar first crumbles from a solid mass into a larger number of fine particles. Finally if there is not too much sugar it will disappear altogether. This is called "going into solution." When water passes through a soil it is treating the soil just as it treated the sugar. It is breaking down the large soil particles and carrying away with it much plant food and also much that is poisonous to plants. No difference how much water a plant had if some water did not pass through the soil and carry away plant poisons with it, the plant could not live long.

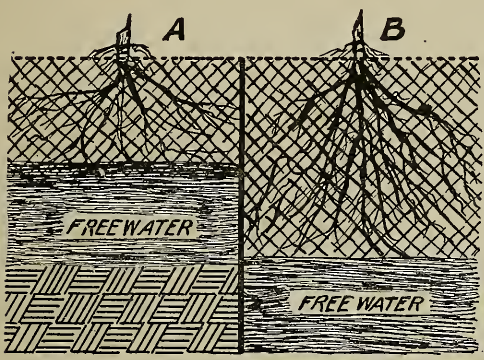


FIG. 32.
Drainage gives roots more room.

Drainage Raises the Soil Temperature: Through the winter the ground remains frozen and filled with water. If the ground is undrained, when spring comes, this cold water remains in the soil for a long time. This water becomes heated very slowly, so that the soil is cold until late. If such a soil is drained, however, the warm spring rains soak into the soil taking the place of the cold water which the drain removes. This change of water increases the temperature very rapidly, and such a soil becomes warm much earlier than an undrained soil. Also in an undrained soil the water escapes by evaporation at the surface and the evaporation of this water makes the soil cold. Drainage would be worth while for the difference it makes in soil temperature if it did no other thing.

Indications That Drainage Is Needed: All good land should be well drained, either naturally or by artificial means. In most cases it is only partially drained naturally, and in some cases not at all. If the subsoil is very loose and open, nature has relieved us from concerning ourselves about the drainage of such land. In some places the surface is so hilly that rainfall is almost all carried away at or near the surface. Such a soil would not need tile drainage.

Almost always a soil which needs drainage is weedy. Weeds have adapted themselves to conditions under which cultivated plants can not live, and if we find a field where our common plants are crowded out year after year by weeds we can rest assured that such a soil needs drainage.

If we find mosses and sedges growing on a soil, it indicates the need for drainage. A soil which is undrained will generally refuse to produce a crop of clover, on account of the injurious substances which are left at the surface by the evaporation of moisture. Therefore, if a soil will not produce a clover crop, drainage is one of the first things that should be looked to for the failure.

Drainage Prevents Heaving: Crops can not thrive on a soil that becomes filled with water. In winter the freezing water in the soil expands, forcing the soil grains upward, for that is the only way they can move. When the ice melts the soil grains settle close together again. Each time that this happens the roots of the plant are lifted a little farther out of the ground. This breaks off all of the fine rootlets which are so necessary for the plant. When there is considerable freezing and thawing during a winter, plants are lifted almost entirely out of an undrained soil. It is absolutely impossible for them to live under such conditions, and the only way such a soil can be made valuable is by drainage. The accompanying illustration, Fig. 33, shows what happens as a result of the heaving of the soil. Many farmers have tried to grow alfalfa on this kind of soil. Can you see why they have failed?

History of Drains: People have long realized the need of drains, but until rather recent years no permanent methods were devised for successfully draining a soil. The open ditch was

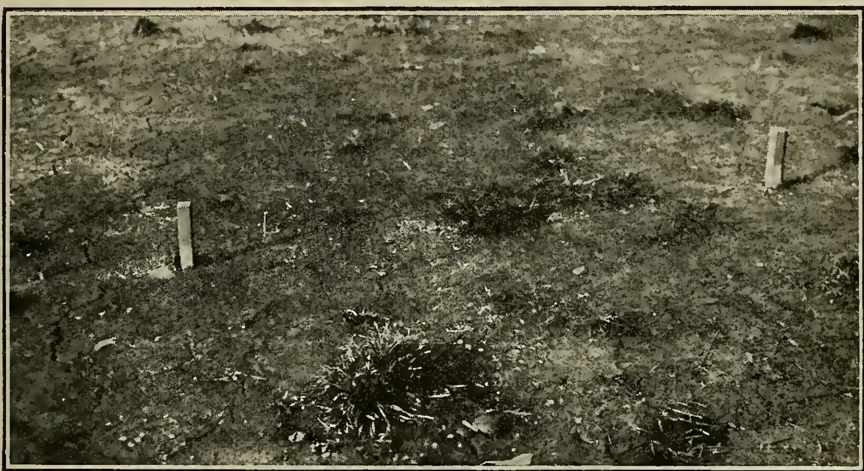


FIG. 33.
The stakes in the above picture were driven with their tops even with the surface of the ground in the fall. The winter's freezing and thawing lifted them almost entirely out of the ground. Do you see why plants cannot thrive in such a soil?

the only method used for a long time, but such a ditch took up a great deal of room and was always needing repair. So men began to search for something better to serve as a drain. When this necessity for drainage was first realized in America, hollow tile were not to be had. Instead men tried to make drains by burying bunches of poles, end to end. The spaces between the poles left open places where the water could pass and such drains were all right until the poles rotted. To overcome this difficulty the idea of taking the rocks which had to be removed from the fields and making drains of them was started. Men dug open ditches, placed a few layers of boulders and rocks in the bottom of them and then filled them with soil. The stones like the poles left spaces, through which the water could flow. Such drains worked very well. Later the use of hollow tile was adopted.

Hollow Tile For Underground Drains: The first burned clay tile used here were shipped to America from Scotland. Most people made fun of them and said that they would ruin the soil in which they were placed. The average farmer at that time and for a long time after could see no use or value in drainage. For this reason and on account of the expense the use of tile drains was very slow in being adopted. At the present time the value of drainage is well recognized, and although still expensive, excellent systems of drains are placed on all of the more modern farms.

Hollow tile were almost entirely made of burned clay until quite recently. Large quantities of them are now made of concrete. Larger tile are made of concrete than it is possible to make of burned clay. However, the smaller tile can still be made cheaper from burned clay than from concrete.

How Drainage is Accomplished: All moisture leaves the soil either by passing over the soil or through it. That moisture which passes over a field without soaking into the soil is said to have been removed by surface drainage. In the spring, when the rainfall is heavy, a great amount of water runs off of a field as surface water. This water not only does no good, but it does a great deal of damage. It carries as sediment a great number of fine soil grains which, as has been mentioned, are the best part of the farmer's field. After a flood or a heavy rain you often see quantities of rich black soil along the roadsides. This is valuable plant food which has been washed from the neighboring fields. The water which runs off of a field as surface water does not help to decay or break up the subsoil, which is one great thing that water does in the soil.

Possibly the greatest advantage of having water seep through a soil and flow through a drain is the fact that it dissolves and carries away many poisonous and injurious substances called salts, which are continually accumulating in the soil. Just as water is used in your home to wash away undesirable dirt, so it behaves in the soil by removing these poisonous substances. As mentioned previously, plants can not live very long where there is no passage of water through the soil. For the above reasons it is much better to have the water which falls pass through the soil, rather than over it.

Underground Drainage By Covered Drains: Underground drainage has to do with all water which passes through the soil and is removed through some underground outlet. Underground drainage takes place naturally in most soils, but in many soils it is not as effective as it should be. In order that underground drainage shall be more effective, the farmer is oft-times compelled to supply some artificial drainage.

Percolation (seeping of water) as you know depends upon the structure of the soil. If the soil or subsoil is hard and packed the water gets through very slowly. In such soils the drains must be close together to remove the extra water from all parts of the soil. If, on the other hand, the subsoil is coarse and open the water can percolate very rapidly and it needs no drainage. The rapidity with which water is able to percolate through a soil determines the depth to which we can place our underground drains, as well as the value of both open and closed drainage systems.

Drainage By Means of Open Ditches: Drainage by means of small, open ditches is rapidly going out of existence. This is as it should be, for open ditches are a nuisance to any farmer; besides it is expensive to maintain them. The ground which an open ditch occupies will yield larger returns if replaced by a covered drain and tilled. Open drains scatter weed seed and cause work and worry each year. The expense of all this is ultimately greater than the cost of tiling such a ditch.

Some farmers maintain that the open ditch is very valuable as a source of water supply for live stock. However, in this respect, tile drains may be made even more valuable than open drains. By leaving a small runway down to the water and then leaving out a few tile, stock can obtain water as long as water flows through the drain. If this is done the earth may be dug out a little below the tile, and clean gravel put in its place. The ends of the open tile should be screened so that nothing injurious will get into the openings to clog the drain. Such an arrangement makes a more convenient and cleaner watering place than can possibly be obtained by an open ditch.

A tile drain, unlike an open drain, compels the water to pass through the soil, and, as has been stated, this is a decided advantage. However some subsoils are so hard that water is unable to soak through. Where such a soil exists, open drains must be used until the structure of the subsoil is modified.

Laying a Drain: The tile used in laying a drain should be strong and well burned. A cracked or damaged tile should not be used, for it is sure to give trouble at sometime. If a tile will not make a good joint on account of a broken or crooked edge it should not be used. If it is used the joint should, at least, be protected with a piece of a broken tile.

It is poor economy to use for drainage a tile less than 4 inches in diameter. Tile smaller than this dimension are easy to clog and do not perform as much service as they should. It costs but very little more to use larger tile and they can be relied upon to give more and better service. In laying a drain great care should be exercised to get the tile in line, for any places where the tile do not join properly furnish spaces for dirt to lodge and clog the drain. This is especially true of the small tile.

Distance Apart and Size of Drains: The distance of drains from each other and the depth at which they should be placed depends upon the character of the soil. On light porous soils they should be deeper and farther apart; on heavy soils they should be close together and near the surface. Tile 4 inches in diameter laid three or four feet deep, from 80 to 100 feet apart, under ordinary conditions, make a very good drainage system. In laying out a drain provision should be made for a fall of at least 2 inches in 100 feet. Less than this amount is undesirable, and less than 1 inch to 100 feet is unsatisfactory. It is best to obtain the services of a drainage engineer if the fall is slight and the drainage system complex. For ordinary work a farmer who can use a level should be able to lay out the drain.

Laying out a tile drain and figuring the fall which it should have presents a practical problem, which would make a very good field exercise for a class.

Staking for a Drain: Take a number (a dozen or more) stakes, one inch square and three or four feet long, an axe, a level, a tape line and a ten or twelve foot straight edge, to a field that has an open stream running through it.

Go to a portion of the field that is quite distant from the stream and there start your tile ditch. First drive a stake to mark this point (the source). Then go down along the stream and near the water's edge drive another stake which is to show where the end (outlet) of your drain is to be. Now proceed as follows:

About ten feet from the stake at the source of the proposed drain drive another stake in direct line between it and the one at the outlet. In a like manner at regular intervals (say fifty yards) drive the remainder of the stakes, being sure to keep them in line with the first two driven.

Now get the first stake driven (the one at the source) straight up and down and rigid. To do this you may have to drive it farther into the ground. Then drive the stake, which is ten feet away from this one, down until the tops of the two stakes are exactly level. You can tell when they are correct by laying the straight edge across the two stakes and testing with the level. After the first two stakes are perfectly level, have a boy sight over the tops of them, while another boy makes pencil marks on all of the rest of the stakes. These marks should be made at a height which the person sighting designates as being level with the stakes over which he is sighting. When all of the stakes are marked except the two over which the sighting was done, we are ready to establish the depths. This can be very easily done.

First decide how deep the drain should be at the mouth. Usually a short distance above the water in the open ditch is about the right height for the outlet of the closed drain. Measure the distance from the line on the stake at the outlet, to the depth you want the bottom of the drain; for illustration, say seven feet. Write this depth on the stake.

Now if you want a fall of one inch in one hundred feet, for example, and your next stake is one hundred and fifty feet away, the distance from the line on that stake to the bottom of the drain will be one and one-half inches less than seven feet, or six feet ten and one-half inches. Write this number on the second stake. You can readily see that it would be one and one-half inches less to the bottom of the drain here than it would be fifty yards farther down.

In a like manner put the correct figures on all of the rest of the stakes. The figures on each stake show the distance from the line on that stake to the bottom of the ditch. This work should require several recitations and the drain should be designed on paper as well as laid out in the field. The drain should be so laid out that it would do its full share of work if it were constructed.

How Water and Air Get Into a Drain: The water enters a tile at the joints, and does not seep through the tile as is popularly supposed. For this reason, we need to have good joints (but not watertight) to prevent the water from carrying dirt into the drain. We have stated that the air which gets into a soil through a drain is one of the benefits of a drain.

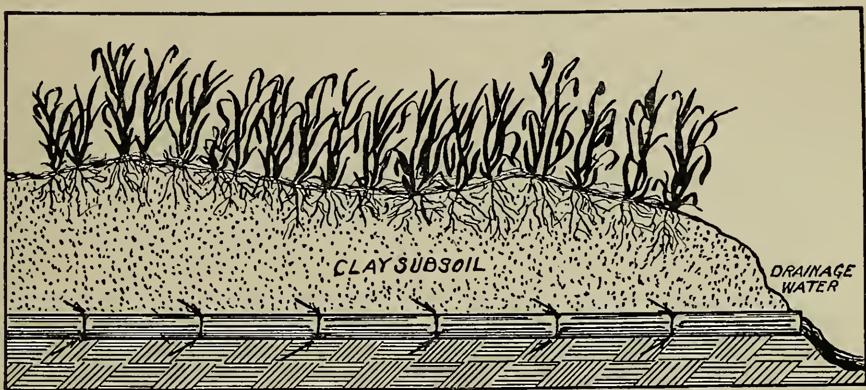


FIG. 34.
How water and air get into a drain.

In order that a tile drain may admit a great deal of air to a soil, it is best to have the source of a line of tile open to the air. This can be accomplished by standing tile on end at or near the source of a drain and letting the top tile come just above the surface of the soil. This tile should be screened to prevent rabbits, etc., from getting into the drain. It is best brought to the surface along a fence, or at some place where it will not be in the way of farming operations. Such an arrangement at the source of a drain permits a free flow of air through the drain thus aerating the surrounding soil to a great extent.

Soils That Should Have Drainage: There is always a doubt in the farmer's mind about the advisability of putting an underground drain in his field. While the special conditions of every field must be considered before we can know positively regarding that field, yet the following is a list of places where it is almost always wise to put a tile drain:

(1) *Flat lands along streams that overflow in the spring.* On such lands we must lower the level of the water in the soil as soon as possible after the overflow. If we do not drain such a soil we can not get our crops planted early, or save any crops that may have been planted before the overflow.

(2) *Flat land having a clayey subsoil.* On such a land natural drainage can not take place, so artificial drainage must be supplied.

(3) *Low places or valleys in hilly land.* The water must be drained from such places to remove the extra water that flows from the higher land all around.

(4) *Swamps and Marshes.* Such places are wet almost all year and unless drained they are of little value. When such soils are properly drained they oft-times make our very best soil.

EXPERIMENT NO. 25.

Effect of Lime on Turbid Water.

A clay soil will become more open and in better condition if it contains lime. This lime unites with the carbon dioxide of the air and flocculates (sticks together) the clay soil particles. A very excellent experiment for showing the action of lime on clay may be performed as follows:

Stir a tablespoonful of clay with a pint of water. Let stand a moment and then fill two glass vessels with the muddy water. Glass tumblers or beakers are very good for this purpose. Into one of the glass vessels put a teaspoonful of lime and shake or stir it thoroughly. Leave the second vessel untreated, except to stir thoroughly. Let both vessels stand and observe them every few seconds to note any changes that may occur. Explain what happens. Account for this change. Write a discussion upon the value of lime. (See Fig. 35.)

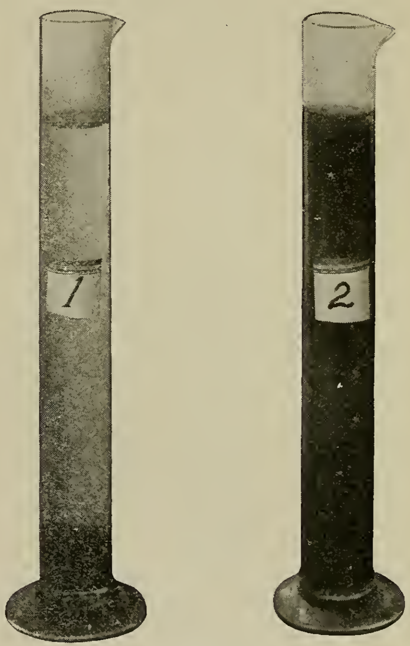


FIG. 35.
The effect of lime on turbid water.
1. Muddy water to which lime was added.
2. Muddy water without lime.

EXPERIMENT NO. 26.

The Effect of Lime on Soils.

Take two pans and make a stiff batter in each by stirring clay and water together. Have the pans of clay to the same degree of stickiness, as nearly as possible. Now stir a tablespoonful of lime in one of the vessels, adding a trifle more water if necessary. Stir until the lime is thoroughly mixed with the soil.

Leave the other pan of soil untreated and set both pans aside to dry. Place them where they will get as much sunshine as possible. When thoroughly dry, break or crush the two pans of soil and note the relative hardness of each. Explain in your note-book the results of your experiment.

EXPERIMENT NO. 27.

Effect of Drainage Upon Plant Growth.

Obtain two tin cans, and with a nail punch holes in the bottom of one of them. These holes will provide drainage. Fill both cans with rich soil and moisten the soil until it is saturated. Plant 5 to 10 seeds in each can, and cover them about 1 inch deep. Label and set aside, water them regularly and alike for a week, examining occasionally to note progress. Describe in writing the value of drainage upon germination.

A B

FIG. 36.

A—Hard puddled clay soil without lime.
B—The same soil after having lime added, and being exposed to winter weather.

EXPERIMENT NO. 28.

Temperature of Drained and Undrained Soils.

Obtain two tin cans, and with a nail punch holes in the bottom of one of them. Fill both cans with rich soil and saturate each soil with moisture. Leave both cans exposed to the air for a day. At the end of a day insert a thermometer into each soil and observe the temperature. Take readings every hour for several hours. What can you say of the temperature of a drained soil compared with an undrained soil?

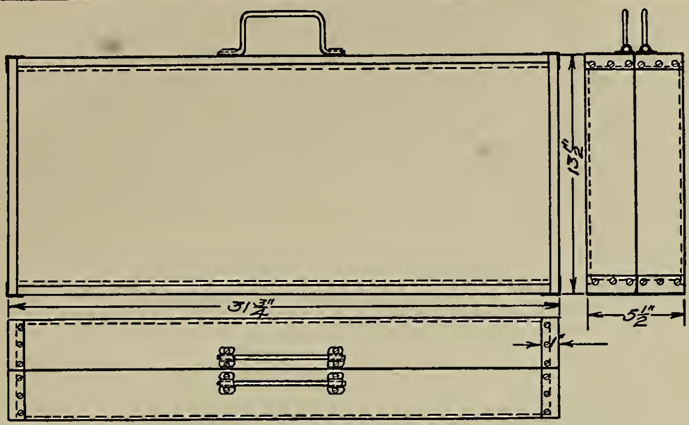


FIG 1—SPECIMEN CASE

FIG 2—SPECIMEN MOUNT

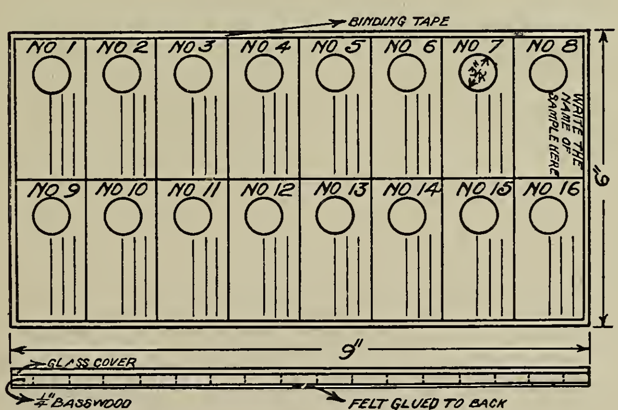


PLATE 6.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Specimen Case for Exhibit of Plant Foods.

The case shown in the picture below is a very valuable addition to a school laboratory and furnishes also a very excellent Manual Training Lesson. The case may be used to hold different kinds of soils; to hold seeds; to display cereal products; diseased animal or plant tissue; and, in fact, a very elaborate display can readily be collected for use in such a cabinet. The making of this cabinet

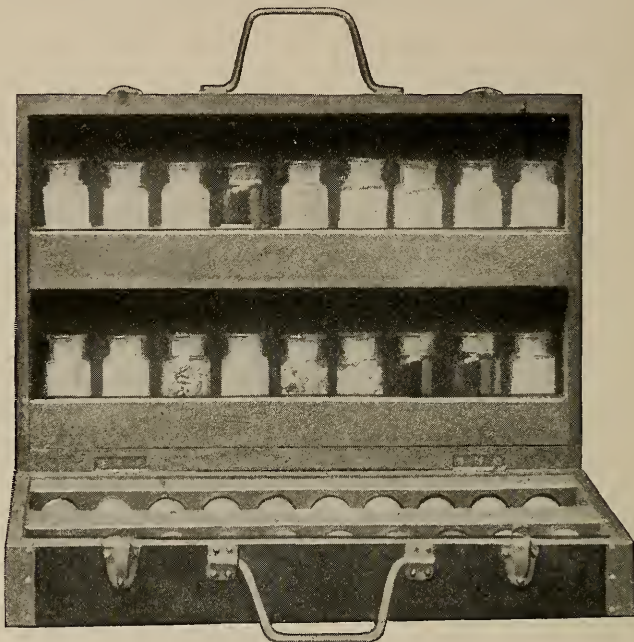


FIG. 37.
Specimen case opened.

involves the principles of making a simple box. The drawing on the opposite page, Plate 6, gives an idea of how the case is made. Seven-eighths-inch material is used and the inside is arranged to accommodate the bottles to the best advantage possible. This arrangement depends largely upon the size and shape of the bottles used. The picture above shows a very good method for arranging the display bottles. (Fig. 37.)

Before beginning the work on this case make a detailed drawing of the inside of each section, showing just how and where every bottle will go. When your drawing is complete submit it to your teacher for his approval.

The metal handles and the corners should be made entirely by the student. Sheet iron will do for the corners, but sheet brass gives the work a much better appearance. The handles may be made of either metal or leather.

Finish the case with stain and shellac. It may require several coats of shellac to get a satisfactory polish, but regardless of the labor required, the case should be well polished before it is used as an exhibit case.

Mount for Small Samples.

The mounting of a few seeds or a few types of soil may be neatly done as follows:

Obtain a one-fourth-inch board of the desired size and smooth both sides. Bore one-half inch or three-fourths inch holes equal distances apart in rows across the board. Sandpaper one side of the board until it is clean, and give it two coats of shellac or varnish. When dry, near each hole which you have bored, write the name of the seed or soil you intend to place in that hole. See Plate 6 on opposite page.

Now obtain a piece of glass the same size as the board, and with passe-partout paper, or tape, bind the glass to the face of the board. Then place the board and glass face side down and fill each hole with a thin layer of the specimens. Plug the holes with felt or pasteboard, and cover the entire back by pasting felt over it. This will give you a very permanent and convenient mount. Details of a very conveniently arranged mount are shown on the opposite page, Plate 6.

QUESTIONS AND PROBLEMS.

1. What is the circumference of a tile 4 inches in diameter?
2. How much will a tile hold 4 inches in diameter and 16 inches long?
3. How many tiles 18 inches long will be required to lay a drain 4 rds. long?
4. If a ditch has a fall of 12 ft. in 1 mile, how much fall per 1,000 ft.?
5. If water soaks into the soil at the rate of 6 inches per hour, how many hours will it take for the water to reach a ditch 8 ft. below the surface?
6. An open ditch is 18 ft. wide at the top. How many rows of corn, planted 48 inches apart, could be planted on this space if the ditch were covered, and the rows started 3 ft. from one side? Make a drawing to show this.
7. A man has to travel 100 yds. out of his way to cross a ditch at the bridge. How many feet would he have to travel if he crossed the bridge 100 times? How many miles?
8. Supposing that drainage of a field would double the crop, if a 40-acre field produced 20 bu. of corn per acre worth 60c per bushel before it was drained, how much would drainage be worth per year?
9. If 12c per foot is to be paid for a tile drain, what would it cost to lay a drain 80 rds. long?
10. What is one of the plant's greatest difficulties?
11. Name 4 disadvantages of a wet soil.
12. Give 6 advantages of drainage.
13. How does drainage help plants during dry weather?
14. How can you tell when drainage is needed?
15. Mention some soils that should be drained.
16. What is heaving?
17. What causes tile to clog?
18. How does water get into a tile drain?

THE STORY OF TILLAGE.

There is an ancient myth of a father, who on his death bed called his three sons. When they had gathered at his side he said:

"Children, I have left each of you a fortune which is hidden in the ground on my farm. I want you to have this fortune which I have left, so do not cease to labor until you have found it."

Before the sons could question the father about their inheritance he died and they were left to wonder where to look for their promised wealth. But the boys were all strong and of a determined mind, so taking spades and shovels they began to dig every place that it would have been possible to hide money. Day after day they toiled until finally the entire farm was turned topsy turvy. However, they did not find a single coin and they began to say to one another,

"Could some one else have found our money, and stolen it, or was our father playing a trick on us?"

While the sons were busy digging up the farm the faithful servants had been sowing the crops of wheat as usual, except that they complained bitterly when they had to sow grain on the uneven ground where their masters had dug.

A few weeks later the younger son, while strolling over the farm wondering where he might dig next to find his fortune, noticed the wonderful crop of grain that was ripening. Running to his brothers he exclaimed,

"Behold, brothers, we have found our fortune. Here it is growing for us. This wonderful crop which is soon to be harvested, is the fortune which our father intended for us to find."

And so it was. Year after year the sons dug up the ground, and year after year the soil produced great crops until the sons were all very wealthy.

And so tilling the soil has continued to this day, and without its benefits we would all be very poor and unhappy.

(This story was told me many years ago and I always want to believe that it is true. Is it not a pleasant way to think of soil tillage?)

CHAPTER VII

TILLAGE.

The term "Tillage" refers to any method of working the soil in order to secure better conditions for the growing of crops. We ordinarily divide the term into two main divisions as follows:

1. Deep tillage, as with the plow.

2. Shallow tillage, as with the harrow and cultivator. When shallow tillage is practiced between rows of growing crops it is further classified as inter-tillage.

History of Tillage: Tillage has been practiced since the very beginning of Agriculture in some form or other. During all of this time constant improvements have been made in the tillage implements. The first plows were merely crooked sticks. These sticks were dragged along over the soil and merely scratched it enough that seeds could be sown. Fig. 38 shows a primitive plow.

Later the plow was improved, so that it had a sort of mould-board which turned the soil and crumbled it. Then an iron point was added and this form of plow was considered a wonderful machine. It was used for many years, and worked fairly well. Changes continued, however, and at the present time we have large plows with excellent mould-boards and made entirely of iron and steel. We have at present many kinds of deep tillage machines, each maker claiming his machine to be the best suited for its particular work.

Purpose of Tillage: If you were to ask the average person why he tills the soil, he could possibly give you only one, or, at most, two reasons. There are many reasons for tillage, the following being some of the most important ones:

1. Tillage makes a good seed bed by crumbling the soil and making it fine.

2. Tillage destroys weeds by covering them and cutting off their roots.

3. Tillage covers manures, stubble and other organic matter so that it can easily decay.

4. Tillage unlocks plant food in the soil by breaking apart the soil grains.

5. Tillage makes the surface soil deeper and gives more room for the roots of the plants.

6. Tillage warms the soil by preventing evaporation.

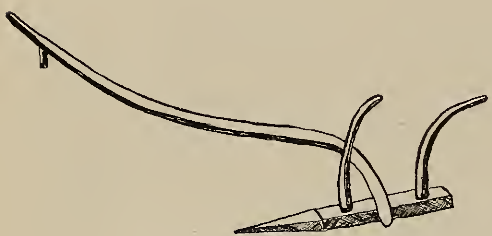


FIG. 38.
The first plow.

The value of thoroughly pulverizing a soil to liberate plant foods may be shown by a very simple method.

Fill two tumblers with water, and into each put a tablespoonful of salt. Stir one tumbler thoroughly. Compare the amount of undissolved material in the two tumblers. What effect do you think stirring a soil would have on the plant foods present?

The Value of Securing Good Tilth: Experience has taught us that it requires great care and attention to bring a field into the proper condition for planting seeds (that is into good tilth). Also, we have learned that the stiffer and more resistant a soil is the more care it requires to bring about a desirable tilth. Some people scoff at the idea that good tilth is an important factor in successful farming. They say that since nature neither plows nor harrows, yet produces abundantly and leaves the soil in an ideal condition, why should men give so much time to the consideration of tilth. Nature, if left alone, will cover the whole universe thoroughly with vegetation, even to the steep rocky cliffs and hills which men could not possibly cultivate. Since nature practices no cultivation, how then can she maintain this thrifty condition, is the question they ask.

How Nature Maintains Fertility: If we examine Nature's methods we can easily see why she succeeds. Where she expects one plant to grow she sows a thousand seeds. Where one plant is not suited by environment to grow another is given its place. Many different kinds of plants grow on the same field, some rooting deeply, others shallow, and both growing at the same time. It is these roots that are plowing the soil, and the tops of the plants that are protecting the surface from baking, leaching and puddling.

Such a practice, if attempted by the farmer, would not only be expensive, but impossible. A thrifty method of farming demands that every seed planted must grow, and that certain crops must occupy certain fields at regular intervals, to the exclusion of all other plants. To do this requires that each field be put in the proper tilth by an artificial method and maintained in that condition just so far as possible.

Relation of Tilth to Root System: When a seed starts to germinate the food in the seed must be used quickly by the young plant or it will decay and become unfit for the plant to use. As soon as this food is exhausted the plant must have a means of getting food from the soil, which requires that it have a rather complete root system. If the soil in which the seed is planted is hard and compact, the seed has a very hard time establishing a connection with the soil and sometimes dies. If however the soil is loose and porous the little roots soon establish themselves around each soil grain, and begin to collect food. Thus it is upon tilth, to a great extent, that the first growth of plants depends.

In a poorly cultivated soil the roots, even if they do develop, are crowded, cramped and insufficient. In such a case, much time and plant food is lost, beside the fact that small and misshapen plants are produced. Again good tillage produces a great deal of soil area by destroying large clods and hard spots, thus giving the plant more chances to obtain plant food.

Continued Cultivation Injurious: Even the best of tillage, if continued year after year, breaks down the compound grain structure of the soil, and causes it to run together after each rain, and to become too fine in structure. This condition cannot be entirely avoided, therefore we may consider as a general fact that the longer a field is under cultivation the more cultivation it requires. This explains one reason why a soil that is said to be worn out by long cultivation must have such careful treatment in order to produce a satisfactory crop.

To Restore Tilth: In order that tilth may be restored to a soil that has been under cultivation, it becomes necessary to seed it down to grass. After it is once covered with sod, the puddling action of rain is prevented, the soil particles are wedged apart by the roots, and finally when the plants decay and tillage is again practiced, the soil is open, mellow and fertile. Thus seeding to grass is a part of tillage, and does more than merely add plant food to the soil. However the more complete tillage is, and the more care exercised in its practice, the better are the results that follow.

Effect of Moisture Upon Plowing: In stirring soil to improve its structure great care must be exercised that the soil is in the proper mechanical condition. If the soil is filled with water when it is plowed the soil grains are in no wise held together and the stirring of them causes each soil grain to get as close to every other grain as possible. This mass of soil upon drying becomes very hard, and is said to be puddled. What takes place may be illustrated with sand and gravel. Take two pint cups and fill one one-half full of gravel and the other one-half full of sand. Pour the gravel into the one-half cup of sand.

This will give you a cup almost full of sand and gravel. Now, stir the two. You will find after they are thoroughly mixed that you have very little more than a half cupful of the mixture, and that all open spaces are well filled. This is exactly what happens in a puddled soil.

If, on the other hand, a clay soil is very wet, and we wait until it is thoroughly dry before stirring, the clay will break up in large, hard clods. This is because the moisture collects around large numbers of soil particles, and holds them together. To get such a soil to break up into a crumbly structure, we should break up the shallow crust on the soil just as soon as horses can walk over the soil without sinking more than an inch or so. This cultivation can be very shallow, and can later be followed by the plow, or cultivator, when the soil will be found to be in good tilth. The structure of a clay soil depends largely on the way it is treated, and since structure is so important to the growth of plants, it should receive very careful study. The kind of plows used, as well as when they are used, is important, therefore the various tools for tillage will be mentioned here.

TOOLS FOR TILLAGE.

For Deep Tillage we have several kinds of plows now in use. We have walking plows and riding plows. We have disk plows and mouldboard plows. When we hitch two or more plows to the same frame we have what is known as a gang plow. Plows larger than two plow gangs are usually drawn by gasoline or steam traction engines. (See Plate 8.) Very deep plowing is sometimes done by means of a plow called a subsoil plow.

For Shallow Tillage we have even a greater number of machines than for deep tillage. Of the harrow classification, the spring tooth, the spike tooth, and the disk are the common forms.

A weeder is a modified form of the spring tooth harrow. Plankers, drags and rollers are the common forms of compacting tools used for smoothing and compacting the soil.

For intertillage, we have the cultivator in many forms. We have walking and riding cultivators; we have single shovels, double shovels, straddle rows, and are now coming to use, to a great extent, the double row cultivator. Of these cultivators there are both the disk and the shovel types. The disk cultivator is rather a recent tool for intertillage. The many other forms of

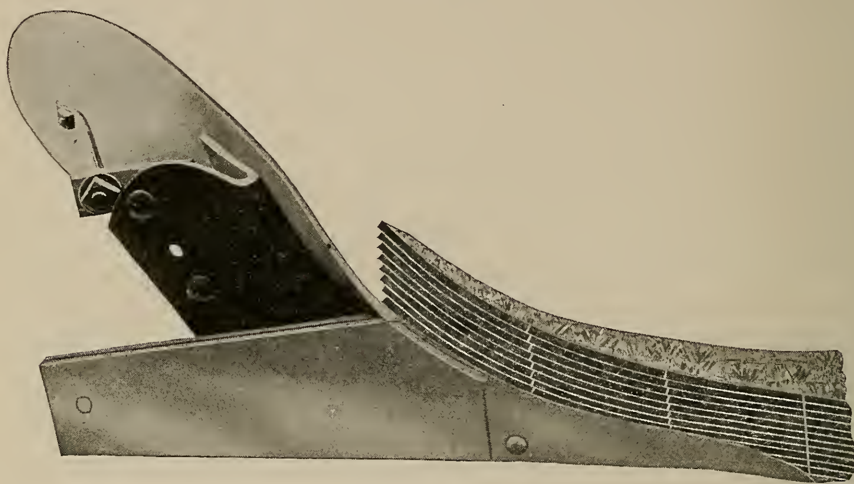


FIG. 39.
How a plow pulverizes a soil.

small cultivators used between narrow rows of plants are placed under the one classification—Garden Cultivators.

We will discuss here the use of just a few of the most important tillage machines.

The Plow: All of our various kinds of plows may be classed in two main types: the Mouldboard Plow and the Disk Plow. Both are intended to break up and pulverize the soil thoroughly. The more complete this pulverization of the soil is made the better the job of plowing. Pulverization of a soil prevents the escape of moisture, and warms the soil. It makes a better seed bed. It makes more plant food available, in fact, we can almost measure our profits by the plowing which is done with the breaking plow. No amount of after labor will make up for poor work done with the breaking plow.

The Mouldboard Plow: The mouldboard plow breaks apart the soil grains by making them slide upon one another. As the furrow slice slides along the curved surface of the polished mouldboard, the particles of soil close to the mouldboard must travel farther than those farthest away from it. This breaks them all apart, just as the leaves of a book slide over one another if you bend the book. Fig. 39 shows how the soil grains slide past one another.

Kinds of Mouldboards: There are three main forms of mouldboards suited to the different soils:

1. The mouldboard for sod is long and has a very slight curve. The curve of this mouldboard turns the sod more nearly upside down than the other types would. See Plate 7.

2. Stubble ground (a field where a crop has been cut) should be left by the plow well crumbled, and with the furrow slices more nearly on edge than in sod. In order to get this result the mouldboard is short, steep and sharply curved. The sudden bend of the soil in the furrow slice caused by such a mouldboard breaks the soil into a very loose mass, if it is in the proper tilth.

3. The average mouldboard is medium in form, classed between these two extremes. It is used for general purposes and will do fairly good work on all kinds of soil, although this is not the best practice when it can be avoided. We should never lose sight of the fact that in doing any piece of work it is always best to study its particular condition, and select the implements and methods best suited to its need.

PLATE 7.

Since the mouldboard is really the most important single part of a plow, and the part which should be differently shaped for different kinds of work, it is well to get one plow and three different plow bottoms, if it can be afforded. This includes the mouldboard and the plowshare. Such an arrangement will accommodate the different kinds of soils. Plate 7 shows the different kinds of mouldboards in general use.

PLATE 8.

The Disk Plow: The disk plow has one very decided advantage over the mouldboard plow. When the soil slides past the rolling cutters the bottom of the furrow slice is broken off and not cut as with the mouldboard plow. This is an important point. In the mouldboard plow the downward pressure upon the bottom of the furrow is as great as the upward pressure which turns the soil. This downward pressure at the bottom of the furrow greatly compacts the soil, and makes a hard layer which the plant roots have difficulty in getting through. If the ground is a little wet, the plow sole slicks the bottom of the furrow, which puddles the soil and makes the soil below the furrow slice almost worthless to the plant during that growing season. A disk plow does not do this and for that reason deserves a place among our farm implements. Also, deep plowing can be done with a disk plow to a greater advantage than with a mouldboard plow. If we plow very deep with a mouldboard plow we turn a large amount of subsoil on top. Since this is poor soil, crops cannot grow so well in it as if we had not plowed so deeply. With a disk we can plow 12 inches deep, or deeper, without bringing the subsoil to the top, and yet loosen the entire mass.

There are, of course, some places where the disk plow will never do, on account of peculiar conditions such as very rough and rocky fields, but in most places it will ultimately find an important place.

Depth of Plowing: In taking up this discussion let us keep in mind the fact that we refer to plowing the soil in preparing the seed bed, and not to the cultivation of a growing crop. It is the usual practice on most soils to plow from 4 inches to 6 inches deep. The tendency now is towards deeper plowing. This is as it should be, and in almost all cases shallow plowing is to be discouraged. Deep plowing makes a deeper seed bed. It exposes more soil to the weathering agencies, which makes more food for the plant. It increases the moisture capacity of the soil. It kills many injurious insects.

Soils that have been plowed shallow year after year, and which have a poor subsoil, should not be plowed deep all at once. The increase in the depth of plowing should be gradual under such conditions, increasing the depth an inch or two each year until the seed bed has been sufficiently deepened.

The average farmer does not plow deep enough. Light horses and haste are the principal causes for this condition. It is well to bear in mind that such practice is not haste, but rather waste. It is better to spend more time in preparing the seed bed than in the cultivation of the crops. Farmers too many times plant the seed before the soil is ready and then try to make up for their neglect by deep intertillage. Such practice cannot be too strongly discouraged.

Fall Plowing: When barnyard manure is to be turned under, fall plowing gives more time for its decay and the crop grown the next spring can use it as food. Also a heavy application of coarse manure plowed under in the fall is quite advantageous while if not plowed under until in the spring it separates the soil from the subsoil and cuts off the moisture supply from the plants. Fig. 40 shows such a condition.

Heavy clay soils plowed in the fall are greatly improved in texture by the freezing and thawing which they undergo.

A farmer has more time for plowing in the fall than in the spring, and can get a great deal of work off of his hands by doing as much as possible of the plowing at this time. Crops suffer less from want of moisture in a fall plowed field than in a late spring plowed field. When fall plowing is practiced many insects in the upturned soil are destroyed during the winter.

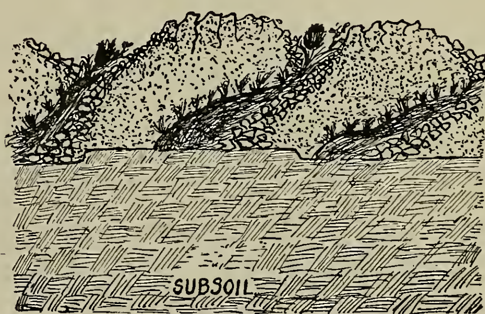
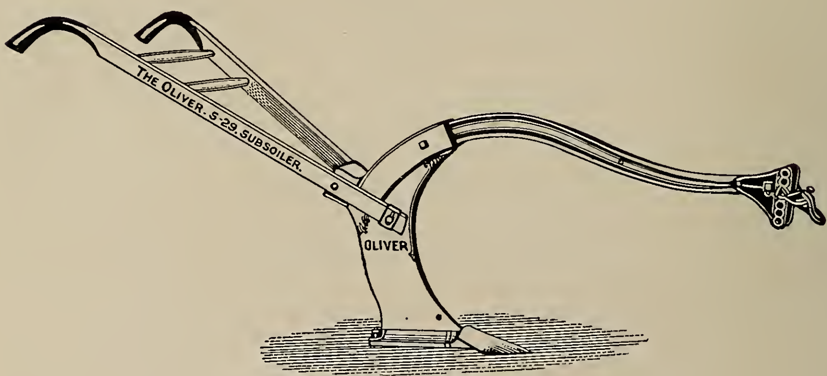


FIG. 40.
A disadvantage of plowing under organic matter in the spring.

Spring plowing, on the other hand, has the great advantage of permitting a winter cover crop (such as rye, clover or alfalfa) to grow. This is very important and will be mentioned again under the topic "Green Manures."

The Subsoil Plow: This plow does not turn the soil, but merely loosens it. Such a plow follows the regular plow and breaks the bottom of the furrow to the desired depth. It is not usually considered profitable, for it is expensive and slow. Dynamite is used in some localities in preference to the plow to loosen a subsoil.

The Disk Harrow: The disk harrow is used in various forms modified to suit the special need at hand. Sometimes the disks are notched and such a harrow is known as a cutaway disk. The disk harrow is excellent to cut up a sod before it is plowed, or in an orchard, where it is not to be plowed. Where a sod is disked before it is plowed the plow does much better work.



SUBSOIL PLOW.
(Oliver Plow Works.)

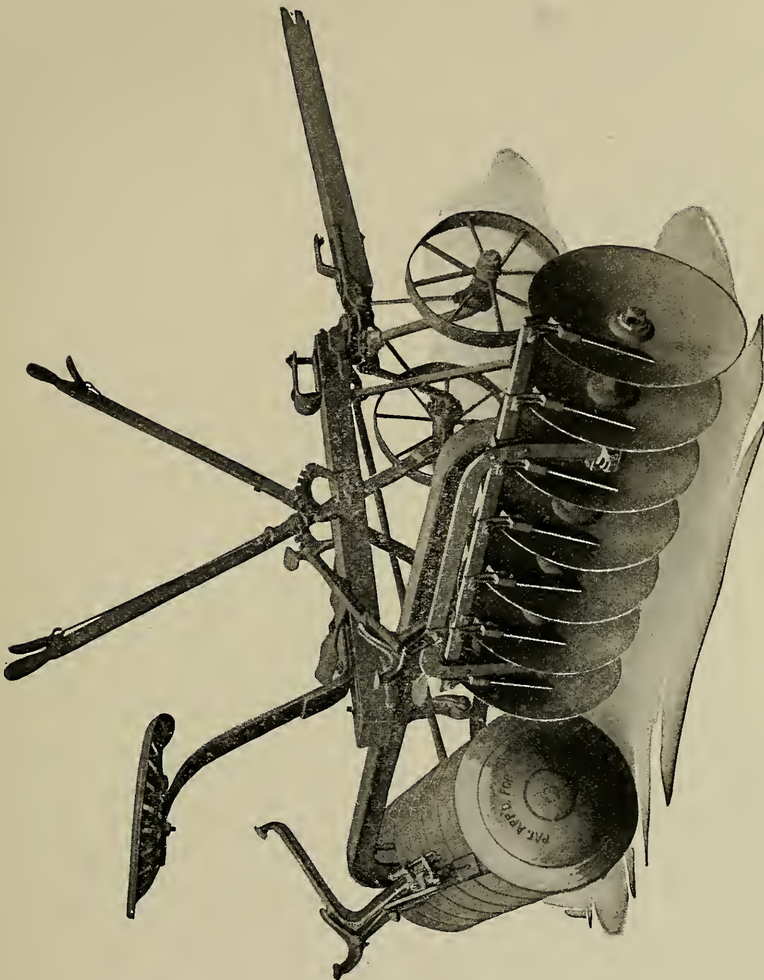


PLATE 9.

One of the best uses of the disk harrow is in making a soil mulch for the conservation of soil moisture. By going over all of the land which is to be plowed in the spring with the disk harrow, the first thing, we make a mulch which prevents moisture from evaporating and keeps the soil in excellent tilth. This prevents trouble in spring plowing, as a farmer who has a large amount of land to plow in the spring is sure to get to the last acre rather late. In such a case the soil, if disked, retains its tilth and can be plowed, without inconvenience. Plate 9 shows a disk harrow.

The disk harrow is excellent for preparing a shallow seed bed for small grain crops, as wheat or oats. It can be used advantageously to put plowed soil in good tilth, although it does not level the seed bed so well as a roller.

Rollers: Rollers are very excellent machines for compacting the seed bed after the seed has been sown. They also crush clods and level the soil. The first rollers to be used were made of logs, but now we have large hollow iron rollers made in sections, to any desired size or length. Some of our rollers are not solid surfaces, but are composed of strips. It is said for this style of roller that it crushes clods better than the solid surface roller.

Use Of The Roller: The main use of the roller is to restore capillarity after the seed is sown. In order to germinate well the seed must absorb a great amount of moisture. If the seeds are sown in loose soil the moisture does not come in contact with the seeds and germination is slow. If, however, the soil is packed close together around the seeds, capillarity is restored and the seeds obtain the moisture which they need. Have you ever noticed a gardener pack the soil around the seeds which he plants? He does this to make the seeds germinate quickly.

Wherever he walks over the seed bed after it is planted, or in any way presses the soil around the seed, germination takes place very quickly. If the ground is firmed (packed) it should be harrowed as soon as the plants are up to prevent the further loss of moisture from the compacted seed bed. This moisture is coming to the surface and evaporating into the atmosphere. Harrowing prevents it from coming to the surface of the soil, and consequently it cannot evaporate so rapidly.

Rollers can be used to advantage to level the field and crush the clods before the seed is sown. This makes the seeding of a field easier and more uniform. If the field contains a large amount of weed seeds, rolling the soil will cause them to germinate at once. They can then be killed before the crop is planted; indeed, this is the best time of the entire year to destroy weeds.

Cultivators: Cultivators are used more for corn than for any other cereal crop. The old forms of single and double shovel cultivators had very large shovels and plowed 4 inches or 5 inches deep. The present cultivator, most commonly used, is a cultivator that straddles one row of corn, the shovels plowing on each side of the row. The shovels are smaller than the older forms of shovels for the reason that large shovels (by cutting off so many valuable roots) do almost as much harm as they do good.

The first time that corn is plowed it may be plowed rather deep if the weeds are bad, but after that plowing should be shallow. Deep plowing (3 inches or more deep) cuts off a great number of the little corn rootlets and causes much damage. Corn roots grow very abundantly near the surface, and care must be exercised not to disturb them. We cultivate corn principally to form a soil mulch, and not to form a seed bed. A shallow mulch is all that is needed, so we have no reason for deep cultivation. The harm we do the corn plants by deep plowing is not made up by the weeds which we kill.

Cultivators which plow two rows at a time are rapidly being adopted, and they are great labor savers. Disk cultivators are also coming into use and they have many advantages, especially where vines are common weeds.

Garden Cultivators: For a great many years the hoe has been the most common garden cultivator; it is also one of the most primitive. Sometimes this tool is used on a larger scale than in the garden. Small cultivators on wheels, either propelled by hand or horse power, are in a large measure taking the place of the hand garden hoe.

REFERENCES.

Soil Acidity; Tech. Bul. 19; State Agricultural College, Lansing, Michigan.

Physical Improvement of Soils; Cir. 82, State Exp. Station, Urbana, Illinois.

Hatch and Hazelwood Agriculture; published by Row Peterson and Co.

39 Experiments in Soils; published by Chas. L. Quear, Muncie, Indiana.

EXPERIMENT NO. 29.

Soil Mulches.

We have learned that soil mulches are very valuable because they stop the waste of soil moisture. You can perform a very interesting experiment to show just how a mulch behaves towards soil moisture. Take four loaves of cube sugar and a small quantity of powdered sugar. Obtain a small amount of solution colored red so it can easily be seen. Diamond Dye is excellent for the purpose, or water colored red by means of red ink will do. Sprinkle a thick layer of powdered sugar on top of each loaf of cube sugar. Stack three or four loaves of the cube sugar upon one another, with the powdered sugar between, and set the whole thing carefully in a shallow pan containing the colored solution. Note the time it takes for the colored solution to rise through to each cube and the time required to pass through each layer of powdered sugar. Compare the time required to pass through the cubes and the time to pass through the layers of sugar. You can see that the powdered sugar, which represents the fine soil (the mulch) does not allow the moisture to come up through it very rapidly. How does the time compare with thickness in each case?

In your note-book write a discussion upon the value of mulches to conserve moisture.

EXPERIMENT NO. 30.

Rolling a Soil Increases Capillarity.

The simple act of pressing the soil above the seed on planting it has oft-times saved a valuable crop that would otherwise never have sprouted. To prove the benefit of firming the soil the following experiment has been prepared:

Either in the seed testing box or in a plot of ground out of doors, if it is late enough in the spring, prepare a very fine seed bed of loose, light loam. Plant some seeds in rows, being careful not to pack the soil any more than is absolutely necessary. If you have prepared a plot out of doors, plant the seeds regular distances apart. If you are using the indoor seed bed, plant the seeds about three inches apart with the rows about six inches apart. Now, carefully firm the soil around the seed in every other row of the. bed which you have planted. If this is properly done, in half your rows the seeds will have the soil snugly pressed around them, while in the other half the soil grains will be very loose and not so close to the seeds. Which seeds will have the best chance to get moisture? Record the results at the close of the fourth day and every other day thereafter for ten or twelve days. At the close of your experiment, write a discussion on "How Seeds Should Be Planted."

Examine a corn planter, giving careful attention to the shape of the wheels, and find out why they are made as they are, and whether or not they are designed to firm the soil around the seed.

Write a discussion entitled, "The Best Type of Corn Planter Wheels."

EXPERIMENT NO. 31.

The Effect of Puddling a Soil.

Puddling the soil means making the soil very compact in structure. The common mouldboard plow, as we have shown, has a tendency to puddle the soil below the plow sole. The soil is firmed by the plow sole due to the fact that the plow acts like a wedge when it is pulled through the soil.

Fill two bottles each one-half full of loose clay soil. Then pour into each an inch of thoroughly wet soil. Tamp this wet soil until it is thoroughly puddled. Now fill the bottles to within an inch of the top with the same kind of soil that you have below.

Fill two other bottles within an inch of the top with the same kind of soil, but do not moisten any of it. Let the puddled layer of soil in the two bottles become dry before continuing the experiment. In a pan of water immerse the mouth of one of the bottles containing the puddled layer of soil and one which contains the loose soil.

Record results at regular intervals to show in which soil the water rises to the top in the shortest time. Pour water into the other two bottles and observe the rapidity with which the water percolates through and drips from the bottom. What is the effect of puddling a soil on the passage of soil moisture either up or down?

EXPERIMENT NO. 32.

Action of Frost on Soils.

Puddle about a quart of stiff clay by adding water and stirring thoroughly. Mould this puddled clay into three balls of about the same size.

Place one ball of clay where it will freeze. If the experiment is performed in winter, place the ball of clay on the window sill, and leave it over night. Place the second ball where it will be subjected to ordinary room temperature. Place the third ball on the stove and bake it. Compare the three balls of clay on the following day. What happens in each case? If no results show in the clay that was exposed to a freezing temperature, let it freeze a second time.

From the results of this experiment, what would you say of the practice of fall plowing heavy clay land?

Is there any advantage in fall plowing, aside from the action of frost on the soil? Are there any disadvantages to fall plowing?

EXPERIMENT NO. 33.

The Plow.

The primary and most important tillage machine is the plow. It is more generally used than any other machine. We usually feel that there is not much difference between plows, but that a plow is a plow, no more and no less. Although a plow is not very complex, it is very delicately adjusted, and if improperly set will do very poor and unsatisfactory work.

A walking plow has three important parts for us to consider: the share, landside and mouldboard. In observing a plow, give attention to the following details:

Name of the plow; where made; whether plow is best suited for stubble or for sod; size of the plow; distance from point of share to the center of hitch; vertical distance from bottom of the plow to the highest point of the beam; distance and reason the beam extends outside of the landside; note the concave nature of the landside; the concavity at the bottom of the plow along the landside, and explain the value of this concave construction.

Explain why the mouldboard has a high polish.

Examine a dull plowshare and point, and compare with a sharp one. What is the value of having the blacksmith sharpen the plow?

In like manner, examine a riding or sulky plow. Compare the two, and make note of any differences that you may find.

If there is a hardware store in your town, have the dealer explain to you the different kinds of plows, and the value of each.

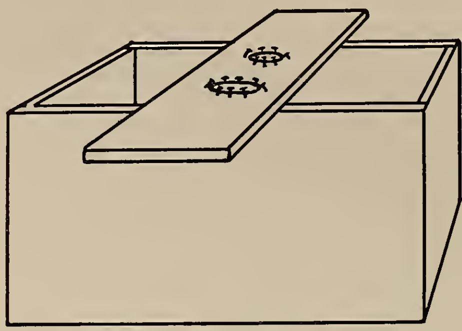


Fig. 1 Corn Sheller.

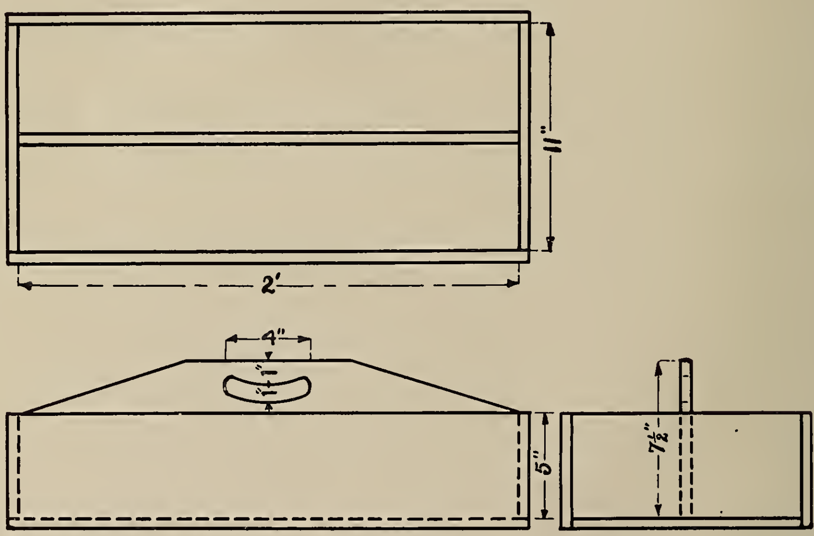


Fig. 2 Tool Box.

PLATE 10.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Corn Sheller.

This device was designed especially to remove the tips and butts of ears of seed corn. It will save time and blistered hands if properly made and used. Where there is not enough corn to be shelled to demand a corn sheller it is a very excellent device for shelling entire ears of corn.

Obtain a good smooth board as near 1 inch by 6 inches by 2½ feet as possible. Soft pine will answer very well. Near the center of the board about 1 foot apart bore two holes, one hole 2 inches in diameter and the other 1½ inches in diameter. Drive nails at an angle around each hole as shown in Plate 10, Figure 1; 4d nails with the heads cut off are very excellent for this purpose. They may be used without removing the heads, although they do not work quite so well.

The board should be laid across a box to catch the shelled corn. By inserting the butt of the ear in the large hole and giving it a twist the shelling is accomplished very easily. The small hole is for removing the kernels from the tips of the ears.

If you make and try this little device you will never again resort to the slow method of hand shelling the butts and tips of seed ears of corn.

Tool Box.

A tool box that will contain the ordinary hand tools used on the farm is a very desirable addition to the farmer's handy conveniences. It is not only handy, but it saves tools, and time spent in hunting for mislaid articles.

The box shown in Plate 10 is large enough to hold all the tools the average farmer desires to carry. The dimensions given are all inside dimensions. The box may be made of any kind of materials desired; seven-eighths-inch soft wood makes a very good and serviceable box. If you have made several pieces of work with tools, design a box similar to the one shown in the plate and make the box after your own design.

QUESTIONS AND PROBLEMS.

1. If spring tooth harrows cost $1.00 per tooth, what would three sections cost, each section containing 14 teeth?
2. If a man plows 1 acre per day, how long will it require to plow a field 160 rods wide and 480 rods long?
3. If a plow cuts a 16-inch furrow, how many times will it have to go around a field to plow a strip 2 rods wide?
4. A man can prepare 10 acres for oats in one day with a disk harrow. If he uses a plow it will require 10 days. How much would he save if his time was worth $4.00 per day, and if the seed beds were equal in value?
5. If a farmer plowed 1½ inches deeper each year, how many years would it take to increase the depth of his plowing from 4 inches to 10 inches?
6. If one-half of the roots of a corn plant are found equally distributed in the first 8 inches of soil, what per cent. of all of the roots are cut off when a man plows 4 inches deep? 2 inches deep?
7. Suppose that the labor of a horse is worth $1.00 per day and that of a man $2.00 per day. How much money would a 2-row cultivator save over a single row cultivator per day if it required one more horse tc pull it, and does twice as much work?
8. At the above rate, how long would it take to save enough to pay for ε 2-row cultivator if it costs $40.00?
9. Define tillage.
10. What were the first plows like?
11. Give reasons for tillage.
12. What is deep tillage?
13. Name two tools used for deep tillage.
14. Name the parts of a plow.
15. Describe the three types of mouldboards.
16. What is one disadvantage of a mouldboard plow?
17. What is the advantage of deep plowing?
18. What is the advantage of fall plowing?
19. Why do we have small shovels on a cultivator?
20. Why do we cultivate corn?

CHAPTER VIII

ELEMENTS VALUABLE IN FERTILIZERS.

Any substance which when added to a soil will increase the yield of a crop is regarded as a fertilizer. The main use of a fertilizer is to furnish food for plants. Out of the ten plant foods which all plants must have in order to live only three are likely to be lacking in a soil. These three are, therefore, the ones which we consider when buying or using a fertilizer. We call them essential elements. They are: Nitrogen, Phosphorus and Potash.

Classes of Fertilizers: As just mentioned, fertilizers are used principally to add plant foods to a soil. Also they are used to improve the soil by changing its texture or physical nature.

All fertilizers are divided into two classes, depending upon which of these purposes they serve in the soil.

1. If a substance added to a soil contains either Nitrogen, Phosphorus, or Potash, it is called a *direct fertilizer.*

If it contains all three of them it is further classified as a complete fertilizer.

2. If a substance increases the yield of a crop by merely improving the physical nature of the soil without applying any essential plant food, it is called an *indirect fertilizer.* For example, lime very often improves a crop when applied to a soil, yet it is not a plant food. It is called, therefore, an *indirect fertilizer.*

Value of Indirect Fertilizers: Although indirect fertilizers do not add plant foods to a soil, they improve it in many ways.

Some plant foods which are already in the soil will not dissolve in water. We have already learned that until they will dissolve in water they are of no use to the plants. When plant foods are not in a form which will dissolve they are said to be *unavailable* plant foods.

Indirect fertilizers put on soils help to break down this unavailable plant food, and make it soluble. They also improve the structure of a soil, usually causing an increased crop for this reason. Some indirect fertilizers are used to sweeten sour soils and to prevent available plant foods from being washed out of the soil.

FIG. 41.
The value of an indirect fertilizer.
On the left an acid soil untreated. On the right the same soil with limestone added.

Nitrogen: Nitrogen is one of the important three essential plant foods. It is the one most often lacking in a soil, and costs the most when we put it in fertilizers. In a good compound the pure nitrogen costs about 18 cents per pound. All nitrogen comes at some time from the air. Four-fifths of the air around us is nitrogen worth 18 cents a pound if we could only get it into the soil. Would it not be a good thing if we could find a method to get this nitrogen from the air and put it into the soil for the plants?

It seems at first thought that it would not be of any use to do this. Instead we might let the plants help themselves to the nitrogen in the air as they need it. However, we know of only a very few kinds of plants that can do this, the most common of which are mentioned below. Most plants would die for want of nitrogen if there was none in the soil, even with nitrogen all around them in the air. The few kinds of plants that can obtain nitrogen from the air are very valuable on this account, and they should be grown a great deal on the farm.

How Plants Obtain Nitrogen: The plants which can take nitrogen from the air are called nitrogen gatherers, or legumes. The clovers, alfalfa, cow peas, soy beans, peanuts, vetch, etc. (in all, 14 cultivated varieties) belong to this class.

For a long time it has been known that pea-like plants were good for the soil, but until recently it was not understood how they benefited it. It has been shown lately that bacteria on the roots of leguminous plants gather nitrogen from the air and supply the plant.

This very recent discovery regarding the power of plants to take free nitrogen from the air is one of the most important discoveries of modern times. This fact gives the farmer a means under his direct control by which he may, at will, enrich any soil he desires with nitrogen drawn directly from the atmosphere.

Nature of Bacteria: The bacteria which take this nitrogen from the air are very little understood, but it has been satisfactorily shown that they exist in various soils in great numbers, and have the habit of locating themselves upon the roots of certain plants, and establishing there a home. The bacteria themselves are little plants so small that one single plant could not be seen at all. However, these little plants collect in great numbers and are surrounded by bunches, or knots, at the places where they become attached. These places are called nodules or tubercules.

Look at the roots of any of the plants which we have mentioned, and you will find little knots on them. Inside of each knot are thousands of little bacteria which collect nitrogen from the air, and furnish it to the plants in compounds which it can use. In return for this nitrogen furnished, the plants upon which the bacteria thrive obtain substances from the soil and air, and in the leaves convert it into food, a part of which is furnished to the bacteria.

FIG. 42.
Nodules on the roots of soy beans.

Partnership Between Plants: Thus we have the beautiful green leaves of the clover plant manufacturing food in the sunlight, and sending this food underground to furnish power to the little organisms which are so essential to the life of the entire plant. The clovers could no more live without the bacteria than the bacteria without the clovers, yet men have grown clovers for hundreds of years without any idea that these plants needed anything other than soil.

Year after year, when legumes refused to grow on fields where bacteria was not present, men attributed their failure to weather, soil, etc., entirely ignorant of this perfect partnership existing between these two friends, each doing for the other the work which it was unable to do for itself.

Life of Bacteria: Since these nitrifying (nitrogen gathering) bacteria can be found in soils after a crop has been removed, some people claim that they can exist independently of the roots of plants. But it has been lately shown that the bacteria cease to live after the roots and stubble of the plants have entirely decayed. This usually takes five or six years. So, we might say that the bacteria in a field is lost if no legumes have been planted for a period of six years. Sometimes there is a way by which bacteria is carried to a field each year. Running water is an example.

Classes of Bacteria: Another very important fact regarding bacteria is, that certain bacteria live on certain varieties of plants, and will not live on any other variety. For instance, the bacteria which thrive on red clover will not live on the roots of alfalfa, and vice versa.

This fact has shown us that there are various classes of bacteria, and that to grow any leguminous crop successfully, we must see to it that bacteria peculiar to that plant is present. Thus if we desired to get a stand of alfalfa we would have to supply the bacteria adapted to alfalfa, in order that the alfalfa plants could have a constant supply of nitrogen.

How to Supply Bacteria: The best and easiest way to do this is to take soil from a field upon which alfalfa has been growing for several years, and spread a little of it over the field to be planted. This gives the bacteria a start, and they will soon cover the roots of the young alfalfa. The bacteria of alfalfa and sweet clover are the same and can be used interchangeably. This is not true of most bacteria.

This shows us the way to answer our question regarding how to get nitrogen from the air into the soil. By growing legumes and leaving the plants on the field we would soon have an abundance of nitrogen for the use of plants that can not supply their own nitrogen.

FIG. 43.
Nodules on the roots of alfalfa plants.

Legumes and Fertility: We must remember, however, that if we grow legumes, and then remove all that we can in the form of hay, without replacing anything, we are not returning any more nitrogen than we are taking away. A crop of clover every few years will not be sufficient to keep a soil fertile.

The preceding picture shows the roots of an alfalfa plant which are covered with nodules. Such a plant is able to live in a soil in which very little of this expensive element, nitrogen, is present.

Legumes Do Not Always Obtain Nitrogen: Sometimes farmers have had good stands of legumes, such as alfalfa, and yet their soils have become deficient in nitrogen as well as in other plant foods. Such farmers have been disappointed in the apparent value of alfalfa, and without investigating and discovering the reasons for the failure, have incorrectly classed it as a crop not good for the soil.

This condition is no fault of the crop, but is due to lack of bacteria. This lack of bacteria may be due to an acid soil, or to the fact that the soil needs inoculation. Under such a condition the alfalfa thrives for a time upon the food present and then becomes scarce for lack of food. In such a field alfalfa would add no more plant food to a soil than an equal amount of corn.

Compounds of Nitrogen: Nitrogen is found as a part of several different substances. The most common forms of this fertilizer are: Nitrate of Soda, Dried Blood, Dried Meat, Fish Scraps, Tankage, etc. They are all good commercial forms of nitrogen, but none are so inexpensive as the nitrogen obtained from the air, or from barnyard manure.

Nitrogen in the soil makes plants dark green in color. It makes them grow rapidly and it promotes leafiness. Nitrogen does not help to produce seeds or fruit, and for that reason you can see it is not so valuable a fertilizer on cereal (grain) crops as on truck crops. Truck crops usually yield large returns per acre and for this reason we can afford to put expensive fertilizers upon them.

Phosphorus: Phosphorus in the plant goes to make the seed and fruit of the plant. Phosphorus is an especially good fertilizer to put on a cereal crop, such as corn, for it helps to produce large well filled kernels. Phosphorus exists in the soil in rather small quantities, therefore we must be very careful to maintain enough of this food to supply the plant.

How Phosphorus Is Removed From a Soil: Since most of the phosphorus which a plant takes from the soil is used in the grain, but very little of it that is taken into the plant is ever returned directly to the field. We either sell the grain, or feed it to the stock, and in either case the phosphorus is removed from the farm. If the grain is fed to stock, most of the phosphorus in the grain goes to build up the bones of the animals, and only a very little is returned to the soil in the manure. When the animals are sold, they take away with them this phosphorus which came from the soil.

How to Supply Phosphorus: We cannot supply phosphorus to a soil like we can nitrogen. The only way to obtain phosphorus is to buy it in the form of fertilizer and put it on the fields. There is no doubt that the average soil which has been cropped with cereal crops would be greatly benefited by an application of a fertilizer rich in phosphorus. The great question is: "What form of phosphorus is the best to use?"

Compounds of Phosphorus: Most of the phosphorus which we buy as commercial fertilizer is dug out of the ground. We have large mineral deposits of phosphorus in Carolina, Tennessee and Florida. This rock as it comes from the mines is called rock phosphate. It is burned to remove the organic matter. Then it is put in huge crushers and ground into a very fine powder.

This is the form in which it is usually sold. In this raw or unchanged form it is called "Floats." Sometimes the floats are treated with sulphuric acid. This changes the raw rock so that it will dissolve in water. In this form it is called acid phosphate.

Raw Rock Phosphate: Phosphorus in its raw rock state will hardly dissolve in water. It is therefore said to be unavailable. Since it is so slow to become of use to the plants it does not produce any extraordinary results the first year.

FIG. 44.
A good method of spreading raw rock phosphate or limestone.

However, it remains in the soil from year to year, and does good until it is all consumed. If raw rock phosphate can be put on the fields with organic matter, such as manure, it will become available rapidly and will show excellent results.

The best way to apply raw rock phosphate with organic matter is to throw a few shovelfuls of the raw rock on each load of manure before it goes to the field and spread the two together. Where this can be done, considering the inexpensiveness of the material, raw rock phosphate is to be preferred to any other form. No load of manure should go to the average field without this added plant food.

Acid Phosphate: Acid phosphate usually does not injure the soil, as many suppose, by making it acid. In some acid phosphates there is a small excess of acid and such fertilizers if used in large quantities become injurious. This is unusual and is not a serious objection. The only objection to acid phosphate is its price. Considering the difference in price it is more economical to use raw rock phosphate if the soil is rich in organic matter. It is of very little benefit, however, to use raw rock phosphate on a soil which is lacking in organic matter. Acid phosphate is partly soluble in water, and is called an available form of phosphorus for this reason. It gives quicker returns on a soil than raw rock phosphate. However its good effects do not last so long.

In general then we may say that either form of phosphorus is desirable, depending upon the nature of the soil, and whether or not returns are desired quickly. It is well to remember that any fertilizer applied on a field that is to produce a cereal crop should contain a large per cent of phosphorus. Do not hesitate to use phosphorus as a fertilizer. If you cannot decide upon which form to use, try both. There is but a small chance to lose in either case.

Potash: Potash is not so important for us to consider as either phosphorus or nitrogen, although it is just as necessary for the plants. Ordinary soil is naturally richer in this element than in either of the other two. Very little of it is found in the grain of plants, but mostly in the stalk and leaves. For this reason most of that which the crop removes is returned to the soil in the straw and manure. Potash gives the stems of a crop stiffness. For example, oats blow down badly if they lack potash. We say that they lodge. Another indication which usually shows lack of potash is color. If a plant becomes a blue green color instead of the healthy green color usually present, it is due to a lack of potash. However, plants may lack potash and still not show a blue green color.

Light sandy soils and swampy land usually lack potash. Some special plants, such as potatoes, tobacco, roots, etc., require larger proportions of potash than other plants; its application is especially good for such crops.

Potash is found in wood ashes, tobacco stems, barnyard manure, and in several chemical compounds. Potash behaves in the soil a little like lime, and since it adds to the value of a soil in more ways than merely to increase the amount of plant food, it should receive rather careful study. Usually our fertilizers do not contain as much potash as they should. Large quantities of potash have a tendency to make a soil deficient in lime, another important substance although it is not a plant food. We should be careful and not let this happen to our soils.

Lime: Lime is the common name for a substance which the chemist calls *Calcium Oxide.* The several compounds of lime, as limestone, caustic lime, etc., will be explained later. Since it is not one of the necessary plant foods, lime is not considered a direct fertilizer. However, it plays such an important part in the life of a plant, that it has well earned the name of an indirect fertilizer. Although in itself not a food, it is a great aid to the plants in obtaining the foods which they need.

Acids and Bases: Before we can understand properly the importance of lime, we must understand the difference between an acid and a base. An acid is sour to the taste. Lemon juice and vinegar are acids. Possibly you can think of other substances that are sour, or acid. A base is bitter to the taste. Lye is a base.

To show Acids and Bases take a little Hydrochloric acid and some Sodium Hydroxide Solution. With a piece of blue litmus paper test each. You will find that the acid will turn the paper red while the Sodium Hydroxide solution or base will turn it blue. Put the litmus paper in a vessel and pour over it a few drops of Hydrochloric acid. Then add to the acid very slowly, Sodium Hydroxide until the litmus paper is neither blue nor red. Taste the product. What is it? You have made a very valuable substance out of two poisonous compounds. Lime would have produced similar results if mixed with an acid. This is the chief office of lime in the soil. It is attacked by the harmful acids and beneficial substances are produced.

When plants grow in the soil we have learned that they give off acid. A soil that is producing crops will, in time, become very acid or sour if something does not prevent. When a soil

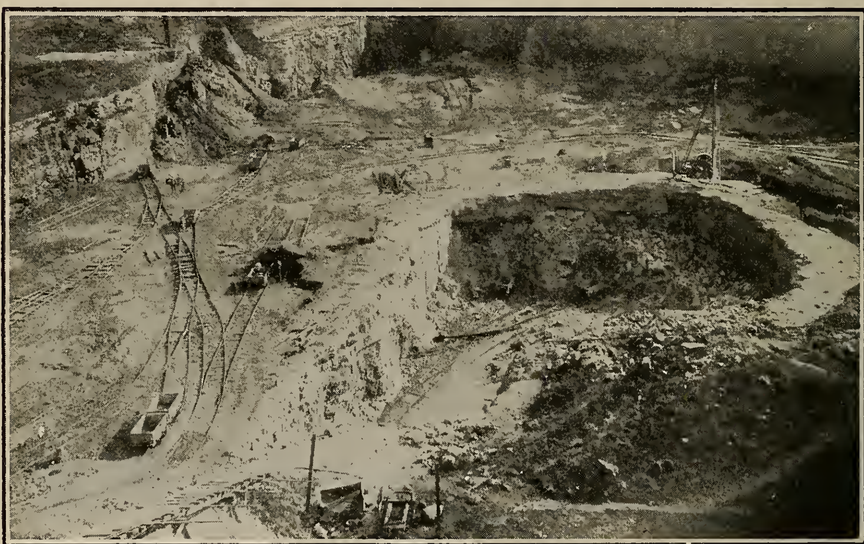


PLATE 11.
A limestone quarry.

becomes sour most plants refuse to grow in it. Even the little bacteria which we have mentioned will not thrive on a sour soil. Such a soil is worthless until something is done to sweeten it so crops can thrive again.

Lime is the most valuable substance that we have for neutralizing this acid. We say that it sweetens the soil for when lime is put on a soil the acid is neutralized. Bacteria which are so necessary begin again to grow, and the soil soon becomes productive. A soil that is poor in humus usually is poor because it lacks lime. Lime saves the humus present in a soil. In other words, lime on a soil makes the manure last longer.

Limestone is a very common rock, usually grayish in color and rather coarse grained. There are many varieties of limestone, varying in color from pure white as in marble to black. Marble is limestone changed by great heat and pressure. (See E, Fig. 45.)

Limestone makes an excellent building stone, is used in purifying iron, in making glass, as ballast for roadbeds, as a fertilizer, and has a myriad more valuable uses. When heated by man limestone becomes caustic, and is then valuable in cement, as a plaster, in preparing cloth for use, as a medicine, etc. In fact outside of sand limestone is the most valuable rock we have and likewise very common.

In the above picture you can see the drill derrick which bores holes in the limestone to a depth of twenty feet or more. Giant powder is placed in these holes and exploded. The loosened masses of stone are placed on the cars shown in the picture, and these cars are hitched to a cable which pulls them to the top of a very high building.

From the top of this building the stone descends through various crushers and screens, and is finally deposited in bins ready for its various uses.

How Lime Came Into Use as a Fertilizer: Many years ago the value of limestone as a fertilizer was recognized by no one, and its use came to be realized through a very round about way. Railroads needed crushed stone as ballast for their road beds, and where limestone was plentiful they used it in large quantities. Great crushers were installed at the limestone quarries to crush the large rock to the desired size. In the course of this work a large amount of limestone dust began to accumulate and this dust was not only worthless to the railroad people, but was in their way. Farmers near the quarries were hired to haul the dust away, and were instructed to dump it in out-of-the-way places where it would do no harm. After this had been going on for several years, some observant persons noticed that along the wagon road, over which the rock dust had been hauled, a very excellent growth of clover was present. This started an investigation which has proved that a product once considered worthless is more valuable than the purpose for which the stone proper was originally used. Now great quantities of the stone are ground directly to a powder and placed upon the soil. The picture on another page shows you the operation of a limestone quarry whose entire output is used on the soil, and in road building.

Limestone Stops the Waste of Phosphorus and Nitrogen: When phosphorus or nitrogen is liberated in the soil it begins to escape at once if there is no lime present to unite with it. Much plant food is lost just this way each year. However, if lime is in the soil, the phosphorus or nitrogen will unite with the lime and thus, cannot get away until taken up by a plant. Usually for this reason a soil that is rich in lime is rich in both nitrogen and phosphorus.

Add Limestone: Limestone is the very keynote to a fertile soil. You cannot build up a soil without limestone any more than you can build a house without a foundation. If you have only a little limestone in your soil, as is usually the case, get more. There is no danger of using too much of it on your soil. A greater part of it will remain until it is used. It will not in any way injure your land. Four tons to the acre should be put on a soil that shows it needs lime at all. If it needs lime badly, eight tons to the acre is not too much. One hundred tons on an acre would not hurt a soil in the least. If you want to save your manure; if you want to build up your soil, start right by seeing to it that your soil has plenty of limestone. The best soils contain one to two per cent limestone. This means that the top foot of such a soil contains about 30 tons of lime to each acre.

Many people say that *lime* tears down a soil and in a few years makes it worthless. Natural lime (limestone), the kind you should use, does not attack the soil, and therefore cannot tear it down. The other substances in the soil which are trying to escape, and which are valuable, attack the lime and are merely retained by it. Natural lime builds up instead of tearing down.

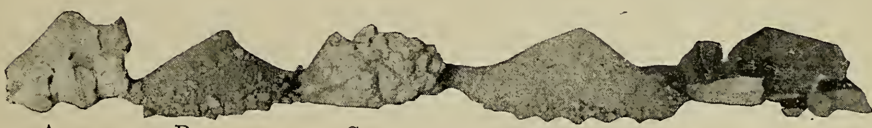

A B C D E

FIG. 45.

Forms of lime—
A—Quicklime. B—Marl. C—Water slaked lime. D—Air slaked lime. E—Limestone as marble.

Burned or caustic lime may tear down a soil, so we must be careful of its use, if we use it at all. In order that you may understand the difference between the different forms of lime, we will discuss each separately.

Raw or Natural Lime is limestone just as it is found in Nature. It is an inactive substance and does not attack other substances. Soil acids decompose limestone and in doing so are themselves destroyed. The more lime on a soil, the less it is torn down, and a soil without natural lime is, indeed, on the road to ruin.

Burned Lime: When raw lime is burned it becomes caustic or active. It is this form of lime which we call quicklime and use in plaster. Burned lime will eat into the hands, shoes, or harness, and will attack organic matter in the soil. Too much of it will ruin a soil, and even small amounts must be used with care. It is not so desirable to use as raw lime. Fifty-six pounds of burned lime is equal in fertilizing value to one hundred pounds of raw lime but costs a great deal more.

Slaked Lime: Burned lime when exposed to the air for a long time changes and loses its caustic or biting nature. It is then called air-slaked lime; or if we pour water on burned lime it soon loses this caustic property and is said to be water-slaked. Either water or air-slaked lime may be used in soil with safety, although not so much is required as of raw limestone, because it is stronger. As a fertilizer, seventy-two pounds of slaked lime is equal in value to one hundred pounds of raw limestone.

Applying Lime: Lime in any form may be applied at any time with equally good results. When you have time is the best time. If you are using natural lime apply in any manner you please. Harrow it into the soil; leave it on top; or plow it under, it makes but little difference. Usually it is best to leave it near the surface, for lime naturally sinks.

Cost of Limestone: Crushed limestone is very cheap and its cost should not keep any one from using it. Good ground limestone can be bought on the car for 75 cents per ton. The cost of transporting and applying it is more than the cost of the limestone.

Indications That Lime Is Needed: Lime is needed if a soil is sour, or when it is neutral. When clovers will not grow, if the land is drained, the soil is probably sour. If crab-grass, redtop, etc., grow well and exclude plants that must have a sweet soil, apply lime. If a soil is poor in color—that is, if it is not black, apply lime and with it, organic matter. When clovers lose their color, and begin to die, lime is usually the remedy. Go along a crushed stone road and notice how high and thick the sweet clover—and, indeed, all clovers, have grown. You do not see such fine plants over in the field. It is the lime ground from the rocks by wagons and washed to the roadsides that has made the soil here so fertile for the growing clover plants. If you will but use your eyes and reasoning power you will convince yourself of the value of lime.

Remember of lime that it does not take the place of the plant foods in the soil, and is of no value without plant foods. But also plant foods are of very little value without the lime. Each one is necessary for the success of the other. When we stop to think how much lime is being removed by the rain which falls year after year, and by the crops that are removed, we should no longer wonder at the need for applying this most necessary element to our soils.

REFERENCES.

Barnyard Manures; Bul. 346, State Experiment Station, Wooster, Ohio.

Fertilizers and Their Uses; Bul. 169, State Agr. College, Manhattan, Kansas.

Liming the Soil; Cir. 33, State Experiment Station, Lafayette, Ind.

Liming Iowa Soils; Cir. 2, State Experiment Station, Ames, Iowa.

Farm Manures; Cir. 9, State Experiment Station, Ames, Iowa.

Elementary Exercises in Agriculture; Published by the MacMillan Co.

Mayne and Hatch; Beginning Chemistry; Published by the American Book Co.

Productive Farming, by Davis; Published by Lippincott Publishing Co.

EXPERIMENT NO. 34.

Testing Soils for Nitrogen.

We usually think of a black soil as a rich soil. Farmers generally say they have a rich, black soil. The black color of the soil usually denotes that the plants which grow in it will be large, green and healthy. This is due to the nitrogen which is present in such a soil. It is very valuable to be able to tell how much nitrogen is present in a soil. To do this accurately requires the use of an elaborated equipment, but there has been devised a rapid method which will answer for all practical purposes, and which does not require much apparatus.

Try the following experiment on several soils, and see if you can not form a rather definite conclusion:

To one tablespoonful of soil, add five tablespoonfuls of ten per cent. Caustic Potash solution. (This can be obtained at any drug store.) In another vessel, add to one tablespoonful of the same kind of soil five tablespoonfuls of water. This one is for a control. It is merely to compare the treated with the untreated sample. It is well to put these mixtures in glass vessels, such as beakers.

Heat the solution of soil and caustic potash to the boiling point, and stir the solution of soil and water thoroughly. Set both mixtures aside for five minutes. At the end of that time compare the two. What differences do you note? If the liquid that you heated is black and opaque it shows a large amount of humus. If, however, it allows light to pass through, it shows only a small amount. If the liquid is only yellow, or yellowish brown, it has practically no humus content.

Try this experiment on different kinds of soil, and write the results in your note-book. If caustic potash is not to be had lye may be used instead.

EXPERIMENT NO. 35.

Testing Soil for Acidity.

This test for soil acidity is a very simple test and is very valuable to make a quick determination. Although it is not always to be relied upon, it usually gives very good results. Fit two thicknesses of filter paper or one of white blotting paper in the bottom of a tumbler or beaker. Under the filter paper place a small piece of litmus paper. On top of the filter paper place an inch or more of the soil to be tested. Add enough distilled water to saturate the soil. Prepare a second tumbler like the first, except leave out the soil. (See note.) Use the same amount of water that you used in the other tumbler. This is for a control. Cover both tumblers and set aside for a couple of hours. Then examine the litmus paper through the bottom of the tumblers, and note any change of color that may have taken place. Red or pink color denotes the presence of a large quantity of acid; a neutral color denotes a slightly acid condition, while a blue color denotes an alkaline condition.

Now remove the soil and mix with it a tablespoonful of lime, and stir thoroughly. Put new filter papers into the tumbler containing the soil, but do not change the litmus paper. Put the soil containing the lime back into the beaker and proceed as before. Note if the litmus paper is affected.

You might mix acid with a sample of soil and repeat the experiment to see the effect of acid if you so desire.

Note: Remember that the litmus paper should be handled with forceps, especially if the hands are sweaty. Sweaty hands give off acid and will turn the paper red. If distilled water is not to be had, rain water may be used. Obtain rain water that has not come in contact with a roof, or any surface where it might collect impurities. If caught directly in a pail it will work very well.

QUESTIONS AND PROBLEMS.

1. A farmer grew 30 bushels of corn on an acre of ground. The next year he applied 100 pounds of acid phosphate and produced 50 bushels. If acid phosphate was worth $25.00 per ton and if corn sold for 65c per bushel, how much did he make or lose the first year?
2. What is a direct fertilizer? What is an indirect fertilizer?
3. What is a complete fertilizer?
4. What is the value of an indirect fertilizer?
5. What is meant by unavailable plant foods?
6. What is a legume?
7. Describe the use of Bacteria to plants.
8. What are "Floats"? Define Acid Phosphate.
9. Name some forms in which Nitrogen can be purchased.
10. In what kind of soil is Potash most often lacking?
11. Name three compounds of lime.
12. What does limestone cost per ton in your community?
13. What is the value of limestone to a soil?
14. A fertilizer added to a soil increased the wheat crop for three years as follows: The yield the first year was 29 bushels, the second year 24 bushels, and the third year 30 bushels. The highest yield before the fertilizer was applied was 22 bushels. How much profit did the farmer receive from the fertilizer if it cost him $21.00 per acre?

CHAPTER IX

NATURAL AND ARTIFICIAL FERTILIZERS.

The subject of Artificial Fertilizers is a very important problem and one worthy of careful study. Probably there is no subject which the farmer takes up so blindly as the application of fertilizers—both natural and artificial.

When to Buy Fertilizers: The artificial fertilizers are not produced on the farm. They must be purchased by the farmer through a fertilizer agent who sells what is termed "Commercial Fertilizers." The term Artificial Fertilizers is taken to mean

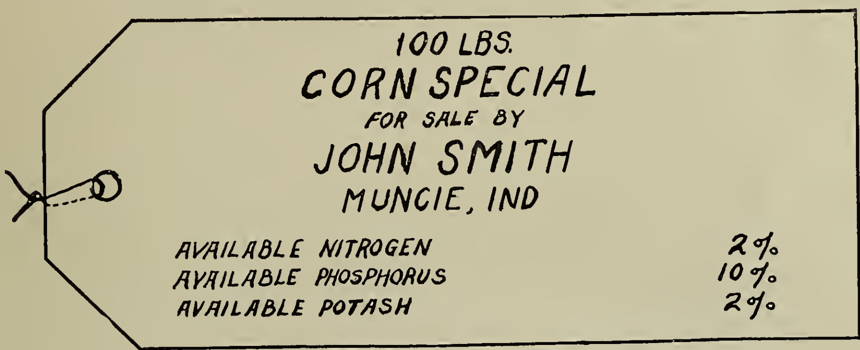


FIG. 46.
A fertilizer tag.

the same as Commercial Fertilizers. Many farmers buy commercial fertilizers and put them on their soil to cover a poor job of farming. No farmer is ready to buy fertilizers to put on the farm until he has increased his fertility as much as possible by drainage, tillage and natural manures.

Unless these conditions are the best it is possible to make them, no amount of commercial fertilizers can produce a good crop. The average farmer should rather spend his time and energy in producing manures on the farm, in getting his soil in the proper condition, and in practicing economy of production rather than to spend his time and money in the purchase and application of commercial fertilizers.

Do not get the impression that commercial fertilizers are not valuable. They are valuable, and have their proper place in farming, and should be used, but they should not be used blindly, trusting to luck. The expectation that no matter what kind of tillage a soil receives, if it has an application of commercial fertilizer an excellent crop will result, is always a disappointment.

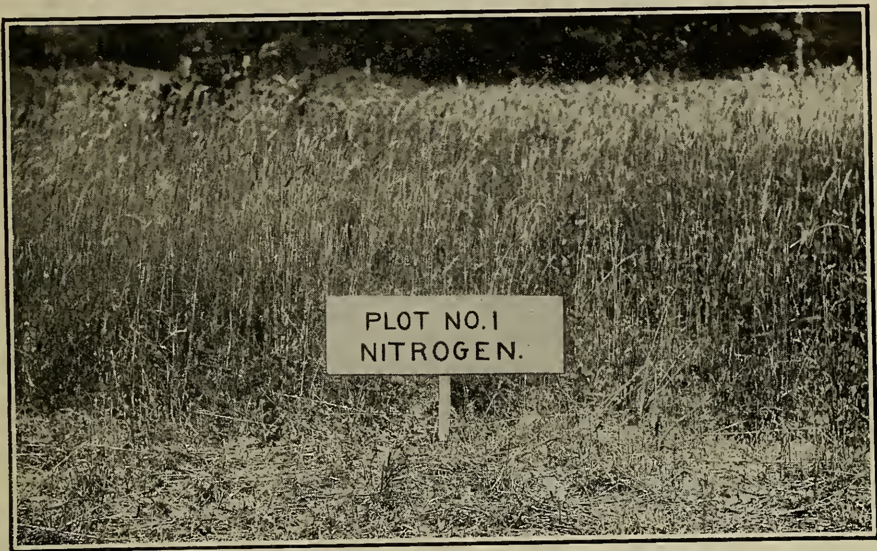
Usually the three essential plant foods are found in any commercial fertilizer. We have various names for these fertilizers, depending upon the amount of each of the essential plant foods—Nitrogen, Phosphorus and Potash—which they contain. For example: A fertilizer that contains two pounds of pure nitrogen, eight pounds of pure phosphorus and four pounds of potash in one hundred pounds of substances is called a 2-8-4 fertilizer. A 4-6-2 fertilizer would mean that the fertilizer is four per cent nitrogen, six per cent phosphorus and two per cent potash.

How to Tell the Value of a Fertilizer: We can easily estimate the value of any commercial fertilizer if we know what it contains. Nitrogen is worth on the market about 18 cents per pound. Phosphorus and potash are each worth about 4½ cents per pound. The price of potash is very variable, due to the fact that most of it comes from foreign countries; 4½ cents is an average price, but at the date of this publication it is costing 25 cents per pound.

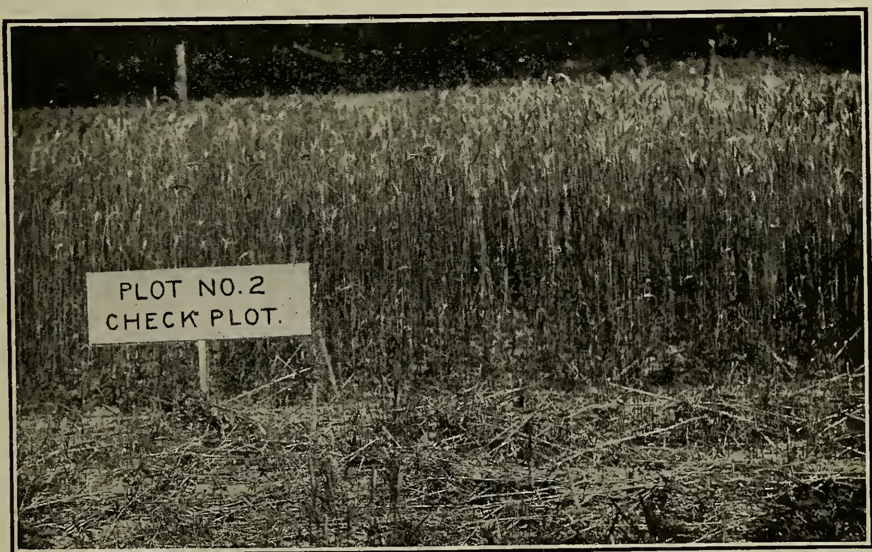
You can readily see that the more nitrogen there is in a fertilizer, the higher priced it will be. An easy way to figure about what a fertilizer is worth is to multiply the first figure of the three by four, and add to this sum the other two figures. This

A PICTURE STORY.

The following eight pictures show you what various fertilizers will do on poor, acid, clay ground. If you will study them carefully you will find a great deal that is of interest regarding the value of various fertilizers.



The Nitrogen on this plot did very little apparent good. While Nitrogen was needed it alone was not enough to increase the productive power of the soil to any degree. The form of Nitrogen used was Nitrate of Soda, applied at the rate of five hundred pounds per acre.



This plot shows what the ground will produce in its present natural state of fertility; an average of ten bushels of wheat per acre.

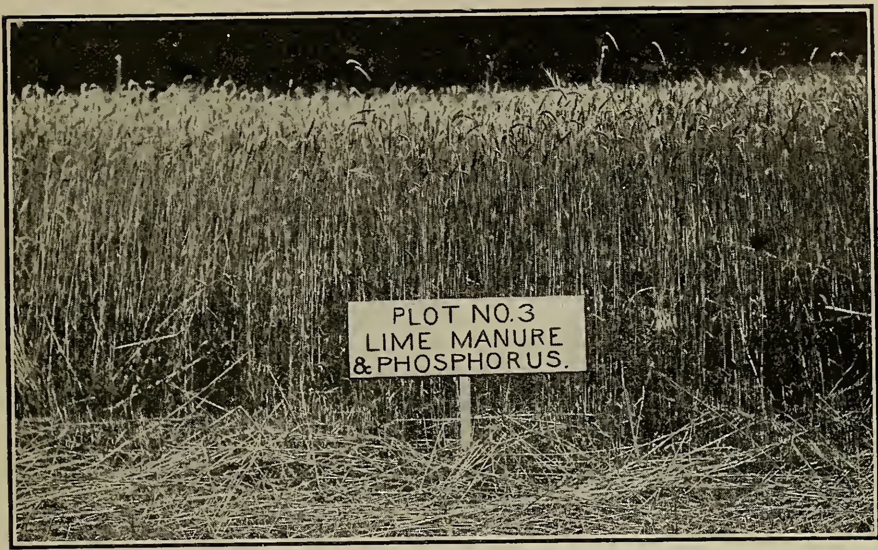
PLATE 12.

will give you in dollars the approximate value of your fertilizer. For example: a 2-8-4 fertilizer is worth $4 \times 2 + 8 + 4$ or $20.00 per ton.

The Amount of Plant Food in a Complete Fertilizer: When we buy a ton of complete fertilizer we buy only a small amount of real plant food, the remainder of the ton is called "filler." It may be of any substance to make out the desired weight. Sand, lime, sawdust, or ordinary soil, etc., are used as fillers. Since we have to pay freight on our fertilizer it is rather a poor practice to buy a complete fertilizer and pay the freight on so much useless material. It is much cheaper and easier to buy each of the substances—nitrogen, phosphorus and potash—separately and mix them on the farm. In this way, we know just what we are getting. We can mix them to suit ourselves and we do not have to pay others for handling waste material called filler.

By putting the separate substances together on a barn floor and shoveling them over thoroughly they can be mixed practically as well as they are mixed at a fertilizer factory. The plant foods can be purchased in many compounds, some of which have been previously mentioned in this chapter.

Barnyard Manure: Since barnyard manure is especially good, both to supply plant food and to better the structure of the soil, it should be placed on that part of the farm where neither plant foods nor good structure is present. Such places are usually found on the high land, especially if it has been cropped. Of course it would be best to cover the entire field, if that much manure were to be had, but usually the supply of barnyard manure is not sufficient for all of the farm. If a large amount of manure is not to be had it is best to spread the amount which can be obtained in a thin covering over the entire field. A thin coat of manure over a large area will do more good than the same amount over a small area.



A fine growth. The best fertilizer for this ground and crop. Lime was applied at the rate of two tons to the acre; Phosphorus at the rate of one thousand pounds of acid phosphate per acre, and the manure at the rate of three tons per acre.

Excellent results and cheap in price. A very economical fertilizer for such land as above shown. Fertilizers were applied at the same rate as in plot three.

PLATE 13.

Spreading Manure: The only way to spread manure properly is by means of a manure spreader. A spreader puts on a coat of uniform thickness and even over the entire area. It saves labor, and makes the same amount of organic matter cover more ground. A farmer who has a manure spreader will have more manure to spread than one who does not have a spreader, because he will see that all of the waste made on the farm is saved. Manure spreaders prevent unnecessary handling which is an expensive operation, as well as hard labor. Almost all men who have owned manure spreaders call them the best labor saving machines on the market. Although this statement may be somewhat overdrawn, the fact remains that they do save a great amount of labor.

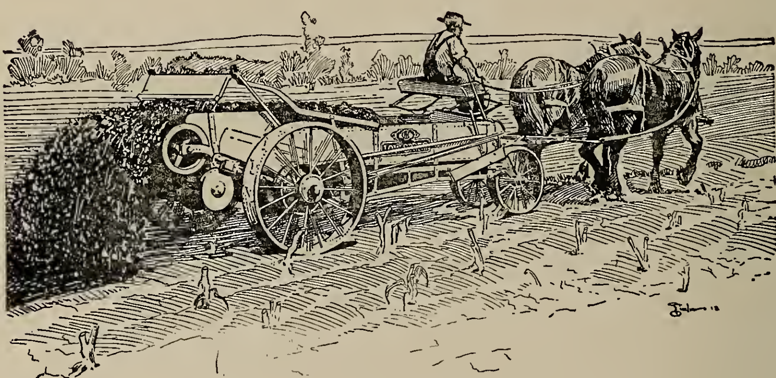
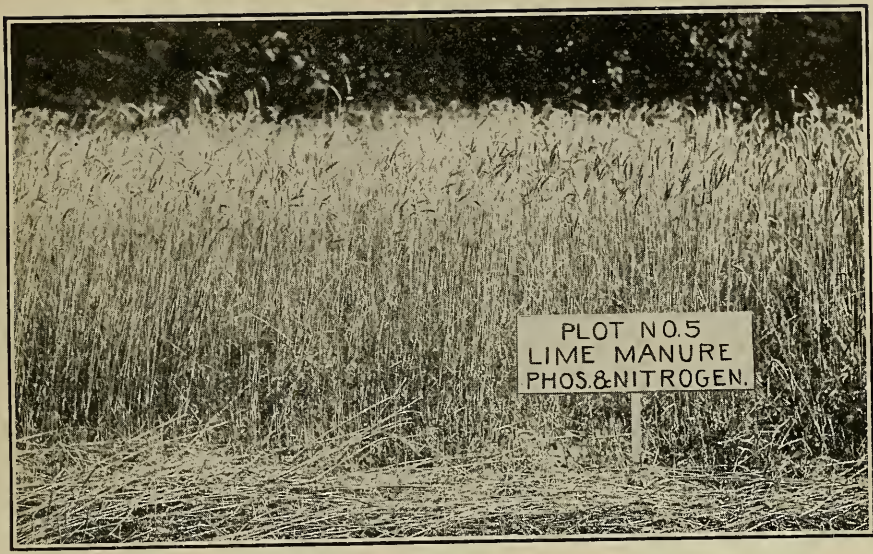


FIG. 47.
Manure spreader at work.

Many people make it a practice to haul the manure to the fields and pile it in small piles. Later they fork it around over the fields. This method makes it necessary to handle the manure four times before it is finally placed. At the expense of such great labor as this, but little profit can be expected. No value is added by repeated handlings except as it prevents heating, which will not occur if it is placed directly on the fields.

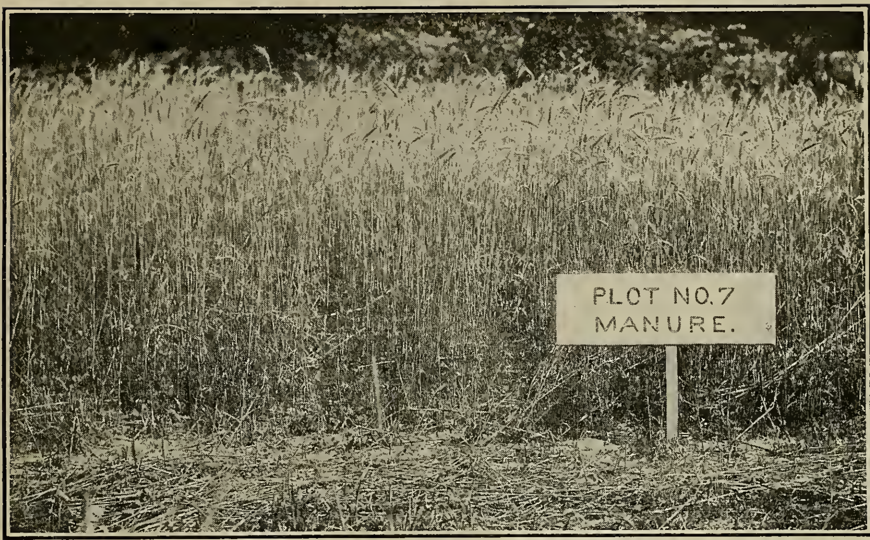


A complete fertilizer with lime added. The phosphorus in this plot as well as in plot three made a better crop than that produced in plot four.

Phosphorus alone improved the crop but without manure and lime it would have to be considered a failure or at least unprofitable on such a field as shown above.

PLATE 14.

Waste of Manure: A great amount of manure is wasted every year. Much of this waste can be avoided by proper care. One of the greatest sources of waste not usually mentioned is the loss caused by not supplying sufficient bedding for the animals. The bedding is especially valuable, because it absorbs the liquid excrements from the animals. It is even considered profitable to use more hay than the animals will consume and allow that which they do not relish to be removed from the stable floor as manure, for this roughage will prevent the liquid manure from escaping. However, it is still more profitable to use straw and cheaper roughage for this purpose. Large quantities of bedding in the form of straw, stover, etc., make large amounts of manure. This bedding is worth all of the labor required to use it, for the manure alone, to say nothing of the added cleanliness and comfort of the animals. On many a farm you can find large straw stacks out of doors rotting, while the animals in the barns are without bedding. Such a condition is indeed a wasteful method of farming.



Manure alone made a great improvement in the crop but not so much as in plot four where lime was also applied.

Phosphorus and manure should give excellent results. In this case they did not improve the crop so much as the manure and lime.

Judging from all of the above it would seem that this soil needs first, organic matter, and second, lime.

PLATE 15.

Storage of Manures: It is a very poor practice to store manure out of doors during the winter months, to be hauled to the fields in the spring. It is better to place it directly upon the fields as soon as possible. Where it is impossible to do this and where manure is to be stored during the bad winter months a shed, at least, should be provided to keep water from soaking through the manure heap.

The following picture shows a manure heap kept under the eaves of a building. Do you consider this good business management? Why?

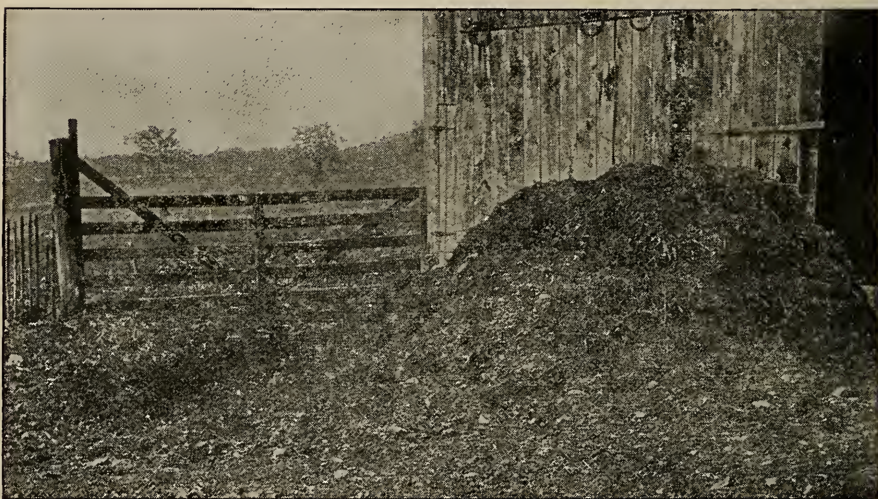


FIG. 48.
A common way of disposing of manure.

Such a practice is extremely wasteful. This manure heap will have lost a great part of its value by spring, besides the fact that it looks very unattractive so placed. Manure thrown out of the stable window from day to day piles up against the stable wall and rots the building. The water which falls from the eave of the building not only soaks out most of the plant food, but it oftentimes finds its way into the stock well and makes the water very unhealthful. Since there is no reason for handling manure in this careless manner, the practice should be vigorously discouraged.

Some people believe that if manure is spread on the field during the fall and winter months, that by spring it has lost most of its fertility. This is a wrong impression, because most of the fertility which leaches out remains in the ground, so that the real loss of plant food is practically nothing.

Realizing the value of the liquid portions of manure, some farmers have provided concrete boxes in which to store the manure until it can be hauled out upon the fields.

Green Manures (any crop used to enrich the soil): Without a doubt, any field that is cropped regularly will lose its fertility unless it receives liberal applications of organic matter. Nature made the soil fertile by mixing organic matter with the little rock particles. So just as the addition of organic matter to a soil is Nature's way of keeping up its fertility, so must it be our way of keeping the soil rich and fertile.

A fence corner left alone first grows weeds, then finally becomes covered with grass, and at last grows bushes and trees. When such a place is finally plowed, its tilth is entirely restored, and it closely resembles virgin soil (soil that has never been tilled). We say that it is better because it has rested, but Nature never permits a soil to rest. Its very name soil depends upon its ability to grow crops and to grow them all of the time. It has become like virgin soil because the grasses covering the surface prevent the rains from washing it during the winter and keep the hot sun from baking it during the summer. The dead grasses mingle with the soil and soon the entire mass is loose, full of organic matter and ready again to produce bountifully any crop adapted to the climatic conditions. As nature uses this plan to restore soil fertility, so we must operate by growing crops at times when our fields would otherwise be barren, and by plowing under such crops as often as possible.

Nature has furnished us with a great number of crops that will supply us with organic matter in abundance. We do not have to hunt long for a plant that will be satisfactory in this respect; we have only to pick out the best ones among the many that we could use. Ordinarily, it is considered that barnyard manure is better than green manure, but since the average farmer does not usually have enough barnyard manure to cover one-tenth part of his fields, he will have to resort to green manure to cover the remainder.

Although barnyard manure holds first rank as a fertilizer, some farmers regard green manure as being equal, if not superior, in value. Which one is the more valuable is an open question, but the truth is not to be denied that green manure is valuable to the soil, especially if the soil lacks humus, as most soils do. Green manure puts more organic matter in the soil, ton for ton, than barnyard manure, but not so much plant food. This may account, in part at least, for the differences that crops show when green and barnyard manures are applied.

Ideal Crop for Green Manure: The ideal crop for a green manure is one that can be planted during the late summer, and will make enough growth to cover the soil during the winter. It should grow rapidly, so as to make as much organic matter as possible by the following spring. It should have an extensive root system, for this helps to open and aerate a soil. To be the best manure crop it should belong to the class called Nitrogen Gatherers.

Rye as a Green Manure Crop: Examine a field of rye in the spring, and you will find a perfect mat of roots and leaves. The plants cover the ground almost like sod. A crop of such plants is worth almost as much plowed under as an equal amount of barnyard manure.

Rye may be sown in the fall, in the cornfield, at hardly any expense or trouble. If desired it may be pastured until it is plowed under in the spring. Since rye is not a legume it does not get nitrogen from the air. Some people say that because

FIG. 49.
Rye: A good green manure crop. It will prevent baking, washing and leaching of this soil during the fall and winter.

it cannot add food to a soil, it is of no value as a fertilizer. But a crop of rye during the fall and early spring saves a great amount of plant food from being lost, for instead of letting it wash away as fast as it becomes available, the plant builds these food elements into its system.

It gives up this food when it decays, and the crop which is planted in the spring gets the benefit of this stored up food. A green manure crop prevents the water from washing the soil during the rainy seasons. It also prevents soil from wind blowing.

Some people object to rye on the ground that it sours the soil; however, this objection is not well founded. Barnyard manure sours a soil just as quickly as any green manure crop will, but no one objects to barnyard manure for this reason. A soil that is sour needs drainage, but it does not need less organic matter. Rye grows well on poor land, either clay or sandy in texture. We little appreciate the wonderful restoring power of this plant for our worn-out lands.

Vetch: We have in vetch a most excellent manuring crop. It has all of the excellent qualities of rye and in addition to these it has the advantage of being a legume. It grows well on the poorest land. It can be sowed late in the summer and plowed under the following spring. It has a very extensive root system, and brings up much plant food from the subsoil to be used by the crop that follows it. Many people consider vetch the best green manuring crop now in existence.

Clovers as Green Manures: Clovers are all good green manuring crops, but they are not often plowed under. They are usually cut for hay. Many people grow clovers in their crop rotation, cut the clover for hay, and say they are building up their soil by growing clovers. They are only deceiving themselves when they advance such an idea. As much nitrogen as is obtained from the air by a clover crop is removed when the crop is harvcsted, and the soil is left poorer in the other plant foods.

Cow Peas and Soy Beans as Green Manure Crops: The growing of cow peas and soy beans greatly improves the soil. Either crop plowed under is very valuable to increase the organic content of the soil. Usually this is not done, for the crops are valuable both as forage and seed crops. Even when the crops are harvested the roots improve the soil, since they alone leave more food and organic matter in the soil than is removed as hay. The roots do the soil more good than clover roots, for clover roots leave only about one-third as much plant food as they obtain from the soil. Also clovers do not feed so much from the subsoil as the roots of cow peas, soy beans or vetch. The food brought from the subsoil to the surface is very important, for it is food that is beyond the reach of many crops, and can not be used by them until brought nearer the surface by deep-rooted plants.

REFERENCES.

A Phosphate Problem for Illinois Land Owners; State Exp. Station, Urbana, Illinois, Cir. 130.

Floats; Cir. 105, State Experiment Station, Wooster, Ohio.

Commercial Fertilizers; Farmers Bul. 44, U. S. Dept. of Agriculture.

The Liming of Soils; Farmers Bul. 77, U. S. Dept. of Agriculture.

Barnyard Manures; Farmers Bul. 192, U. S. Dept. of Agriculture.

Barnyard Manures; Farmers Bul. 192, U. S. Dept. of Agriculture.

EXPERIMENT NO. 36.

Testing Soil for Acid by Means of Ammonia.

Many tests for acid in a soil are unreliable and inaccurate. Many others are expensive and elaborate. The following experiment is neither inaccurate nor expensive.

Obtain a few cents' worth of concentrated ammonia, a sample of the soil to be tested and two tall, slender glass vessels. Beakers or glass tumblers will do, but something having a smaller diameter and taller is better. Stir a pint of water with one-fourth pint of the soil to be tested, and pour equal

FIG. 50.
Cylinder 1 contains a water solution and 1A an ammonia solution of a black soil well supplied with lime.
Cylinder 2 contains a water solution and 2A an ammonia solution of an acid black soil.

amounts of the muddy water into the two vessels. Into one pour a tablespoonful of ammonia. Let the two beakers stand for an hour, and examine. If the soil contains lime there will be no apparent difference between the two samples. If the soil contains acid, the beaker to which you added the ammonia will appear the darker of the two and will be turbid after the other one has become clear. (See Fig. 50.)

Try this experiment with different kinds of soils, and explain your results. Is ammonia an acid? Test it with red litmus paper. What does this show you?

EXPERIMENT NO. 37.

The Effect of Different Kinds of Soil Mulches.

It is very desirable to keep a soil mulch around a growing crop, as we have already learned. But some mulches are very much more efficient than others. It is, therefore, important to be acquainted with the value of various soil mulches and to know where each can be applied to an advantage.

Obtain six empty cans, such as tomato cans, some loam soil and a pair of balances. Punch a number of nail holes in the bottom of each can. Fill each can two-thirds full of loam soil, and jar each one to settle the soil. Pour water in each can until it begins to drip from the bottom. Leave it until the soil is dry enough to cultivate, then remove an inch of soil from each can. Replace this inch of soil in each can as follows: In one can put an inch of sand; in the second use fine clay; in the third use humus, such as barnyard manure; in the fourth use fine loam; in the fifth use fine straw or clover chaff; and leave the sixth without anything as a check upon the others.

Weigh each can of soil and record the entire weight. Leave the cans exposed to the same conditions for a day, and reweigh. Compare the loss of weight in the various cans.

Which is the best mulch? Which is the poorest? What is the value of a straw mulch around potatoes? Do you believe that it would be worth while to mulch a potato patch with straw or manure after the plants get a good growth? Give reasons for your answer.

EXPERIMENT NO. 38.

Plant Food Collection.

Make a collection of all the plant foods you can obtain. Put these in bottles and label each. Write to fertilizer companies and obtain samples of the fertilizers which they sell. Learn which ones they recommend for corn, and why. Learn which ones they recommend for wheat. Learn the amount of plant food in each fertilizer and figure out at what price it should sell. Compare the price for which the fertilizer sells with the price you figure it to be worth. Obtain, if possible, some quicklime, raw lime, air-slaked lime, raw rock phosphates and acid phosphates. You can devise many experiments with the various plant foods.

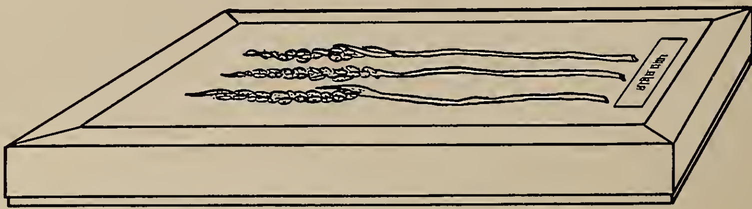


FIG. 1.

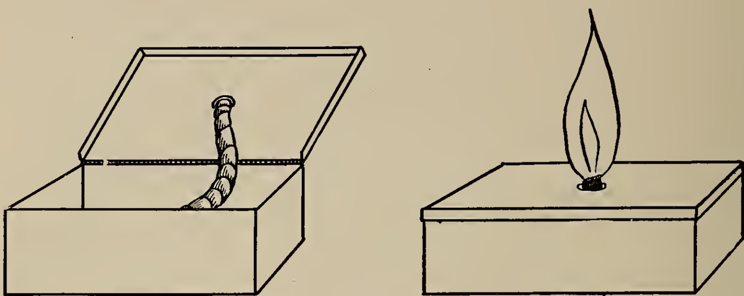


FIG. 2.

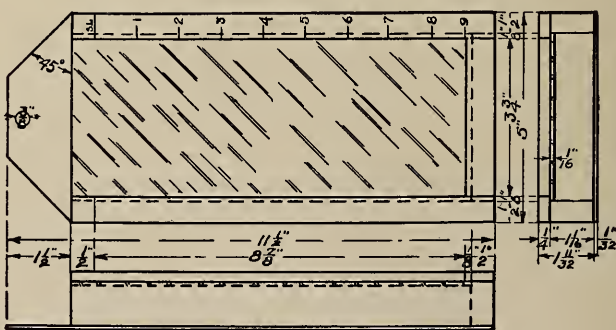


FIG. 3

PLATE 16.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Depth Planting Box.

A drawing with all dimensions for making the depth planting box is given on Plate 16, Fig. 3. The back of the box may be made of either tin or wood, tin being preferable. The one shown in the drawing is of tin. The sides and bottom are made of ½-inch soft wood, with strips ⅛ inch thick and ⅝ inch wide in front. This gives ⅛ inch overlap on the sides and bottom to hold the glass. The student should cut the glass to fit, out of a scrap, such as a broken window. When the box is completed, and marked in inches along one side, as shown, fill with soil and jar slightly to settle it. Fill to the line marked SL. Now lay the box on its back and carefully slide out the glass cover. Place six healthy looking kernels of corn in the soil, with the germ side up, as shown in Figure 51. Press them into the soil until the glass will slide back into place without disturbing them. Replace the glass, and hang up the box. Keep the soil moist and observe the results. In a like manner try all kinds of common seeds and make a table in your note-book, showing proper planting depth for each, time required for germination, etc.

FIG. 51.
Depth planting box in use.

Alcohol Lamp from a Tin Box.

An alcohol lamp is sometimes useful around the home, and is needed in the laboratory very often. Alcohol produces a flame almost colorless and very hot. It can be used in direct contact with vessels and does not blacken them with soot.

To make an alcohol lamp, obtain any small tin box, from one-half pint to a pint in capacity, and having a tight-fitting lid. Cut a small, round hole in the lid and file it smooth. Obtain a round wick at the store, or make one by doubling several strands of common wrapping twine. Force the wick through the hole, leaving plenty of wick inside the box. As soon as it is filled with alcohol your lamp is ready for service. The more wick you pull through the hole the larger your flame will be. Plate 16, Fig. 2 shows a lamp made from a tin box. An old ink bottle may be used instead of the tin box.

Specimen Mount.

Make a specimen mount as shown in Plate 16, Fig. 1. Such a mount may be made from any shallow pasteboard box, having a tight-fitting lid. On the lid lay out with a ruler and pencil a line entirely around the box ½ inch from the edges. With a sharp knife cut on this line, thus removing the center of the lid. Cut a piece of glass a little larger than this hole to fit underneath it, inside of the box. Now fill the box with several layers of clean, white cotton. Carefully lay the specimen which you are to mount on the cotton, and lay the glass over it. Then put on the lid and fasten it all around by pushing pins through the sides. The specimen in this mount will keep perfectly for a long time. The cotton furnishes a nice background, and also keeps the specimens dry.

Nothing is more interesting to school children than to make a number of these mounts and preserve specimens in them. Plants, seeds, insects, cocoons, etc., may all be preserved in this manner. Have the pupil put a card inside the mount upon which is written the name of the mount, his name and the date. Let the pupil design and make his own card.

The mount shown in Plate 16 is 1 inch deep, 7 inches wide and 12 inches long. This makes a very good size.

QUESTIONS AND PROBLEMS.

1. How many square feet in 1 acre? If there are 35,000 tons of nitrogen evenly distributed over 1 acre of soil, how much on 1 sq. ft.?
2. What is a 2-10-5 fertilizer worth per ton?
3. How many pounds of nitrogen in a ton of 4-8-4 fertilizer? How many pounds of phosphorus? How many pounds of potash?
4. What would a ton of the above be worth with the nitrogen worth 18c per pound and the other two each worth $4\frac{1}{2}$c per pound?
5. What would a ton of the above be worth figured according to the rule you have learned? How much difference between the two answers? Which is the more accurate way to figure the value of a fertilizer?
6. If 56 lbs. of quicklime is equal in value to 100 lbs. of raw lime, how much quicklime is equivalent to 82 lbs. of raw lime?
7. If 56 lbs. of quicklime is equivalent to 72 lbs. of air-slaked lime, how many pounds of quicklime is equal to a ton of air-slaked lime?
8. What is a direct fertilizer? An indirect fertilizer?
9. What is another name for raw rock phosphate?
10. From where is raw rock phosphate obtained?
11. From where is nitrogen obtained?
12. Give one good method of applying rock phosphate.
13. What is a legume?
14. If a ton of fertilizer contains 600 lbs. of filler, and the freight rate is 10c per 100 lbs., how much could a farmer save on freight alone, by mixing 10 tons of fertilizer himself?
15. If nitrate of soda is 14% nitrogen, how many pounds would you have to buy to get 80 lbs. of pure nitrogen?
16. If dried blood is 18% nitrogen, how many pounds would you have to buy to get 80 lbs. of pure nitrogen?
17. What do you consider the most valuable green manuring crop? Why? What green manuring crops are used most in your locality?

CHAPTER X

THE HOTBED AND WATER SUPPLY.

In the country and village school there is always to be confronted the problem of successfully managing a school garden. The hotbed, in a great measure, will help to solve this problem. It can be used during the early spring months while there is yet school, and by means of it a great many real problems can be demonstrated. Problems in soils, plants, conditions necessary for life, and economic production may be worked out and pushed to completion. Also the making of the hotbed itself is an excellent Manual Training lesson for the boys. Another great advantage is that work in the hotbed may continue regardless of weather conditions. In fact, the importance of having a hotbed in connection with the school course in Agriculture is of so much value that it will be given careful consideration here.

Size of the Hotbed: In constructing a hotbed the first thing to consider is the size best to use. The hotbed may be 6 feet by 6 feet, or 6 feet by 9 feet, or 6 feet by 12 feet, or larger. For a small school a hotbed 3 feet by 6 feet might be sufficient, but 6 feet by 6 feet would be a very convenient size for growing the ordinary variety of plants. The plants grown in such a hotbed may be taken by the boys and girls to the home gardens, where they can be cared for until maturity, even though the school is not in session. In a hotbed larger than 6 feet by 6 feet some plants, such as radishes and lettuce, might be left to mature without removal from the bed. These things should be carefully worked out by the class and teacher before actual work is begun. It is a good plan to know beforehand just what you are going to plant and how much room you will need.

Location of the Hotbed: In choosing the location for the hotbed, select a rather high place on the south side of some building, as close to the school as convenient.

It should be on high ground to insure drainage, for if it were low the pit which must be dug would serve as a reservoir for the heavy rains, and your plants would not grow. The south side of a building allows the plants to receive more sunshine and, at the same time, shuts off a great deal of cold wind.

Construction of the Pit: In preparing the pit for a bed 6 feet by 6 feet, the hole should be dug 18 inches deep and a few inches larger than the outside dimensions of the bed. Care should be exercised to get the pit square and of even depth. If the hotbed is to be set exceptionally early, that is, before the middle of March, it is better to dig the pit 2 feet deep. The deeper the pit the more heat you can store up and the longer the growing season will be. It is better, if possible, to dig the pit in the fall before the ground freezes.

Construction of the Frame: The frame should be made of two inch material, with the back board eight or ten inches higher than the front. If the back board is eighteen inches high, make the front board ten inches high. This will give the top a slant to the south, so that the sun's rays will pass through the glass less obliquely. The ends will be eighteen inches wide at one end and ten inches wide at the other. The back and front boards should be beveled so that the sash will fit properly.

The sides and ends should be fastened at the corners by means of angle irons and bolts. If fastened in this manner they can be removed, and the hotbed put away during the latter part of the summer.

If fastened at the corners with angle irons, two by four posts should be driven at each corner to hold the shape of the bed and keep it from moving.

The frame should not be placed until the pit is filled within two inches of the surface of the soil. This places the bottom of the frame two inches below the surface. It is well to pack some dirt around the outside of the frame, so that after it is placed the surface water will run away.

A piece of two inch material should be placed from the front to the back three feet from either end, and even with the top. This acts both as a brace and as a support for the sash. See Fig. 52.

FIG. 52.
Sash support and braces across a hotbed.

The Sash: Window sashes may be obtained in various sizes, so in order that your hotbed will fit the sashes you use it is best to obtain them before beginning to work. Then you can easily adjust the size of the hotbed to fit the sashes.

You can usually purchase window sashes at your nearest lumber yard. Oft-times you can obtain damaged sashes at a very small cost, which will be just as good for your purpose. Sometimes you can obtain old sashes and glass from home at no expense.

A six-foot hotbed will require two sashes three feet wide and six feet long. These sashes should be double glass sashes. If single glass sashes are used, extra covering of heavy canvas must be provided during cold nights. The sashes should be painted white, both to preserve them and to reflect as much light as possible through the glass.

Filling the Bed: A hotbed must be supplied with artificial heat during the early spring months. Hot water pipes may be used to supply this heat, but they are inconvenient as well as expensive. Many other methods might be used, but horse manure is a cheaper source of heat, easier to get, and requires less care after it is started than any other method of heating the bed.

To prepare the manure for the hotbed, gather fresh manure from the stable and mix it with one-fourth its bulk of litter. Pile the entire mass under a shed and allow it to ferment for about three days. At the end of the third day fork the mass over and leave until the fifth day. On the fifth day repeat this operation, and on the eighth day place the manure in the hotbed pit as follows:

First place in the bed a layer of manure about nine inches deep, and pack it very firmly by tamping. On this place succeeding layers about six inches thick, and firm each thoroughly as before. In this manner fill the hotbed pit within one inch of the surface of the ground. Then place the frame of the bed as previously explained.

Soil to Be Placed Above the Manure: Now that the source of heat has been provided for, we must supply a soil for the plants. This soil should be about six inches thick over the manure, and should contain a good supply of plant food. A rich loam, such as is found in the woods or in the average garden, is a good soil to use, but if it can not be readily obtained, compost should be used.

Compost is soil prepared by piling up alternate layers of leaves, or sod, and manure in the open, and leaving them for six months before using. This material is screened, and the rich loam used in the hotbed.

As soon as the soil is placed on the manure, and leveled, the sash should be put on, and the whole bed allowed to heat. There will be a gradual rise in the temperature for awhile, and then the temperature will slowly drop. As soon as the temperature begins to drop the seed should be obtained for planting.

When the temperature falls below ninety degrees seed may be planted, although seventy degrees is a good average temperature to maintain. This temperature may be maintained by ventilation, or raising the sash. On warm days the sash may be removed entirely. The plants should be watered thoroughly once or twice each week, the amount of water depending upon the weather.

If it is desired, the hotbed may be used in the fall. If set about the middle of September, fresh vegetables may be had, such as lettuce, radishes, etc., until late in the winter. If the temperature begins to get too low, a box filled with fresh manure placed inside of the frame will furnish heat.

As a school problem, the hotbed can sometimes be used as a cold frame after the manure has ceased to heat. However, if it is desired not to start plants until April or the first of May, a cold frame can be constructed. This is similar to a hotbed, but much simpler and easier to construct. Sometimes plants are removed from the hotbed and hardened in a cold frame.

A cold frame is constructed and managed the same as a hotbed, with the exception of the pit. No pit is dug for a cold frame, but a layer of rich soil about six inches thick is put inside the frame in which the plants grow.

Cloth may be used to cover the frame at night, or during cold weather, if sashes are not to be had. Sashes, however, are to be preferred. See Fig. 53.

THE WATER SUPPLY ON THE FARM.

Health on the Farm: Of all classes of people, the farmer has the best chance to have healthy surroundings. He has fresh air, sunlight, and quiet. He is sufficiently separated from his neighbors so that their unsanitary conditions need not influence the conditions of his own home. But with all of these blessings, the farmer is too prone to take healthy conditions for granted,

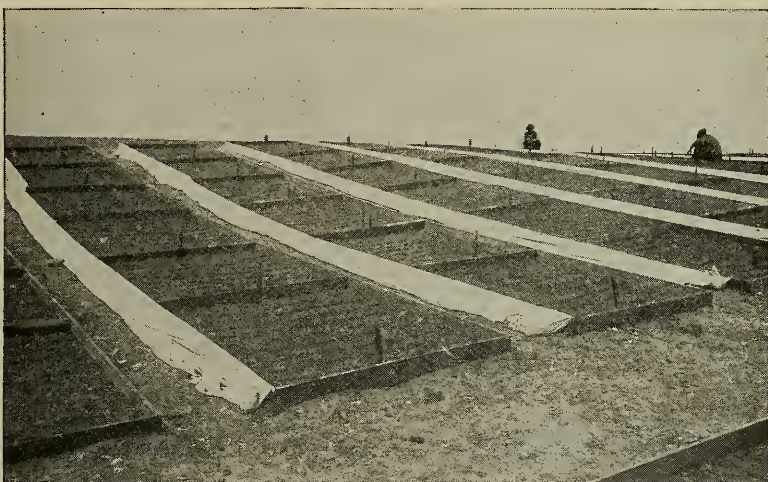


FIG. 53.
Cold frame covered with cloth.

and because he is not so closely watched by the board of health he sometimes permits himself and his family to live under undesirable conditions. While this condition often applies to the farmer and his family, it more frequently applies to the livestock on the farm. A few years ago people did not regard it as worth while to pay much attention to sanitary conditions for livestock, but recent study has changed this idea. There are still a few who make fun of the idea of preparing sanitary quarters for such animals as the hog. Even though a hog apparently enjoys mud and filth, he will respond to sanitary, clean quarters by being healthier and more vigorous.

Upon the health of animals in a large measure depends the health of people, so when we provide sanitary conditions among animals we are aiding in making the human race more hardy. Many diseases of animals are directly contagious (catching) to man. Veterinary Science has done much to promote human health by promoting healthy conditions among animals.

A Sanitary Problem for the Farmer: One of the greatest sanitary agents for both man and animal, under the control of the farmer, is clear running water. To obtain this water, pure and uncontaminated, is the farmer's first problem. The subject of water supply properly belongs with the study of soils, and will therefore be considered here as an agent toward better conditions on the farm.

How Disease Is Carried: Disease in both man and animal finds a ready means of transportation in water; therefore, it is to the interest of everyone in a community that each farm be supplied with plenty of pure water. Such diseases as Typhoid Fever and Scarlet Fever in man, Anthrax and Hog Cholera in animals, are known to be very often transmitted by means of contaminated water. Not only are they carried from farm to farm, but even from the farm to the city.

Bacteria as a Source of Contamination: The contamination of water is produced by very small organisms called bacteria. Bacteria are very small germs which get into water and live on the mineral and organic matter present. The principal way that bacteria can get into water is for them to find lodgment in the soil and be picked up by the water which falls as rain. The first few inches of a soil abound in bacteria, depending upon the organic matter present and the aeration to which the soil has been subjected. Deeper in the soil the germ life becomes less and less, until at a depth of a few feet the soil is usually free from all bacterial life. We may conclude, therefore, that the bacterial content of water is directly dependent upon the germ content of soil. As we are not able to keep the soil free from harmful bacteria, we should avoid drinking water which has collected these dangerous germs. This helps us to understand why surface water or water from shallow wells is not safe.

FIG. 54.
How disease is carried. This beautiful spring is contaminated with typhoid fever germs.

Classes of Water: As has been explained, water falling upon a soil is divided into two classes—that which passes over the soil is Surface Water, and that which passes through it is Ground Water. When the water falls upon the soil it becomes saturated with all kinds of bacterial life, but that water which sinks through a soil soon loses its germs, leaving them deposited in the first few feet of soil. This ground water, as it is called, upon reaching an underground reservoir is generally considered pure water. If, however, we tap this water supply by digging a well, surface water is very likely to get into the well. If surface water does find an entrance to the well it usually carries not only bacteria with it, but organic matter as well, and the bacteria can readily grow and multiply in this organic matter. In a very short time such a well becomes entirely unfit for use.

The Dug Well: If we must have dug wells for our water supply, we should be very careful to exclude surface water. This can be done only by locating the well on a high point and properly protecting the sides and top. This can be done by the use of a large sewer tile, or a watertight cement curb. The curbing should extend several inches above the level of the ground. After the pump is set the curb should be provided with a strong, immovable cover. Gravel or gravel and clay should be hauled and filled in around the curb to the height of the cover; this will provide a water-shed to drain away surface and waste water. Many farmers select a low place to dig a well, because they will not have to dig so deep. This is an exceedingly poor practice to follow.

Again we can very often find the well, especially a stock well, very close to a stagnant pond, or a pile of decaying organic matter, such as manure. The impure water from the decaying material and from the pond seeps through the soil and into the well. The first water may be purified in passing through the soil, but before long the soil becomes filthy with organic material and with bacteria. Soon the water which sinks into the well is not purified, and is no better than the water found at the surface. The accompanying illustration shows a condition not uncommon. (See Fig. 55.)

Giving Animals Impure Water: There is no more excuse for giving the animals on the farm impure water than for the farmer himself to drink impure water. How often does the farmer say that the water in the stock well is not good to drink, yet continues day after day giving the same water to his live stock. Such a farmer has no reason to complain when his animals become diseased, for his own hands have furnished the means for the disease to become established.

Inspecting a Well: In inspecting a well on a farm, look first at its location, and see if there is any probable source of contamination. Then examine the curbing and covering of the well. Finally examine the water for undesirable characteristics.

FIG. 55.
Unprotected stock well. An open well with practically no cover is located under this shed. What do you think would be the condition of a well located so near this decaying material?

The most undesirable thing readily found in water is organic matter, and water containing much organic matter may at once be condemned as unfit for use.

Testing Water for Organic Matter: Oft-times organic matter may be detected by the odor. Perfectly pure water is odor-less. The sense of smell is very delicate, and this method will sometimes enable a person to detect impure water. Let a sample of water stand in a glass vessel for awhile and examine for sediment (substance settling in the bottom of the vessel). If sediment is found it can usually be classed either as organic matter, or sand. A simple and at all times a reliable test for organic matter may be made as follows:

Obtain a clean glass vessel that you can heat, and fill it half full of the water to be tested. A test tube is very good for this purpose. Add a few drops of Sulphuric Acid and sufficient potassium permanganate solution to color the water a very light red. Heat the solution until it boils gently. If the color changes to a brownish tint, it indicates the presence of organic matter. (Potassium permanganate crystals may be obtained at any drug store. A few cents' worth will be sufficient. The solution is made by dissolving the crystals in water.)

Repeat this experiment, using water in which you have placed organic matter, such as bits of paper.

Water which contains organic matter is never safe to use. There are other impurities often found in drinking water, and we will learn about some of them in this chapter. Whenever there is any doubt about the purity of drinking water it should be analyzed by an expert, for we cannot depend upon its taste and appearance to detect harmful bacteria.

Clean, pure water is one of the greatest blessings to human life, and we should cultivate the habit of drinking water in abundance. There is no single agency that will do more to keep our bodies in a good healthy condition than plenty of clean water used both internally and externally.

Mud-Holes on the Farm: Remember that little ponds and mud-holes, such as hog-wallows, are a disgrace to a farm, and are not only places to breed disease among animals, but a source of contamination of well water. If cool, fresh, clean water is always kept for the farm animals, a long step has been taken towards keeping them healthy.

The following are some simple tests of water that will prove interesting and valuable:

NOTE.—Almost all drinking water will show the presence of some of the following mineral substances. They are not considered harmful (when present in a reasonable amount), so you need not feel alarmed if your well water contains these substances.

Test for Chlorides: To a vessel one-half full of the water to be tested, add a few drops of nitric acid and then a little nitrate of silver. If there is any cloudiness the water contains traces of chlorides.

Test for Sulphates: To a vessel one-half full of water add a few drops of Barium Chloride Solution. If there is a whitish precipitate, it shows the presence of a sulphate in the water.

Test for Lime Compounds: To a vessel one-half full of water add a few drops of ammonium oxalate solution. A white precipitate denotes the presence of lime compounds.

NOTE.—All of the above chemicals may be obtained at the drug store at a very small cost.

EXPERIMENT NO. 39.

The Weight of Soil Per Cubic Foot.

If soil contained no open spaces between the soil grains, but consisted of solid rock particles, it would weigh about 165 pounds per cubic foot. But a cubic foot of soil never weighs this much, because it does not consist entirely of rock particles, and besides it contains considerable open space, called pores.

Organic matter in a soil is lighter than rock particles, consequently, as a rule, the more organic matter in a soil the less it weighs. Therefore, by weighing samples of different air-dry soils we can, in a general way, compare their pore space and the amount of organic matter to be found in each. Do this as follows:

Measure some vessel that is rather large and that has a smooth top. Compute its volume. Fill this vessel with a sample of the soil to be tested, and jar to settle the soil. Compact the soil by letting the vessel drop from a certain given height a number of times. After settling the soil, finish filling the vessel and level the top with a straight edge, such as a ruler. Weigh and record the weight. Figure the weight per cubic foot from this weight. Empty the vessel and refill with the next sample. Proceed as before. In compacting the soil, drop the vessel the same distance the same number of times for each sample. Tabulate all data, and compare the results of the weights with the color and texture of the soils tested.

EXPERIMENT NO. 40.

Judging a Farm.

We consider it important to judge and score corn, cattle, horses, and indeed, all products on the farm, whether they are plants or animals. How much more important it must be to score and judge the farm itself, from which all plant and animal life must come.

There are so many points to be considered in buying or selecting a farm, that unless an individual goes over the entire farm, point by point, there are many things which may escape his notice.

In order to examine a farm thoroughly, it is oft-times necessary to follow some sort of guide, not necessarily like the one given here, but one having a similar purport. The outline or score-card given here is merely suggestive, and may be modified by the instructor to suit local conditions.

We must realize first that our score-card depends entirely upon the kind of farming to be pursued. A farm that would be too small for a general purpose farm might be entirely too large for a truck farm. Also remember that the farm is a factory from which we manufacture finished products in the form of plants and animals from the raw material—soil. If the raw material is not rich and fertile, then our whole system must of necessity fail. So look carefully to the soil of a farm, for it is upon the soil that the farm is builded. In using the following score-card, give special attention to the soil conditions, such as drainage, color, texture, depth of soil, kind of crops produced, acidity, and to the general rotation which has been previously practiced.

Go to some farm near the school, and make a thorough examination of the place. Fill out the following score-card to the best of your ability, then have it corrected and fill in the corrected score. Compare the two.

Write a discussion of points which the score-card does not cover.

	Perfect Score	Student Score	Corrected Score	Amount of Errors
(a) Size	3			
(b) Fields—Arrangement	6			
(c) Surface	6			
(d) Fertility	12			
(e) Physical condition of soils	12			
(f) Drainage	8			
(g) Farm improvements	20			
(h) Healthfulness	4			
(i) Location	25			
(j) Water supply	4			
Total	100			

(a) *Size.* The size of a farm determines in a large measure the kind of farming that can be attempted. A farm is oft-times too small for the kind of farming attempted, and almost as often too large. For example, we sometimes find grain farming practiced where dairying would be more profitable, or we find dairying carried on where horticulture could be better practiced. Remember that in inspecting any farm, the size of the farm and the kind of farming must correspond.

(b) *Field Arrangement.* Fields should be arranged so that there is as little loss of space as possible, in the form of lanes, odd sized corners, etc. They should be so sized that none of them are excessively small, and they should be so joined that each field could be reached without driving any unnecessary distance. The farm should be laid out so that every field may be reached without passing through any other field.

(c) *Surface.* The fields should be rather level for grain farming, although if slightly rolling natural drainage is partially provided for. If certain kinds of farming is practiced the ground does not need to be so level.

(d) *Fertility.* Fertility is the very basis of successful farming, and consequently should be looked to carefully. We desire any farm to be in the highest state of natural fertility possible.

(e) *Physical Condition of Soils.* Physical condition determines whether a soil is an early or late soil, whether it is easy or difficult to till, and the necessity of using soil amendments.

(f) *Drainage.* Every foot of a farm should be well drained, either naturally or artificially. Poorly drained land means a poor farm.

(g) *Farm Improvements.* Farm improvements refers to the fences, buildings, roads, ditches and a host of details which each particular kind of farming demands.

(h) *Healthfulness.* Healthfulness is a very important thing for consideration. Things which might influence healthfulness are: disagreeable industries carried on close by; streams into which filth is emptied from some source upstream; swamps adjoining or on a farm, and the climate, which in some places is unhealthful, especially for certain individuals.

(i) *Location.* A desirable farm will be on good roads, near a market and close to public institutions, as churches, schools, etc.

(j) *Water Supply.* On an irrigated farm the water supply is all important. On a farm where irrigation is not necessary the wells should be inspected carefully. Springs and running streams are valuable sources of water supply.

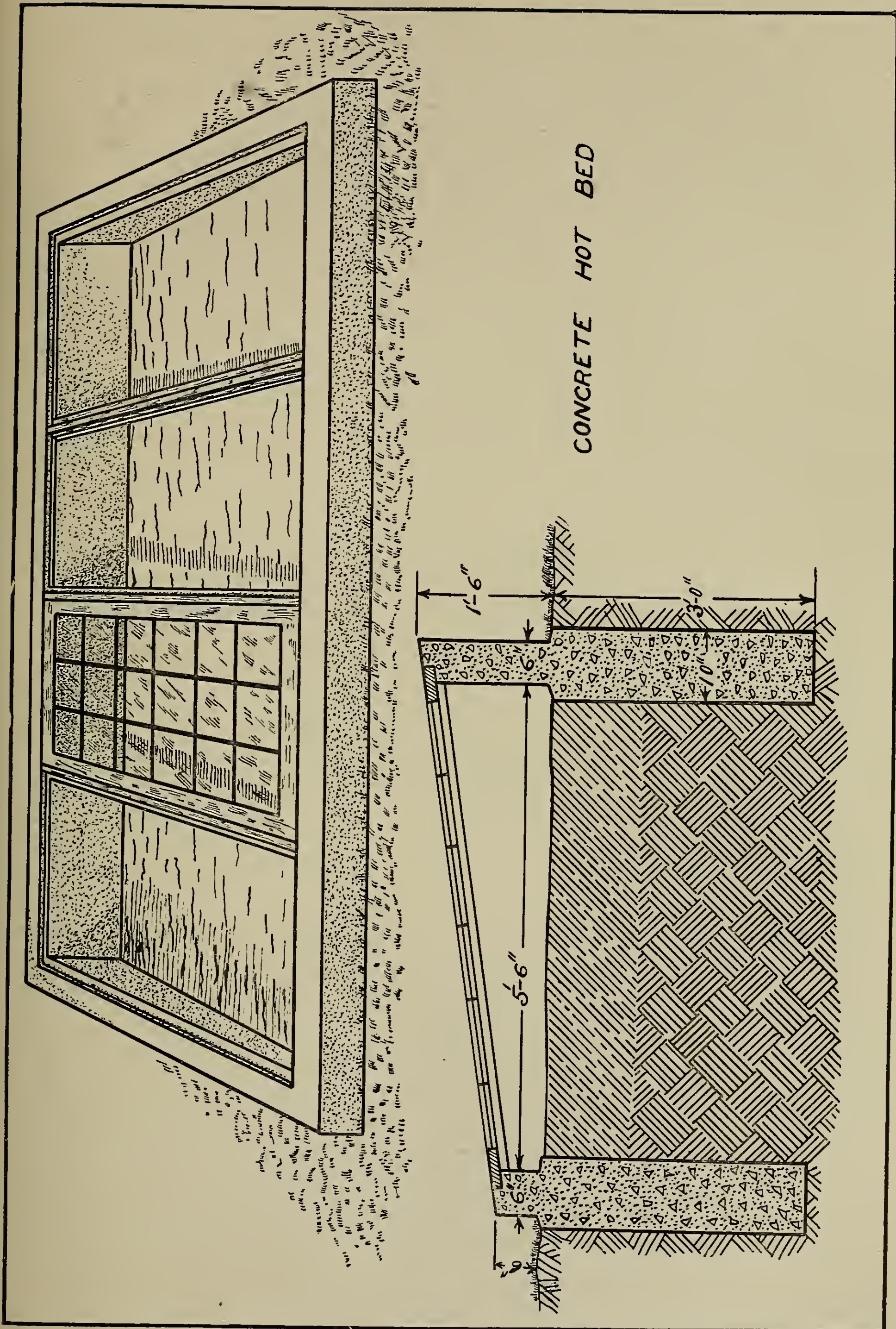


PLATE 17.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

How to Make a Hotbed.

Instructions for making a hotbed must be rather general, for the size, designs and material of different hotbeds will vary.

The drawing on the opposite page shows a concrete hotbed. This makes an ideal piece of work, and if properly constructed will be almost indestructible.

If as a class you cannot or do not care to make the bed of concrete, make one of wood, as follows:

Obtain material two inches thick and of any convenient width. Cut pieces for the front and back to the desired length, outside measurement. Fasten the boards which you have cut for the back together by nailing one by four inch strips crosswise at regular distances. Remember that the back of your hotbed is to be higher than the front and that it is to extend two or more inches below the surface of the ground. Thus if you want your hotbed to be eighteen inches high at the back side you should make the back board at least twenty inches wide.

In a like manner fasten boards for the front together. Now make the ends the width of the back and then rip them so that while they remain the width of the back at one end they will be the width of the front at the other.

Fasten the four sides together, as mentioned previously, by means of nails or angle irons. Bevel the back and front edges of the frame with the plane until a straight edge placed across from the front to the back makes a good fit across both sides.

On the outside of the frame of the bed nail a strip so that it extends about an inch above the edge entirely across the front. This strip is to keep the window frames in place.

One by two inch strips should be nailed across from the front to the back, as shown at the beginning of this chapter. They can be set inside by nailing through from the front and back, but the better way is to cut a notch and fit them in flush with the top.

If the bed is large, stakes may be driven down at the corners on the inside of the bed to prevent it from moving. Design your own hotbed, make out a bill of lumber and figure the costs of the same.

QUESTIONS AND PROBLEMS.

1. How many square feet in a hotbed six feet wide and nine feet long?
2. How many loads of material will it take to fill the above hotbed to a depth of two feet, if a load of material measures one square yard?
3. How many dozen radishes could be grown in one-third of the above hotbed if each radish occupied two square inches?
4. If the temperature outside of a hotbed is 56.3 degrees and the temperature inside is 82.6 degrees, what is the difference in temperature?
5. If muslin is worth 12 cents per square yard how much would it cost to cover a cold frame six feet wide and twelve feet long?
6. If it costs 98 cents a foot to dig a driven well how much would a well cost 190 feet deep?
7. Give some general rules for examining a water supply.
8. Explain how you would locate a dug well.
9. Do you think that it is good business to give animals impure water?
10. Explain how to fill a hotbed.
11. What is compost? How is it prepared?
12. Why do we need a pit in a hotbed?
13. What is the difference between a hotbed and a cold frame?
14. What are bacteria?
15. Explain some of the ways by which bacteria get into wells.

REFERENCES.

Nolan's 100 Lessons in Agriculture; published by Row Peterson and Co.

Bacteria and Soil Fertility; Circular 7, State Experiment Station, Ames, Iowa.

Soil Treatment for the Forcing House; Circular 57. State Experiment Station, Wooster, Ohio.

Frames as a Factor in Truck Growing; U. S. Department of Agriculture. Farmers Bulletin 460.

CHAPTER XI

STUDIES IN CONCRETE.

In studying soils, the three substances, Lime, Sand, and Clay, deserve a careful consideration. We have discussed each of them separately at various times, but we are now to observe a new and wonderful property which these three substances have when combined under certain conditions. Lime, Clay and Sand, when properly mixed, heated and ground, produce a compound known as cement. Cement when mixed with water and left to itself hardens into a stone-like substance almost indestructible.

History of Cement: Although various kinds of cement and limes have been used for hundreds of years, very little was known about them until quite recently. In order that we may understand lime and cement, we will discuss briefly each of them here.

As the use of lime began with the very earliest man—the cave man—so also very early man learned to make and use cement. This cement was not the cement of the modern mills, but cement nevertheless. It is probable that the first cement used by man was produced by nature, and it remained only for man to profit thereby.

Ancient Cement: It is recorded that the ancient Romans found upon the mountain sides a substance which had been mixed, melted and thrown out of a volcano. This substance in appearance was a mixture of pulverized burned clay and sand, reddish brown in color. When mixed with water it had the property of hardening and appearing like stone. It was also found that after this substance hardened it was unaffected by water and remained rock-like in its composition.

The Stability of Natural Cements: So in Rome today there are structures of concrete standing unharmed, after more than eighteen hundred years of wear, although merely made out of a natural product—a kind of volcanic sand. Even now immense beds of this volcanic sand may be found, and it is still used in the construction of modern Roman buildings. The manufactured cement of today is but little different from this natural product except that it is more uniform in its composition and better mixed.

FIG. 56.
Lime kiln.

How Quicklime Is Made: The lime which goes to make the modern cement is taken from the ground as natural limestone, the kind which we learned about in our chapter on fertilizers, and which you can possibly find in the field or on the road. This limestone is placed in huge kilns and burned. The burning destroys its hard nature, and makes what is known as quicklime—you have no doubt seen it used to make whitewash or plastering.

Quicklime: Quicklime has the property of uniting with water, becoming very hot and changing into a white smooth paste. This process is called slaking. The paste, after standing a day or more, is mixed with sand and is used for various purposes, as plastering, laying brick, etc. This combination of quicklime, water and sand is a cement, although usually referred to as "Mortar." It is not so serviceable or enduring as the cements made by modern machinery, and is being largely replaced by the newer product.

The Newer Cement: It was discovered in 1756 that a certain impure, clayey limestone when burned and slaked would harden into a solid mass under water as well as in air.

Portland Cement: The manufacture of cement began at this time and improvement was rapid. Men experimented with different materials in various proportions until they finally produced a uniform true cement. This cement was given the name Portland Cement because when used it closely resembled a stone obtained from the Portland Quarries of England. Portland Cement has come to be a general term, and we usually refer to any good cement as Portland Cement.

Hydraulic Cement: Hydraulic Cement refers to any cement that will harden under water. Thus, Portland Cement has hydraulic properties, but lime usually does not have such properties. When slaked lime, left under water, hardens so that you cannot dent it with a little pressure of the thumb it is called Hydraulic Lime. It is in fact an impure lime.

Manufacture of Cement: The digging of the raw materials is the first step towards the actual manufacture of cement. The limestone used is quarried from open pits and crushed in a huge stone crusher. From the crusher it goes on board cars for shipment to the cement plant.

The sand and clay to be mixed with this limestone are obtained pure and fused as slag from the steel mills. The slag is broken up and shipped direct to the concrete mills. It is almost pure sand and clay.

Grinding the Raw Product: In the Concrete Mills, the slag and limestone are each ground into a very fine powder, after which they are properly mixed and ground together. Then they are burned at a very high temperature until clinkers are formed, very much like the ones you find on the furnace grates.

The clinkers are then ground into a very fine powder and sold as cement.

What Concrete Is: In using this cement, as before mentioned, it is mixed with sand, gravel and stones of various kinds, called aggregates. The mixture is known as "Concrete." The cement is a sort of a liquid glue, sticking the stones together and making of them one solid rock. If the stones are soft, or will sliver, or are mixed with dirt the concrete will crumble and be worthless. If the cement and aggregates (stones) are properly mixed and the aggregates are of a good quality the concrete will usually be entirely satisfactory.

Importance of Concrete: The importance of Concrete on the farm cannot be overestimated. It could profitably be used in the making of so many farm conveniences that we will not enumerate them here. However, with a little knowledge of concrete and its use it is safe to say the average farmer will use it in the future much more than he has heretofore. The amount of work to be done in concrete in the school depends entirely upon school conditions, but it is certain that no school can afford to neglect it entirely.

What the Schools Can Do: Walks could be placed around the school buildings; seats could be made on the playground; in fact, many uses can be found for concrete which will furnish real, practical laboratory work for a class. It is hoped that more work will be done than is given here, but at least the concrete exercises at the last of this chapter should be attempted.

EXPERIMENT NO. 41.

To Test for Carbonates.

Calcium Carbonate, called also Natural Limestone, is the most important ingredient in concrete. While the following experiment does not deal directly with concrete, the knowledge which it gives regarding carbonates is very valuable.

Natural limestone found in soils is frequently referred to as carbonate of lime. This carbonate of lime, or any other carbonate, sweetens a soil and neutralizes any acid that may be present. So if we can determine the presence of carbonates in a soil we may know that such a soil does not contain acid. If acids were present, they would immediately decompose the carbonates.

Most plants, especially legumes, require a soil which contains carbonates, so to know whether or not carbonates are present is very important. We can perform a very simple experiment to determine their presence.

To do this, obtain some concentrated hydrochloric acid (muriatic) and a sample of the soil to be tested. Take a small mass of the soil and mould it cup-shaped in the hand. Pour into this cup-shaped soil a few drops of the acid. If carbonates are present, it will be shown by a bubbling, or effervescence. If, when you pour on the acid, you do not notice the formation of bubbles of gas, test more carefully by putting a little soil into a test tube and pouring over it a little of the acid. Place the mouth of the tube to the ear, and by listening carefully, if there is any effervescence at all, it can be readily detected. If there is none you can conclude, with a reasonable degree of assurance, that the soil is acid and is in need of a soil amendment, such as lime.

This is a very convenient test, as it can be performed out in the field and is inexpensive. It is well when testing in a field by this method to test both the surface and the subsoil, as a subsoil that contains carbonates will be a source of constant supply for a surface soil. The carbonate in some soils can be readily detected by the presence of large numbers of limestone pebbles. Take some small stones from the field and pour hydrochloric acid on them. Do they show the presence of carbonates?

Write the results of this experiment in your note-book.

EXPERIMENT NO. 42.

Carbon Dioxide.

When mortar sets, as the process of hardening is called, it absorbs carbon dioxide gas from the atmosphere. If it were not for carbon dioxide this most valuable property of burned lime would not be exercised. Also carbon dioxide is all important for the part it plays in plant growth.

We have learned that about 50 per cent of the solid part of a plant is carbon, and this carbon is taken from the air in the form of carbon dioxide. The following experiment will enable you to make some carbon dioxide gas out of solid materials.

Obtain some fresh lime, some soda and some vinegar. The carbon dioxide is to be made by the action of the soda and the vinegar. The purpose of the lime is merely to test the gas so we may know that it is present. We will need to prepare some lime water to do this. Pour water over the lime, and stir it until the lime is thoroughly slaked. Let it stand until the lime settles and the water becomes perfectly clear. Pour off this clear liquid into another bottle. Label it Lime Water. This will usually take about 24 hours. In order that you may be certain that the lime is dissolved in the clear water, taste it. Pour a little of the clear lime water into a tumbler.

Into another tumbler put a little soda. Pour vinegar over the soda. Put the two tumblers together and carefully tip the tumbler containing the soda and vinegar, so that the gas which is formed will run over the edge of the tumbler like water. Do not pour the vinegar and soda mixture into the tumbler containing the lime water, merely allow the gas which is forming to come in contact with the lime water. Notice the lime water. After a little while, shake it. What has happened? The milky color of the lime water shows that the gas formed by the action of vinegar and soda is carbon dioxide.

Since carbon dioxide turns lime water milky, we can perform several experiments to show the presence of this substance. With a straw or piece of glass tubing, blow your breath through lime water for a little while. What is given off by the lungs?

Set a dish of lime water on the floor in the room. If it turns milky, what can you say about the ventilation of the room?

In your experiment, did anything lead you to believe that carbon dioxide is heavier than air?

Perform the above experiment, using lime and hydrochloric acid instead of soda and vinegar.

What becomes of the lime in the soil?

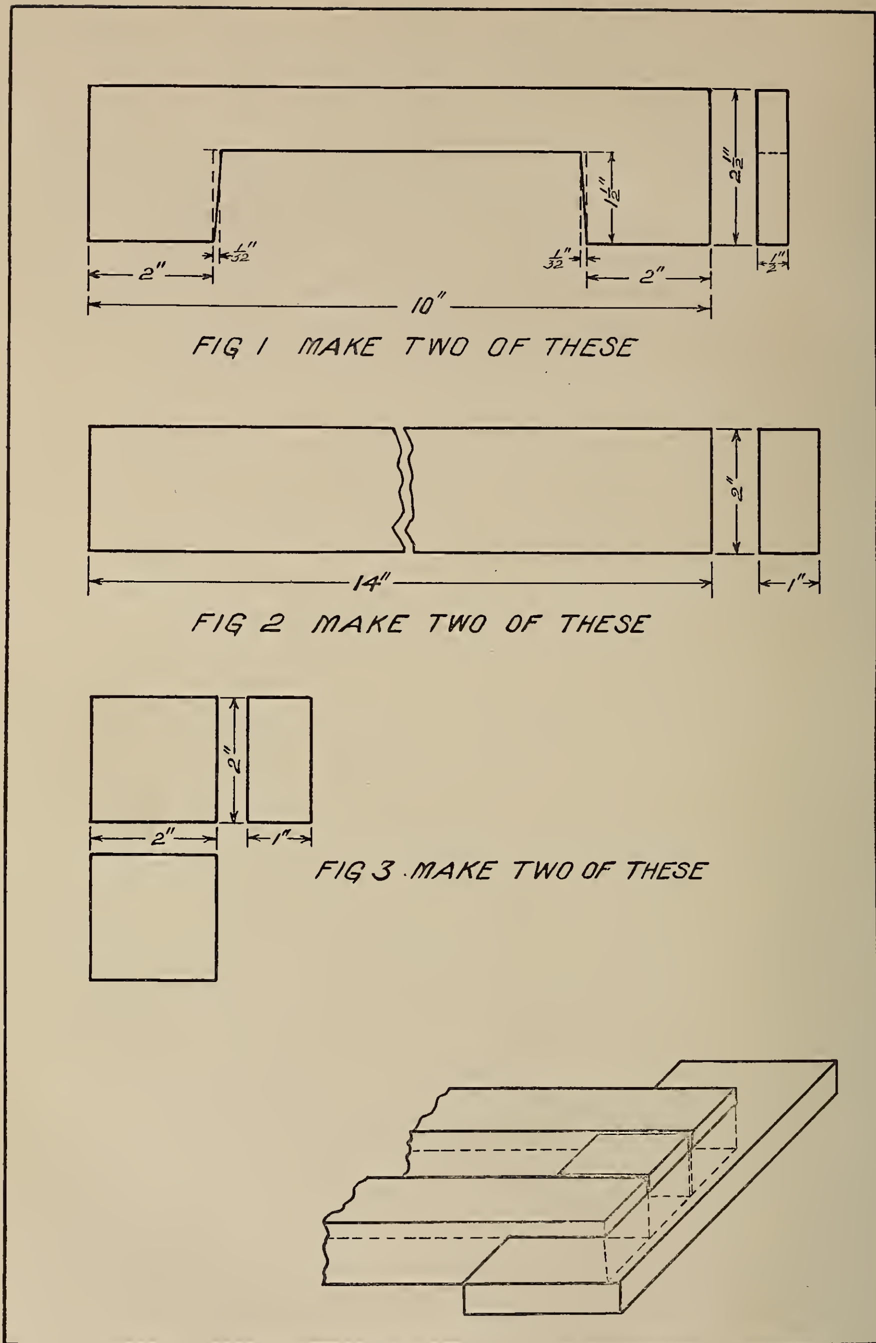


FIG 1 MAKE TWO OF THESE
FIG 2 MAKE TWO OF THESE
FIG 3 MAKE TWO OF THESE

PLATE 18.

AGRICULTURAL APPARATUS AND HOW IT IS MADE.

Concrete Test Beam.

This exercise is a lesson in mixing, tamping, troweling and reinforcing concrete. Each student should make a form complete as shown on the opposite page, Plate 18.

Place the form on a smooth board and make three beams as follows:

Measure out clean, fine sand and pure cement. Mix the two in the proportion of one part of cement to two parts of sand. After they are mixed thoroughly moisten with a *very little water* and continue stirring. *Do not put on too much water.* The concrete will appear wetter after it has been stirred than it will at first. When completely mixed it should be merely moist enough to stick together when squeezed in the hand.

Fill the form with the mixed concrete and tamp with a small rod. Tamp with light blows, and only enough to fill any openings that may have occurred in corners, etc.

When filled and tamped rounding full take a straight edge and with a backward and forward movement crosswise carefully level off the top, so that the beam will be the exact size desired.

Carefully smooth the surface with the trowel. Remove the form, and leaving the beam on the board, set it aside. In one-half hour, give the beam a light sprinkling of water, and about two hours later a heavy watering. In about twenty-four hours give the beam a complete soaking and leave until you are ready to test its strength.

At first we might think that cement hardens merely by drying; this is not exactly true, for it gets its hardness by a peculiar process of *setting* or *curing.* It will cure under water and, strange as it may seem, become even harder than when air cured; this is the reason for adding the water while it is curing—it also keeps its surface from drying too rapidly. You will learn many interesting facts by experimenting thoughtfully with cement.

In a like manner, prepare a beam of a one to three mixture—that is, one part cement to three parts sand.

Also prepare a beam of a one to three mixture and reinforce it by using four wires one inch shorter than the beam. Place a wire in each corner, as near the edge as possible without showing.

When the three beams have cured, or hardened, for a week or two break each and compare as to the strength of the different mixtures. Compare the one to three mixture reinforced and not reinforced.

If possible, make beams reinforced differently and of different mixtures. Write a discussion of the value of the different mixtures. Find some place where men are doing concrete work and find out what mixture they are using. Find out what reinforcing they are using and why.

REFERENCES.

Concrete for the Farmer; Universal Portland Cement Co., Chicago, Illinois.

Concrete for the Barnyard; Universal Portland Cement Co., Chicago, Illinois.

Small Farm Buildings of Concrete; Universal Portland Cement Co., Chicago, Illinois.

Concrete Surface; Universal Portland Cement Co., Chicago, Illinois.

The School Garden; Farmers Bulletin 218, United States Department of Agriculture.

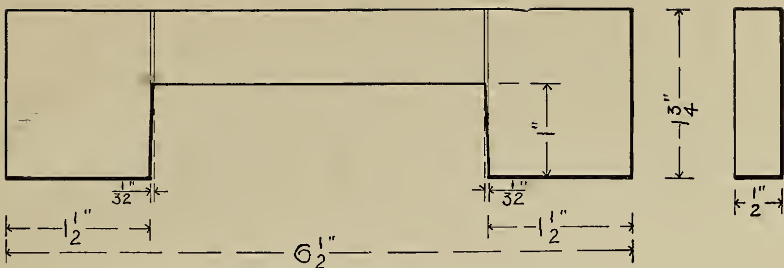


FIG. 1. Make two of these.

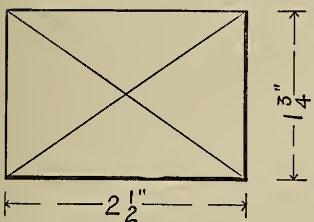


FIG. 2.

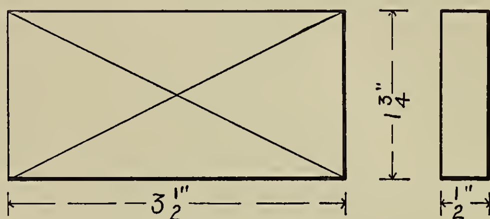
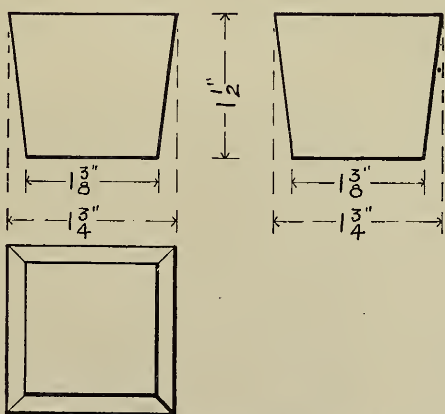


FIG. 3.

Make two of each.



Details of the forms for the
Cement Match Safe.

Cement Match Safe.

Make forms for this article as shown on the opposite page. If you wish to have a design on the sides of your match safe, make a simple design and obtain the consent of the teacher before you attempt to carve it upon your form. A plain surface is easier to make and will look very well, although the match safe in the picture above has a design upon it.

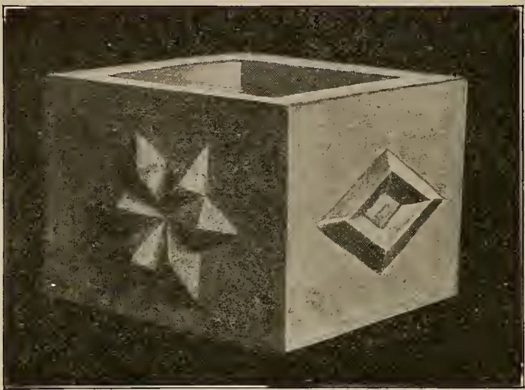


FIG. 57.
Cement Match Safe.

After the form is made, sandpaper it perfectly smooth, so that the cement will not stick to it.

Assemble the form as shown in Fig. 58 and then prepare your cement as follows:

Mix pure cement, add a very small amount of water and mix thoroughly. When completely mixed the cement should merely stick together when squeezed in the hand, and no water should appear, no difference how tightly it is squeezed.

Fill the mould, tamp carefully, level off the bottom and then turn the entire form over. Smooth the cement around the core and insert a screw eye into the center of the core. By pulling on the screw eye and gently tapping the core carefully withdraw it.

Then remove the form by tapping each piece gently and at the same time pulling slightly.

Give the match safe a light sprinkling of water. Do not apply too much or the cement will become too soft and lose its shape. In two hours give it a heavy sprinkling; ten to twenty hours

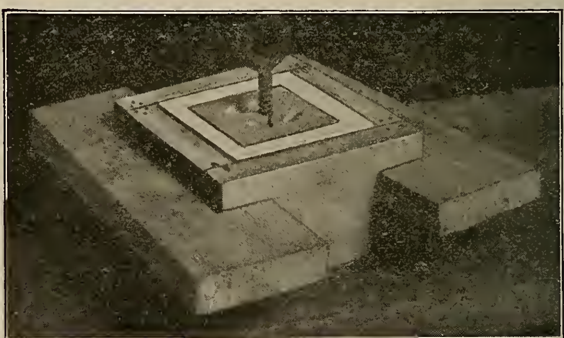


FIG. 58.
Cement Match Safe Forms Assembled.

later give it a final heavy sprinkling. The next day your match safe is ready for use.

If you can obtain white cement and white sand for your match safe it will add to its attractiveness.

LIST OF ARTICLES NEEDED IN THE CONCRETE LABORATORY.

1. Benches at which pupils may work standing; may be made from boxes; do not need to be handsome, but should be solid. One large table can be made to accommodate six to ten students.

2. Shelves should be arranged for storage of apparatus, and articles under construction.

3. A number of bins made of boxes, each holding from one to two cubic feet.

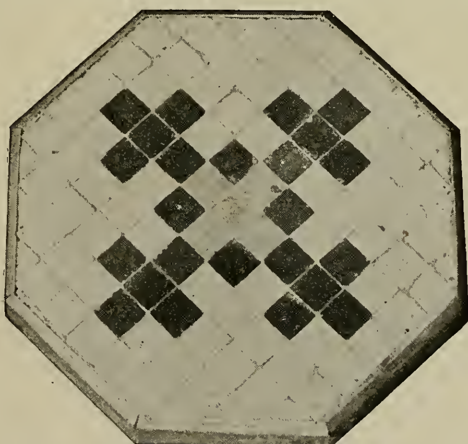
4. The following (or as many as it is possible to obtain) to go into the bins:

(a) Fine wash sand—free from dirt and very fine.
(b) Fine pit sand—the finest to be obtained from pit.
(c) White sand. This comes from the Lake Regions. You may be able to get some from a contractor.
(d) Coarse sand—called also Torpedo Sand.
(e) Fine gravel—called also Torpedo Gravel.
(f) Coarse gravel—nothing smaller than ½ inch nor larger than 1 inch.
(g) Crushed rock screenings—smaller bits from crushed rocks.
(h) Crushed rock coarse—about 1½ inch in size.
(i) Cinders—both fine and coarse.
(j) Lime—both natural limestone and quicklime.
(k) Cement.
(l) Wire of different sizes for reinforcing.
(m) Wood for forms, tampers, straight edges, etc.
(n) Mixing board—plain board 12 in. by 18 in., cleated on the bottom.
(o) Small trowel—can usually be obtained at ten-cent store.
(p) Measuring cups of tin.
(q) Screen for screening sand and gravel.
(r) Few tools for making forms.
(s) Literature—which can be obtained from almost all cement companies.
(t) Exhibits of concrete and reinforcing—can be obtained from concerns handling the products, and can be prepared in the laboratory.

NOTE.—Practically all of this apparatus can be made by the students at no expense. It is worth while. Try it.

CONCRETE POST.

The above concrete post can be made a very practical lesson. It is re-enforced at the edges by wire and can be made of various mixtures. The size can vary to suit the desire of the students. It may be made when completed into a calendar, a paper weight, a thermometer holder, or a pen rack. Here is a good chance to exercise the initiative of the students.



CONCRETE TEAPOT STAND.

The above teapot stand is made of Mosaic tile imbeded in concrete and then polished. The tile can usually be obtained for this article free of charge. The border may be made of either tin, brass or aluminum. It may be left off. However it gives the work a more finished appearance.