S O I L M O I S T U R E S T U D I E S .

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-- Soil Moisture Studies. -

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The importance of the subject of soil moisture has been abundantly shown in many parts of the United States, but is of the greatest importance in the central west where there is such a scarcity and unequal distribution of rainfall, that it becomes necessary to resort to the most practical and scientific methods in order to make agriculture pay on much of the arable land between the Mississippi River and the Rocky Mountains.

In much of this comparatively arable territory there is sufficient rain during the year to raise fair crops of many of the cereals, but the unequal distribution of the moisture causes the crop to grow very rank for a time but later it is often impaired by drouth, or entirely dried up before the grain is matured. Many a farmer after putting in his crop and working hard to keep down the weeds has become thoroughly disheartened when the hot, dry months of July and August came; and his corn was withered before the scorching winds leaving him nothing, not even feed for his hungry stock. Perhaps he becomes discouraged and quits farming or he travels on seeking a more favorable farming locality. But here he finds many others before him and many disadvantages. The population is rapidly increasing, the country is fast filling with settlers, the better farming lands have all long since been taken. Some of us must till these less desirable lands, and we find that to raise crops we must practice new methods of farming. These methods in the main are conditions lessening the damage by summer drouths.

In the Central part of Kansas where we were born and raised sufficient rain falls in the course of a year to raise crops if it only came at the time when most needed. The annual rainfall in central Kansas is about 25 inches, and according to Professor F. H. King only 12 inches of water are required to raise 40 bushels of wheat, and 10 inches to raise 60 bushels of corn. Thus we see that there is water enough were it properly distributed and made use of by the crops. We must have methods whereby we can conserve this water so that it will be available to the crop in the time of greatest need. Then, and only then can we feel assured that our fields will not be destroyed by the lack of moisture.

The importance of this work is of inestimable value to farmers of the semi-arid region. If they learn to know, by moisture determinations, where the water that falls goes to, they are better able to know how to conserve it. The quantity of water in the soil at the various seasons of the year, and the conditions of cultivation which bring the water within reach of the plant are all important questions to the agriculturalist. The lands of the central and western portions of the state are rich in plant food. And the farmer usuallly has plenty of it to work with. Thus the chief object to be gained by soil moisture study is to find out how to produce good crops on fertile fields which are supplied with plenty of water but such very unequally distributed.

The object here is to state the methods of moisture determination and a few things that have been done along this line by the United States Department of Agriculture and State Experiment Stations.

Soil Moisture.- There are various things which effect the moisture of the soil, some of which we shall endeavor to give. By soil moisture as treated here, is meant the entire amount of water in the soil, regardless of whether it can be utilized by the plants in their growth or not. Of course it must be understood that not all of the water in the soil can be used by the plants, and further, that only a part of the water which falls as rain or snow is ever used at all by an average crop in the semi-arid west. But it has been proven by King and others, by many experiments, that if even half of the annual rainfall could be saved so that the plant might use it for its development, the farmer of that great region would be blessed by crops that could not be excelled any place in the Mississippi Basin.

It is interesting to know that different kinds of soil have a very important bearing on the soil moisture content. For instance, a light sandy soil will not contain so high a per cent of moisture as will a fine clay soil, except possibly, directly after a heavy rain; but at the same time the sandy soil will more readily part with its moisture than will the clay soil. Therefore, plants on a sandy soil, while the moisture is sufficient, will make a more rapid growth than they will on a heavy clay soil.

The amounts of water held by the different kinds of soil when saturated are given by Professor King in his Soil Physics as ranging from nearly 53 per cent in the finest clay soil to 32.5 per cent in sandy soil. But such conditions as these never actually exist in the field, and it is therefore better to consider the amounts held by various soils when in actual field condition. This Professor King gives as follows, as the average of the first three feet of the soil: For a sandy loam, 14.3 per cent or about 3 inches of water; clay loam, 20.2 per cent or 3.5 inches of water; humus soil 32.4 per cent or about 5 inches of water. It would seem that the inches of water are slightly out of proportion to the per cents, but it should be remembered that the per cents are calculated on the weights of the soil, and that the different soils are very different as regards their weights, which accounts for the seeming discrepancy. These figures were obtained from soil holding all the water it would, a couple of days after a heavy rain, some of the water having of course drained out of the land. It would appear then that the clay and humus soils are the best, as they contain the largest amounts of water, but the fact should not be lost sight of, that although the sand has the least water in it, it will give up a larger per cent of it to the plant, the trouble being, however, that too much is lost by evaporation, leaving a decided balance in favor of the clay and humus soils.

An experiment by Professor King on the amount of water held by soils is worthy of mention. A field of corn was taken which began to wilt, and the leaves roll up, early in the morning. The soil was clay, down to about 30 inches, and then sandy down to four feet. The amount of moisture was determined and found to be 9.83 per cent for the clay loam, while for the sandy soil it was down to 4.17 per cent, showing that much more of the moisture could be taken from the sandy soil than from the clay loam. A further experiment based on the supposition that each particle of soil is surrounded by a film of water, and the thickness of this film can be computed by the diameter of the soil grains, makes it possible to compute the amount of moisture in the soil. Figuring on this basis it was found that when heavy red clay had 14.24 per cent, coarse sandy soil would be down to 1.11 per cent with various gradations between. These per cents represent very closely the relative amounts of water that are given up by these soils for the use of the crop, and that the sand, in the experiment with the wilting corn, was really the wettest soil there, so far as the available moisture was concerned.

The amount of water which a soil will hold is based on the size of the soil particles, the smaller the particles the greater amount of moisture will the soil hold. As clay is the finest of any of the soils it holds most, so far as this principle determines the water capacity of a soil, and the coarse sandy soil holds least. But while clay soil contains more water than other soils, when the water has been down to a certain point, the plant is unable to secure any more. It is evident however that as the clayey soils will hold more water and retain it better, they are the best soils for the semi-arid region of the west where the amount of water in the soil is so important a subject.

The moisture of the soil may be considered as having various functions, though, of course, strictly speaking it has only one function, that of supplying the wants of the plant. We can divide its work, however, and consider it as it effects the soil for tillage purposes, and for dissolving chemicals to secure plant food, before considering its uses to the plant.

The moisture content of the soil for tillage purposes is a very essential thing to watch, as it is well known that at certain times when the conditions as to moisture are correct, the land is easily tilled, and much better crops are secured, than if the soil is tilled when there is either too much or too little water in it. This is not an item, of course, in untilled soil as on our great plains, but the moment tillage begins soil moisture becomes important. In fact tillage does not begin unless the conditions as to moisture are favorable. No one thinks of breaking prairie land in the hot dry months of midsummer, but in Spring or Autumn when the soil is wet with the rains or snow. Thus we see, that even before tillage begins, and all the time after it is started, soil moisture plays an exceedingly important part.

The next important question of the function of soil moisture, is the dissolving action which it has on the soils. When we remember how running water becomes loaded with various salts, the nature of which may be best determined by knowing the kinds of soil and rocks over which the stream passes, we have only to apply the same principle to the water in the soil, only its action is greatly enhanced. Therefore we see that the work of soil moisture plays a part not to be overlooked, as the agricultural plants need many kinds of mineral salts for their development.

The water which falls as rain contains some carbon dioxide which materially aids in the dissolving power of the water. As the water percolates down through the soil, much of the soluble material is taken up and held in solution in the lower soil, and in this way the salts are used by the crops. Not only does the soil absorb the soluble material, but by slow action the water works on the insoluble matter in the soil and gradually this is broken down. Especially is the latter work manifest in the winter when frost assists the action of the water. It also works on the organic matter in the soil causing it to decay, and break up in such a way that part of the material can, sooner or later, be utilized as plant food. This would in a measure explain why a piece of fallow ground will yield a better crop the next season than one not fallowed. The action of the water has made available a certain quantity of plant food, that has been used up as it became available if there had been a crop growing on the soil. The plants also secrete some acids in their roots which, getting into the water in the soil, aid in making available food material for the root hairs to take up and carry to the leaves of the plant to be utilized as food.

The most important function of water is its use to the plant. It goes without any proof that without the moisture in the soil the plants would soon die; in fact, they would never even start to grow. The enormous amount of water which the plant gives off in transpiration must all come from the soil, and the fact that it requires as high as from 250 to 600 tons of water to grow a ton of dry matter in crops, makes it evident that the roots of a large tree, for instance, take up an enormous amount of water. This is equally true in a field of wheat or corn, where there is also a large amount of leaf surface.

Another very important use which water has to the plant has been referred to, namely, furnishing plant food in the soluble form. The plant takes up the inorganic matter as soluble salts held in solution in the water of the soil as previously explained. It is therefore evident that the more moisture a soil contains, i.e., up to a certain limit, the more food can the plant obtain, as the increased amount of water will tend to dissolve more of the inorganic salts. However, there must not be so much water that it excludes the free air from the soil as air in the soil is necessary to all plant life.

In the discussion of the subject so far, nothing has been said as to how the water occus in the soil. It is very distinctly classed as three kinds, viz.: gravitational, capillary and hygroscopic. Each of these plays a separate and distinct part as regards the growing of plants, and hence in their relation to the farmer. The average farmer may be but slightly interested in the several forms in which water is held in the soil, yet a knowledge of them may at times be of considerable value if he will apply the correct principle underlying the movements of soil water.

Gravatational water is water in a soil that is free to move under the pull of gravity. It fills the spaces between the grain of the soil, and is the water outside of the film which immediately surrounds the soil particle. It is also spoken of simply as free or hydrostatic water. Gravatational water may become injurious in three different ways, if it increases in quantity to such an extent that it will move with ease under the pull of gravity. 1. By washing out the soluble salts which may contain plant food; 2. by excluding the air, causing the suffocation of the plant roots, and the death of the microorganisms which perform a very important work in making available food for the plant; 3. By dissolving cementing materials in the soil, thus destroying its texture.

Gravatational water is beneficial at least in two ways; 1. by replenishing the capillary and hygroscopic water supply and, 2,- by washing out and carrying away injurious soluble salts, such as many of the alkalies, and possibly poisonous materials from some of the decaying organic matter.

Gravatational water, if there is a large supply of it, continues to go down until it gets to the water table, or, to a hard pan layer which is impervious, where the water will move by seepage to the nearest drainage channel. It will be seen from this that it is a bad practice to have a hard pan layer near the surface, and everything should be done to break it up, if there is one as it will very materially aid the soil in holding a large amount of water. In the semiarid west the rainfall is so limited that the soil ordinarily can hold all the water which falls, if the hard pan is obviated, and the soil otherwise kept in good tilth.

That moisture which moves in all directions, wherever it is needed, usually from the moist to the less moist ground, is known as capillary water. It is described as a film of water around each soil particle and outside the film of hygroscopic moisture, grading into it. It is from the capillary water that the plant roots draw their supply. The force of capillarity acts in all directions and may help gravity pull water deeper into the soil, or, more commonly it brings the water from a depth up to the surface; or, in the case of irrigation by ditches carries the water laterally to where it is needed.

The capillary action of soils is influenced in various ways. By the tillage the ground is given; by manuring; firming of the soil, and by rainfall. By tillage of the ground is meant the surface tillage. A heavy soil mulch put on the surface strengthens the tendency to raise the water, as capillarity acts better in a damp than in a dry soil. And as it can not readily get through the mulch it remains near the surface for the use of the plant. A good soil mulch therefore is very beneficial.

The action of manure on a soil seems to be to put it in better mechanical condition, and the soil becoming more porous and open, the upper three feet will gain water at the expense of the deeper sub-soil. This should be sufficient to make people realize the value of farm yard manure. The firming of the soil should be practiced when the land has just been plowed, and the ground is too open for capillarity to act. By carefully firming such ground, water will tend to rise into the surface soil. This movement of soil water is shown also when a small rain wets a few inches of the upper surface, which will cause a capillary rise of water, making the surface contain more water than could possibly be represented by the rainfall.

The capillary movement of water is more rapid in a wet or moist soil, than in a dry one, but it should not be too wet or it will ruin the texture. It will also rise much faster in a coarse than in a fine grained soil, but will not rise nearly so high. The function of the capillary water seems to be to act as a carrier of the soluble plant food to the roots of the plants and to supply the necessary water for plant growth. The hygroscopic water lies closest to the soil grain and is perhaps mainly concerned in the dissolving process. By diffusion the elements dissolved are readily transferred to the moving stream of capillary water, and then brought within reach of the plant roots, which also grow in search of their foods, and coming into close contact with the soil grains, by means of the minute root hairs, assist in the process of solution by the acid which is given off.

There is a difference of opinion as to whether the plant roots receive their supply of water directly from the capillary water or from the hygroscopic water. The theory that the roots absorb the hygroscopic water may be stated as follows: the grains of soil are enveloped in a very thin film of water from which the plant gets its supply - and this is known as hygroscopic water. The movement of hygroscopic water is very limited, and the root hairs have to come to where it is. They envelope the soil particles and thus come in contact with the film of moisture and here take the water and plant food, which they get from the soil. As this moisture is taken, (how is not known), the capillary water replenishes the supply and thus the work is kept up.

The hygroscopic water probably does much to dissolve plant food but soluble material must be carried by capillary or gravitational water from place to place. It is thus readily seen how one class of water depends upon another. The gravitational water comes either from rain, snow, or irrigation to the tillable land, and it is from this that the capillary water gets its supply, and it in turn supplies the store of hygroscopic water, which furnishes the plant with its needs.

<u>Methods</u> of <u>Determination</u>.- The necessity leading to the moisture determination is to find out how much water is contained in the various conditions of the soil at the different times of the growing season, and also to see where this water is and the movement of it up or down through the soil. The movement downward is due to gravity. The capillary movement may be in any direction but usually, doubtless, from greater to less moisture content. This latter movement is prompted, first, by the absorption of water by the roots of the plants, which loss must be supplied from the capillary water. Second, the capillary water is strongly affected by the immense amount of evaporation that takes place from the surface of the ground and water comes up from below to take the place of what has passed off into air.

The means of determining the moisture content and the movement of the water in the soil are: first, by the electrical, and second, by the gravimetric method. We will treat them in the order given.

The principle of the electrical determination is, that a wet soil will conduct electricity better than a dry one. Carbon plates three inches long, three-eights inches wide and three-sixteenths inches thick are used to put into the ground, from which the wires are connected. Each electrode is copper plated on one end, which is connected by an insulated (No.20) wire with the measuring instrument above which records the resistance of the current of electricity passing through the ground from one plate to the other. The drier the ground the greater the resistance will be, and the moister the soil the less resistance is offered to the electrical current passing from one plate to the other.

These plates may be placed at any depth in the soil at which the moisture per cent is desired. The two plates need not be more than an inch apart where buried and are usually put in the same hole bored with a 1-1/2 inch auger. The two carbons are arranged on a small stick of wood in such a manner, that after being placed in the hole at the desired depth the plates can be forced out against the sides of the hole and imbedded in the soil, after which the hole is filled with melted pitch to prevent water from accumulating and at the same time thoroughly insulate the wooden block and the wires. The plates may be left in position the entire season, and by connecting up the wires a reading may be taken every day or as desired.

The amount of soluble salt in the soil water has very much influence on the resistance of the electric current passing between the plates, and the smaller the amount of soluble salt the greater the resistance to the current. This is thought to be due to the fact that the salt is decomposed into its ions, and the free metallic ions of the salt very materially assist the passage of the current. Thus it is seen that a soil that is alkaline or contains much of this soluble salt, with the same per cent of moisture that is contained in a soil without the salt, will give a very different reading on the wattmeter. So that a correction will have to be made for the amount of soluble salt that may be in the soil. This can be done by the electrical resistance, provided the water content and temperature is known. Usually, however, on fields where we ordinarily grow crops there is not enough variation in the soluble salt that it need be taken into account. But it is necessary to first take a sample of the soil and determine the moisture by weighing, and drying by heat, and from these figures work out a standard from which the electrical determinations can be made. This standard after having once been correctly established does not vary enough to materially effect the results providing the temperature remains the same; but as soon as the temperature changes the resistance is affected due to the disassociation of the ions of the salt in the water, and the higher the temperature the greater the disassociation and therefore the less the resistance to the electrical current. There is also a method by means of which this variation in temperature can be recorded through the aid of electricity, and a correction made.

Mr. Milton D. Whitney, Chief of the Bureau of Soils is the instigator of this method of soil moisture determination, and claims that it is much more accurate and can be performed with much less labor than the gravimetric method. He has adopted this method in much of the moisture work in the Department of Agriculture.

Bulletin No.68 of Minnesota Experiment Station says the advantages of this method are very apparent, as the movement of moisture can be obtained daily with a small amount of labor. One man can read forty electrodes in two hours where it would take ten men to do the

Photograph illustrating taking Samples of Soil.

short distances on a plot. Therefore in taking samples, from two to four cores are taken from each foot. Usually more cores are taken from the first and second feet than in those deeper down, because there is more chance of getting an untrue sample than lower down where the soil has never been disturbed. All the samples from the first foot are put in one tray; all from the second foot in another tray, and so on as deep as the samples are taken, which in many cases is 6 feet deep. However, the last two (5th & 6th) feet must be taken with the auger which is about 6-1/2 feet in length, the tube being too hard to withdraw at this depth.

The trays are all numbered (both on lid and box) and when each sample is taken the number is recorded so that it is known exactly where each tray of soil came from.

On reaching the laboratory each tray with its contents is weighed and the weight recorded. The covers are now removed and the trays placed in a drying oven and left there until no moisture remains, which usually requires from 15 to 20 hours at a temperature of from 80° to 100° Centigrade; but for three or four hours more the temperature should be brought up to 110° or 115°. When thoroughly dry the covers are replaced and the trays with their dry contents are weighed and the weights recorded. The difference in the two weights of any tray thus obtained will show the amount of water that is driven off from the contents of the tray. The trays have all been weighed and the weights recorded before leaving the laboratory so now by subtracting the weight of a tray from the weight with its dry contents will give the dry weight of the soil. By dividing the weight of the water in any tray by the weight of the dry soil in that tray the per cent of water is secured for the sample of soil under consideration.

It should be noted that the per cent of moisture thus obtained is computed on the dry weight of the soil, and not upon the wet weight as was formerly done at some of the experiment stations. This method of computation will give a higher per cent than if computed on the wet weight, but either will give the comparative changes of water content in the soil under the various conditions affecting soil moisture.

This method of obtaining the water content of the soil requires considerable labor, and it is also necessary that all of the work be done with the greatest of care to give accurate results. As before stated the electrical method is much the quicker way of taking the moisture content, but to start with it is based upon this method, since a standard must be worked out before any results can be obtained by means of the electric current. Therefore the gravimetric method is perhaps as accurate as the electrical and the instruments are much cheaper; however, the labor is lessened by the use of the electric current.

Some chemists criticise the drying method as above described; but by the use of from 400 to 800 grams of soil the moisture per cent can be more accurately determined than is possible to do by taking the small samples of from 5 to 10 grams as is usually done by the chemist. The drying is done with great care as all the trays are weighed at the same temperature as nearly as possible and the accuracy of the weights on any tray is almost exact as the weight is taken to the tenth of a gram in all cases.

It was found by considerable experimenting that the trays with their contents must be dried at 110° for several hours. It seems to make no material difference in the weight if the oven is heated up to 125° or 150° but if after heating to a high temperature the trays are set out uncovered and allowed to cool they will take up a slight per cent of moisture from the air. The main thing is to be sure to keep them hot enough for a long enough time to drive off all of the water, then put on the cover, allow them to cool enough so that they can be handled and then weigh.

What has been done. - There has been much work done by the experiment stations and some by private individuals to determine the value of various methods of cultivation. The value of some cultivation is apparent to most farmers, but as to the best way of doing it many are not well informed. They have not experimented and recorded results in such a manner that they are able to cultivate their crops to the best advantage.

In the early spring of 1903 an experiment was begun on the College farm with alfalfa land in order to study the moisture content of the soil for various methods of treatment. The field was divided into four plots, No.1 was lightly manured (8 loads per acre) and no cultivation, No.2 was left entirely untreated, No.3 was manured (9 loads per acre) and disced, No.4 was manured (12 loads per acre) and disced. April 1 after the alfalfa had made some growth (3 inches high) soil samples were taken down to a depth of six feet and the moisture determined for each foot. The moisture content of the first foot and an average of the six feet for each of the four plots was as follows:

Table I. Giving Moisture in Soil of an Alfalfa Field.

No. of Plot.	Per cent of water in first foot.	Average for the entire six feet.
1	30.2	24.2
2	28.3	23.2
3	30.	23.5
4	27.4	22.1

It will be seen that plots 1 and 3 showed a decided advantage over plot 2 which had had no treatment, but plot 4 was even lower in moisture than plot 2. Why this should be is not easily explained unless the fact that plot 4 is next to a road, from which practically all of the water runs giving a chance for the water in plot 4 to be conducted by capillarity to the soil under the road.

There are three essential steps that may be considered under the head of cultivation to conserve soil moisture.1 Preparation of the ground to receive water, 2 restoring the capillarity so that the moisture will rise up to the seeds or roots of small plants, 3 preventing evaporation by the soil mulch.

There has been much written in recent years about the preparation of the ground to receive water. It has been claimed that the subsoil plow is a beneficial tool in such preparation, but through many experiments it has been proven that generally the increased yield in the crop (if there is an increase) does not pay for the work expended. However, ordinary plowing as early in the season as possible so as to allow the water from rain or snow to enter the soil, has been found to be very practical. Kansas Bulletin No. 89 and Oklahoma Bulletin No. 42 show the necessity of plowing early in the fall. This will prepare the ground to take in moisture and prevent evaporation of water which the soil already contains.

The reestablishment of the capillarity in soil that has been loosened up deeply by the plow often becomes necessary. The soil stirred has had its capillary force disconnected from those below and hence the water rises from below up to the furrow slice and stops. Thus the ground often needs to be firmed or packed on the lower part of the furrow slice so that the water may be conducted near the surface where it is often most needed for germinating seed or to supply the young plants. Such preparation of the soil is often necessary for securing a good stand when seeding grain, alfalfa or other small seeded crops.

The matter of preventing the evaporation is perhaps the most important thing to be considered in dealing with soil moisture. Bulletin No. 39 of Nebraska says the moisture problem is simply one of evaporation of water from the soil and suggests surface cultivation as the method of controlling it.

It is very apparent to one that has read the moisture experiments, or has had the actual experience himself that the soil mulch is the chief means, in fact, the only practical way of preserving evaporation from the soil.

The time of putting on this mulch has a great deal to do with the amount of water lost from the soil. The Kansas and Oklahoma Experiment Stations have shown in Bulletins No.s 89 and 42 respectively, the great advantage gained by plowing stubble ground early in the fall. In both instances several per cent more moisture was conserved, than when the ground was plowed one to two months later. Many other Stations as well as private individuals have shown the beneficial results of early plowing. Renew the soil mulch (when possible) after every heavy rain, as the ground becomes hard and compact and the capillary pores in the soil conduct the water to the surface, where it is evaporated. Surface cultivation, breaks the capillary connection and thereby materially lessens the loss of water.

Few farmers realize the need of the soil mulch at various seasons of the year, and much water is lost in the spring before it is time to put in the spring crop, also many thousand bushels of corn are lost, simply from the fact that farmers fail to put a soil mulch on their fields after the usual heavy rains that come in June and early July. Then again moisture is lost from the stubble fields when they are left untreated until late in the season. At the Kansas Station one part of a stubble field was disced early, another plowed early, and another plowed late, and later the moisture content determined, and the result was highly in favor of the early treating of such fields.

It was the intention to embody in this thesis the results of several experiments that were started in the spring of 1903. Two cultivation experiments were under way; one was a series of six plots to test the different depths of cultivation from one to six inches. The other was another series of six plots to test the frequency of cultivation. All the plots in this series were cultivated 2-1/2 inches deep, one plot at intervals of three days, another at intervals of six days, others at intervals of nine, fifteen and twenty-one days. This was to ascertain the effect of frequency of putting on the soil mulch. But owing to the fact that there was such an unusual amount of rain in May (having rained on fourteen different days) we were unable to gather any results of value from either of these experiments.

However, one experiment was performed earlier in the season by the writers, in connection with the Agricultural Department of this College, which shows the benefits of preparing a soil mulch early in the spring on the land intended for corn. In this experiment five plots, each fifty-two feet wide were laid off on kafir-corn stubble ground. On April 1st soil samples were taken to the depth of six feet on each plot, after which four of the plots were cultivated, and one (plot 3) was left untreated as a check for the other plots. Plot No. 1 was lap-disced and harrowed. Plot No. 2 was simply lap-disced. Plot No. 4 was listed, five to six inches deep, and rows 3-1/2 feet apart, and plot No. 5 was plowed, and harrowed twice. The plots remained without further treatment until May 9th when samples were again taken from each plot, and all the plots were listed to corn. The per cents of moisture for April 1st and May 9th are here given for the first foot, the average for the first two feet, and average for the entire six feet, from each of the five plots.

Table II Giving Moisture in the Soil of the several Plots, April 1st and May 9th.

No. of Plot	Treatment received.	Moisture in 1st ft. Per cent Apr. 1	Moisture in 1st ft. Per cent May 9	Difference Per cent.	Moisture in first 2 ft. Per cent Apr. 1	Moisture in first 2 ft. Per cent May 9	Difference Per cent.	Moisture in 6 feet. Per cent Apr. 1	Moisture in 6 feet. Per cent May 9	Difference Per cent.
1	Lap disced & harrowed	26.5	27.4	+.9	26.45	27.	+.55	22.15	21.9	-.25
2	Lap disced	26.1	26.5	+.4	26.	24.75	-1.25	21.46	20.9	-.56
3	Untreated	25.1	24.9	-.2	25.	24.3	-.7	20.45	20.	-.45
4	Listed 5:6 inches deep	25.3	25.5	+.2	25.3	25.9	+.6	21.16	20.66	-.54
5	Plowed and harrowed twice.	24.4	26.7	+2.3	24.8	25.9	+1.1	20.06	21.00	+.94

By a study of Table II we find that plot 5 as compared with plot 3 gained 2.5 per cent of water in the first foot, 1.8 per cent in the first two feet, and 1.39 per cent in the entire six feet. Thus it is seen that the water has been gathered in the upper two feet of soil where it is most needed for the plant. It should also be noticed that plot 5 is the only one that gained in the amount of water in the entire six feet.

By further calculation from the table we find that this 1.8 per cent in the upper two feet is equal to .55 inches of rain. Considerable water, therefore, was saved by early cultivation and had it been a dry spring there no doubt would have been a much greater difference.

Frequency of cultivation is not as important as the time and depth of cultivation. To conserve the moisture the ground should be cultivated after every rain because the rain runs the soil particles together and reestablishes capillarity from below. But disturbing the soil too frequently in dry weather exposes more of it to the sun and wind and will perhaps do more harm than good. Considerable judgement must be used as to the frequency of cultivation during a dry spell. It should also be remembered that it costs money to do this work and unless extra cultivation will save considerable moisture and increase the crop it should not be done.

The depth to cultivate to conserve the most moisture is of considerable importance, as much more work is required to put on a deep mulch than a shallow one. It should also be remembered that what soil is used ~~is used~~ in making the mulch is virtually out of use to the plant, for the roots can not obtain plant food from dry, loose soil, and besides the soil that is stirred up dries out much more than that directly under the mulch.

In Oklahoma, according to Bulletin No. 42, forty-four bushels of corn and three thousand three hundred and forty-eight pounds of stover were raised on ground plowed four inches deep as against thirty-seven bushels of grain and two thousand eight hundred and thirty-five pounds of stover on ground plowed eight inches deep. This may be an exceptional case and refers to plowing rather than to cultivation; but much the same principle is involved.

In three trials in 1893 made at the Wisconsin Station by Prof. King the yield of corn was considerably in favor of three inch cultivation against one and five-tenths inches deep. In several other experiments, given by King in the Wisconsin report of 1894, which were carefully performed by farmers the results in all cases favored the three inch cultivation as compared with that one and five-tenths inches deep. As an average for all trials there was an advantage of 6.27 per cent, in favor of the three inch cultivation.

From what has been gathered a mulch of 2-1/2 to 3 inches deep is preferable to either shallower or deeper. When it is deeper it takes too much rich soil from the use of the plant, and when it is shallower there is not a sufficient amount to conserve the moisture to the best advantage.

Conclusion. - Several things which are of importance to farmers have been learned in the study of soil moisture and may be briefly summed up as follows: 1. It has been shown that by preparing the soil to receive the rainfall and then carefully conserving the moisture by cultivation that there is sufficient water to raise a maximum crop. And that by holding the water there will be more plant food made available, due to the action of the water, hence farm crops will make better growth.

2. Having learned of the different forms of water in the soil and the movements of soil water cultivation can be suited to the needs of the soil according to the amount of water present and the requirement of the crop.

3. In the method of determination the object sought and the end obtained is not so much to give the farmer something he himself can use, as to give him a knowledge of the way the work is carried on, and enable him to look with more intelligent eyes on the work which is being carried on in this line.

4. In setting forth what has been done, the results from various experiment stations have been brought together and as nearly as possible the average of these results given, which it is safe to follow as a guide to what may be expected in the future. Several things have been brought out, for instance, that early fall plowing is better than late, whether for wheat or corn; the same is true of early and late spring plowing: The frequency of cultivation gave no material difference either to the crop or moisture content, the value of cultivation depending more on its being done at the right time. Shallow cultivation, (2-1/2 to 3 inches) except in rare cases, seems the best to practice, and especially is this true of a crop that is

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