EXPERIMENT STATION

OF THE

KANSAS STATE AGRICULTURAL COLLEGE,

MANHATTAN.

BULLETIN No.68 – JUNE 1897.

CHEMICAL DEPARTMENT.

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SOIL MOISTURE.

Determinations of the proportion of moisture absorbed and retained by soils in various conditions, and experiments upon methods of saving the moisture of soils, have received attention during the last two years. This work has been in several distinct lines. One line of work has involved the study of the moisture contained in cultivated land as compared with that in raw prairie sod; another, of irrigated ground as compared with like soil not irrigated; another compared the moisture in plats differently treated to learn the efficiency of the several methods of treatment in saving moisture; the same subject was also studied by observations upon soil in pots. The effects of subsoiling and of different proportions of water on irrigated plats also received attention.

In soil studies, there are many circumstances that may render the results negative or inconclusive, and be entirely unforeseen and wholly beyond the control of the investigator. As an illustration, when comparing the moisture content of subsoiled and unsubsoiled ground, it may happen that heavy rains will completely saturate both, and these conditions may continue well through the season. While in another season, after the first good rain the weather may be dry, and the deep soil-bed due to subsoiling be able to retain water, so that the subsoiled ground may be decidedly more moist throughout the season. Another effect of the weather is seen in such cases as this: After the subsoiling is done there may be little or no rain. The subsoiled ground may actually dry out more than that not so prepared, since its connection with the lower soil is disturbed and water cannot so readily rise from below, and there has been no opportunity for the exercise of any greater absorptive power it may possess. But with good showers a difference might appear. The water that could sink into the subsoiled ground might largely run off the compact soil. Further, soils differ in texture. One should not expect the same effects from the same treatment given to compact, impervious soils as to open, loose ones. If observations should be made. under all these several conditions, it is obvious that results would appear to be at variance. But with a knowledge of the circumstances, perhaps the data obtained would be equally valuable. Soil problems must be studied through long periods, or the result will be the little learning that is a dangerous thing. The results of these trials are given not because the work is entirely new, nor because definite conclusions can be drawn in all cases, but in order that they may be used in con ection with other (past as well as future) work to form just conclusions upon some of these problems.

A portion of the trials were on the grounds of the substation, near Garden City, Kan. This station is outside the Arkansas river valley. The soil is the so-called plains marl which covers a large portion of western Kansas, and of course varies somewhat in different sections. The particular soil in question is fine grained, and yet not a plastic clay. In proper state of moisture it is loose and loamy, and breaks up in excellent condition. When too wet it puddles easily, and if it dries out without being stirred it becomes hard. It changes but little in character for a number of feet below the surface. Another set of experiments was upon the Station grounds here at the College. The soil under trial here is a rather stiff upland soil. Still other trials were upon the plains soil at Oakley, Kan. These soils will be designated the Garden City soil, the Station soil, and the Oakley soil, respectively.

PLOWED GROUND vs. SOD.

In one experiment it was proposed to study the moisture content of cultivated soil, or rather of soil that had been brought under cultivation, as compared with that of buffalo-grass sod in an adjoining tract. The soil was the same, and of course received the same rainfall. The first trials were with the Garden City soil. As the lower subsoil in most of the plains region is almost continuously dry, there is a minimum of water lost by draining through the soil, and differences in moisture would mostly be accounted for by differences in power to absorb rainfall, as opposed to letting it run off the surface, and resistance offered to loss by evaporation. These observations were made during the summer of 1895. The cultivated ground was plowed early in the spring to the depth of five or six inches, and was smoothed down by harrow and float. No crop was grown upon the portion of the plat from which samples were taken. The ground was kept clear of weeds by pulling and cutting with a hoe, taking care to disturb the surface as little as possible. Thus the results were not influenced by the effects of summer tillage.

Samples of the soil were taken daily by use of soil tubes furnished by the department of agriculture, at Washington, and we were given the privilege of franking tubes back and forth. In taking a sample the tube is driven down to the depth of one foot, the aim being to take a sample of the top 12 inches. With the best of care the tubes do not always take soil to the same depth. They get choked sometimes and drive somewhat like a stake, partially crowding the soil ahead or aside. When the filling is very imperfect it is discovered and a new sample can be taken. But less imperfect filling is not detected in taking the sample. Moreover, there are inequalities in the moisture of the soil, the rain-water having settled into some spots more readily than into others. Because of these unavoidable errors, there will be differences in the moisture in the daily samples that have no corresponding differences in the plats as a whole. Such small differences are to be viewed as experimental errors. In the average for several days these errors tend to compensate each other.

In placing the percentages of moisture upon a chart for comparison, the curve may be so drawn as to show the general trend, the lines passing intermediately between the daily inequalities; or the actual amounts observed may be charted, giving an irregular, saw-toothed line. The latter method will be followed in this bulletin. The plates numbered I, II and III show the percentages of water contained in the daily samples of these soils during the five months, June, July, August, September, and October. The rainfall for the period is given on page 78. It was the original intention to include in the comparison the moisture content of an irrigated plat adjacent to the plowed ground previously mentioned, and similarly treated except as to the watering of the one. The rainfall during the greater portion of the experiment was so abundant that no water was applied after May 7. Toward the close of the season the ground became somewhat dry, but it was not irrigated. The samples were taken from a portion of a plat growing sugar beets, no beets being on this portion, however, and it was deemed desirable to keep water off in order that the beets might ripen properly. Although it early became evident that the unusual rains had interfered with the success of the comparison of irrigated with unirrigated soil, the samples were taken along with the others. It could not be told that irrigation would not become necessary some time during the season, and the work was continued in order to be able to profit by any such contingency. The figures representing the moisture determinations in this case are shown on the plates with those of the buffalo sod and the plowed ground not irrigated; that is, plates numbered I, II, and III.

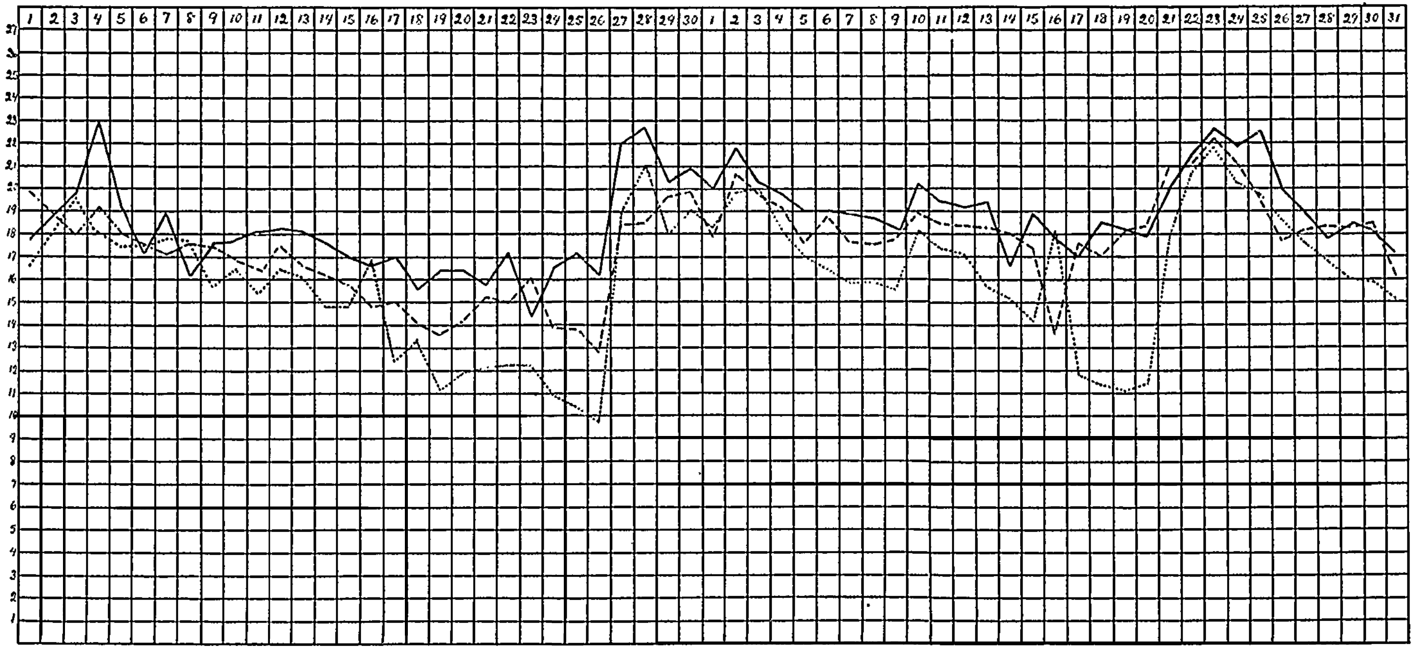
Table I.

RAINFALL AT GARDEN CITY, MAY TO OCTOBER, 1895.
(INCHES AND HUNDREDTHS OF AN INCH.)

DATE.	MAY.	JUNE.	JULY.	AUGUST.	SEPTEMBER.	OCTOBER.
1		.45				
2		1.51	.87	.05	.10	
3			.01			.18
4		Trace.		.25		Trace.
5						.18
6		Trace.				
7			.12			
9			Trace.			
10			.71	Trace.		
11			.01			
12		.46	.04			
13			Trace.			
16	Trace.					
18		.09				
19			.46			
20		.35	1.31			
21	Trace.	.28	1.12		.25	
22		.06				
23	.10		2.28	.16		
25		Trace.				
27		2.13				
28		.15		.02		
29	.43	.05		Trace.		
30	1.33		Trace.			
31				.14		.70
Totals	**1.86**	**5.53**	**6.93**	**.62**	**.35**	**1.06**

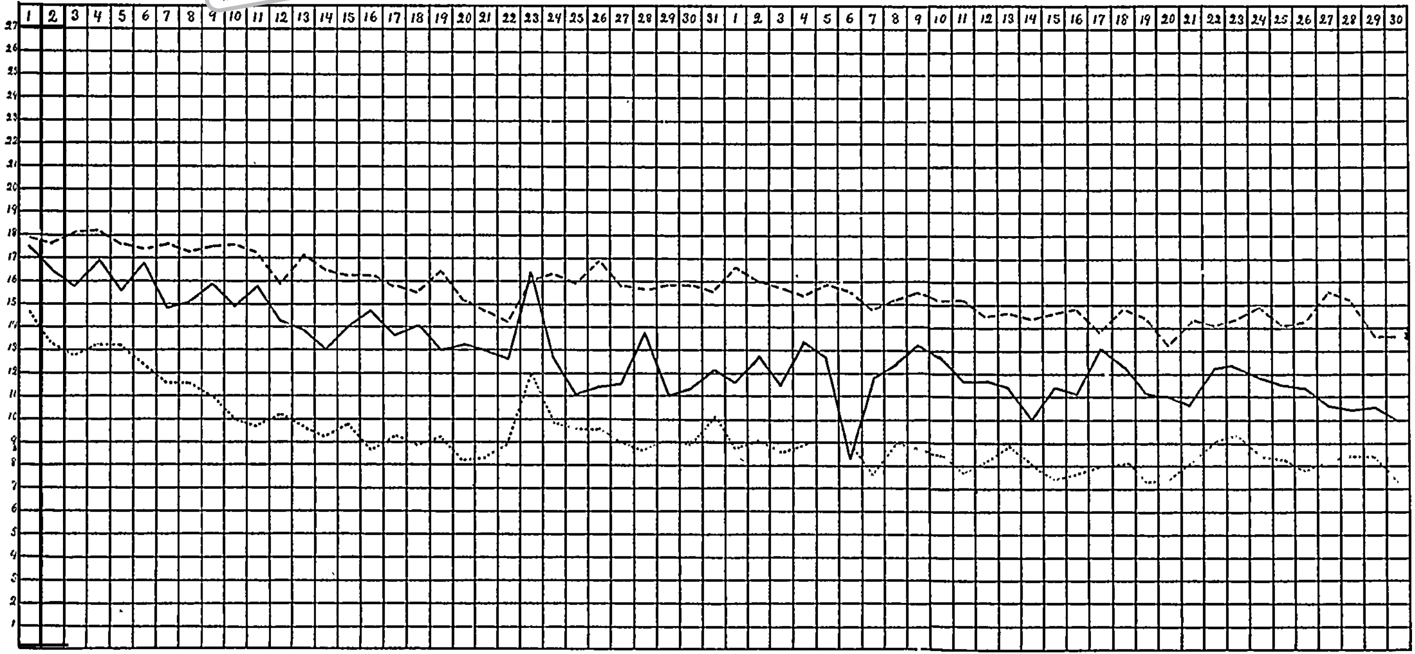
In the plates that follow, the percentages of moisture are represented by the height above the base line, and the days of the month by the horizontal spaces: In studying them, the previous suggestions regarding errors, inequalities, etc., must be kept in mind.

PLATE I.



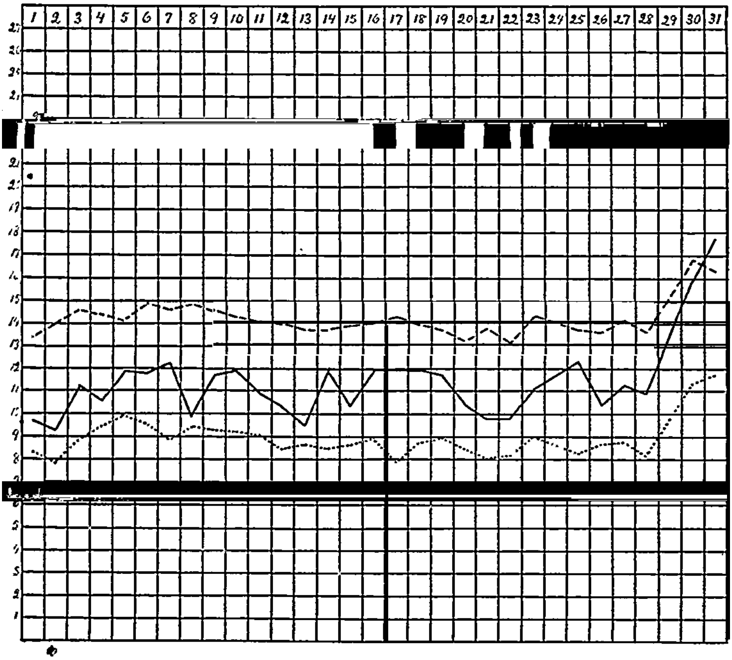
June and July, sod .... Plowed ground — — — Irrigated May 7th ————

PLATE II.



August and September, sod .... Plowed ground ——— Irrigated May 7th ———

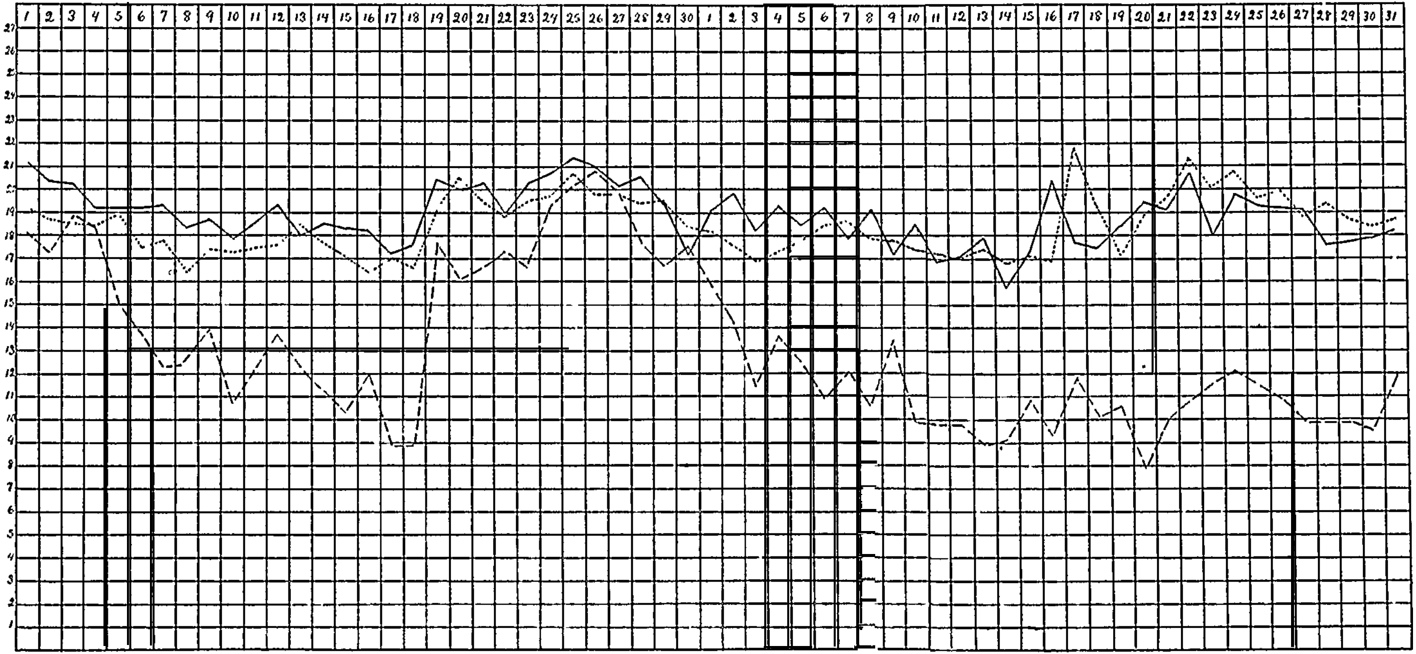
PLATE III.



October, sod .... Plowed ground — — —
Irrigated May 7th ————

In June and July, 1896, observations of a somewhat similar character to those of the previous year were made at Oakley. They differ only in the fact that one plat was subsoiled. A comparison is made between this subsoiled ground, ground plowed but not subsoiled, and buffalo-grass sod, all similar soil naturally. This ground was all buffalo-grass sod until the last of April, 1896. A portion was then broken and subsoiled, another portion simply broken, and a portion left in its original state. As the sod on the broken ground had not had time to rot, the ground was thoroughly prepared by disking and harrowing. These plats were prepared for other experiments, and their use for this purpose was incidental. Daily samples were taken as before. Plate IV gives the results. There were numerous showers during these months, the principal rains being about the 20th to 25th of June and the 22d of July.

PLATE IV.



June and July, '96, sod ——— Subsoiled .... Not subsoiled ———

Certain facts are brought out so prominently in the charts that little need be said further. The most obvious point is the almost constantly drier condition of the sod. Another point is the fact that immediately after a considerable rain the sod is almost as wet in the portion sampled as the other soils. It also decreases in moisture rapidly after the rain. The very great increase in water content produced by a rain is because the water does not soak into the soil easily, and makes the surface very wet-almost, if not quite, to saturation. Because of this the per cent. of moisture in the sample is high. But the water is at the immediate surface, and escapes into the air by evaporation. The cultivated ground is at all times in better condition; is more moist. The rainfall is absorbed more readily and runs down into the soil to a greater depth. The immediate surface does not remain so wet, and when it dries out the moisture below is partially protected. There is a remarkable difference in the condition of moisture of the soil of plowed fields and of that of adjacent sod, even if the plowed ground has upon it a much greater quantity of vegetation than the sod. Often when sod is so dry that it will powder up into dust, and this condition exists for an unknown depth, the soil of adjoining fields, a few inches below the surface, will be in good condition, and the moist layer is of considerable thickness. It is generally dry again below this moist layer. That plowing and loosening up the plains soil has a great influence upon its absorbing and retaining properties cannot be doubted by any one who has made even ordinary observations on the soil in field and prairie. These plates show in definite figures a greater and more persistent difference in favor of the plowed ground than would generally have been anticipated.

COMPARISON OF DIFFERENT METHODS OF PREPARATION.

We had in our experimental plats at Garden City ground that had been prepared in three ways—plowed to the depth of 5 or 6 inches; plowed 9 or 10 inches deep; subsoiled to the depth of about 16 inches. In the latter part of October an examination was made to see if there was a difference in the moisture contained in soils prepared in these ways. Samples were taken from several plats by the following method: The sampling tube was driven down to the l2-inch mark; then a pit was dug to this depth, and the tube removed. Another tube was driven down 12 inches from the lower end of the first one. The pit was sunk to the level of the lower end of this second tube, and another tube driven down 12 inches deeper. By this means the soil and the subsoil were sampled in three 12-inch parts to the depth of 3 feet. Crops had grown on some of the plats thus sampled, and were still standing. Some had been kept bare of vegetation, but had been cultivated. Some had been irrigated, and others not. The results of the examination are given in the table that follows:

Table II.

SHOWING MOISTURE IN SOILS AT DIFFERENT DEPTHS.

Depths.	Unplanted, cultivated.			Cropped with sugar beets, not irrigated.			Light crop of grass and weeds, irrigated.			Averages.		
	Shallow plowed...	Deep plowed...	Subsoiled..	Shallow plowed...	Deep plowed...	Subsoiled..	Shallow plowed...	Deep plowed...	Subsoiled..	Shallow plowed...	Deep plowed...	Subsoiled..
First foot	14.9	14.1	11.5	11.7	11.0	9.9	12.9	12.6	12.3	13.2	12.6	11.2
Second foot	17.0	17.4	16.7	12.2	16.6*	12.0	17.1	17.3	17.9	15.4	17.1†	15.5
Third foot............	17.1	17.2	18.0	11.1	11.7	11.4	16.8	18.1	18.1	15.0	15.7	14.5
Average of 3 feet..	16.3	16.2	15.4	11.7	13.1†	11.1	15.6	16.0	16.1	14.5	15.1	13.7

*These figures are so exceptional that there must be an error. This error will also affect the figures marked †.

†If the figures marked * are too great, as seems probable, these figures are also somewhat too large.

This soil is naturally fairly open, and when in good condition as to moisture is loose and friable. The season preceding the taking of these samples was an unusually wet one for the region. There was an abundance of rain from about the 1st of June until about the 1st of August, and of course the moisture remained in the soil much later. (See table of rainfall, page 78.) It may be that this soil would have made a different showing in a different season, or that other soils would have differed from this one, but these figures give no evidence that the absorptive power of this soil was increased by the special treatment given it. This trial is not deemed in any way conclusive, as one season only is involved, the samples were taken from a limited number of plats, and they could at best only represent the condition of the soil at the time the samples were taken, and not the history during the season. But samples from this depth were not taken earlier.

In the table which follows, the results of the examination of the soil at different depths in subsoiled and unsubsoiled ground at this Station are given. The ground had been prepared for wheat and drilled in on September 18. All plats had been treated alike, except that the odd-numbered plats had been subsoiled to the depth of about 14 inches, on the 8th of August preceding the taking of the samples on November 16. The subsoiling was followed by heavy rains. During the 10 days just before the taking of the samples there were four showers, amounting to about one inch of rain. At the time of sampling, the subsoiled ground was loose to the depth of subsoiling; a rod could be easily pushed down as deep as the plow had run. The ground that had been plowed in the ordinary way to the depth of about eight inches was hard below this, so that the rod could with difficulty be forced into it. No difference between them could be detected by sight. One could not tell the depth of the plowing nor subsoiling by looking at the side of a pit.

All plats were sampled to the depth of 26 inches. From the subsoiled plats a sample was first taken to the depth of subsoiling, 14 inches. From the lower end of this tube 12 inches more were taken, giving 26 inches in all. The ground not subsoiled was sampled by first taking 8 inches, representing the depth of plowing; then 6 inches, making 14 inches of soil; and then the 12 inches below this were taken, giving the 26 inches as before. In all these cases the short interval between the subsoiling and the moisture test may not have given sufficient time for the true and full effects of subsoiling to become apparent. Further, two soils may contain the same absolute amount of water, and crops upon one of them grow normally, while upon the other the crops show distress. In one water easily and rapidly moves to the plant roots; in the other it moves more slowly. These characters of the soil are not shown by tests of quantity of moisture. Even if any special preparation of the soil has not increased its moisture content, it may not be without effect upon crop production; there may be a greater root expansion in the soil, and water and plant food may be more abundantly supplied within reach of the plant.

Table III.

SHOWING MOISTURE IN SUBSOILED AND UNSUBSOILED GROUND.

Depth in Inches.	*45 Subsoiled ...	*46 Not subsoiled......	47 Subsoiled ...	48 Not subsoiled......	49 Subsoiled ...	50 Not subsoiled	51 Subsoiled....	52 Not subsoiled......	53 Subsoiled....	54 Not subsoiled......	55 Subsoiled ...	56 Not subsoiled......	Average subsoiled	Average not subsoiled......
0–14....	17.3	......	16.2	......	15.8	......	16.6	......	17.1	......	16.7	......	16.6	......
14–26....	19.6	......	16.6	......	16.8	......	16.7	......	17.1	......	17.3	......	17.3	......
0– 8....	......	17.2	......	16.5	......	16.5	......	16.7	.....	16.6	......	17.0	......	16.7
8–14....	......	19.3	......	16.5	......	15.8	......	17.0	......	17.3	......	17.6	......	17.2
0–14....	......	18.3	......	16.5	......	16.1	......	16.8	......	16.9	......	17.3	......	17.0
14–26....	......	17.9	......	16.6	......	16.7	......	17.8	......	18.2	......	17.2	......	17.4
0–26....	18.5	18.1	16.4	16.6	16.3	16.4	16.6	17.3	17.1	17.6	17.0	17.2	17.0	17.2

*All these plats are long and narrow. The samples from 45 and 46 were taken from the w end of the field; the others from the east end, on higher ground. The samples from subsoi and unsubsoiled ground are entirely comparable, the same number of each being taken fr each situation.

A TRIAL OF CHEMICALS.

It was questioned whether the application of such substances as common salt and gypsum would affect the proportion of moisture in the soil under experiment. They are known to have certain effects in a strictly chemical way, due to their action upon the minerals of the soil, tending to render some of the necessary elements more soluble; and salt is said to make heavy clays more pervious.

Salt was applied in two proportions upon two plats, at the rate of 450 pounds per acre and 900 pounds per acre. The same quantities of calcium sulphate, in the form of plaster of Paris, were used on otherplats.These trials were made on the Garden City soil, a soil that is ordinarily friable and not very rich in organic matter, during the summer of 1895. The only form of calcium sulphate available was plaster of Paris. After being applied to the soil it would take up water, and would presumably act the same as ground-up gypsum. Sugar beets were growing on all the plats. There was an excellent stand of beets, and a good crop was produced. All were irrigated on May 7, as nearly alike as the water could be controlled, and received the same rainfall, of course. Samples for determination of moisture were taken from these plats every third day, through the months of July, August, September, and the first half of October. There was a great similarity in the water content in all the plats throughout the period of trial. There was no difference that could not be accounted for by the unavoidable errors of sampling. The average of the percentages of moisture found in the several plats was almost exactly the same, 12.4 per cent. being the highest average and 12 per cent. the lowest. The plat giving this highest average had received 450 pounds of salt per acre. The lowest was a plat receiving 450 pounds of plaster of Paris. Because of the inconclusiveness of the experiment no further details are published at this time.

REMARKS.

The substation at Garden City was abandoned by the Board of Regents at the close of 1895. The experiments begun there, some of which are treated more or less fully in this bulletin, had to be abandoned with the ground. It was fully realized when the experiments were planned that a series of years would be required to make them conclusive and give them much practical value. It was supposed that there would be an opportunity to so continue them. It has been beyond the power of the writers to carry on the work as planned for the reason mentioned, and for the further reason that a reliable supply of water for irrigation was not available. We have regretted this but it has been unavoidable. Several lines of work taken up at Garden City had not been brought to even the same degree of advancement as those already described in this bulletin, and they will not be mentioned otherwise.

The same general remarks apply to the work undertaken during 1896 at Oakley. The station was in our possession during the summer of 1896 only. It was an unbroken sod when work was begun upon it. Everything was brought into shape, and work that would require a period of years to conclude laid out and started. The place passed out of our possession last winter, and work there was dropped accordingly.

Much of the work on soil moisture was undertaken in western Kansas because conditions seem most promising for success in that region. There is less liability of interference by wet seasons, and, when irrigation is involved, it is generally possible to have any degree of moisture in the soil that may be desired by controlling the irrigation. And further, any principles deduced would there be most profitably applied in practice. None of our work at Oakley was brought to a conclusion. One line, although continued through the summer, is of such nature that no conclusion whatever can be drawn from the one season's work. This experiment is an attempt to study the moisture requirements of crops under the conditions prevailing at the substation. As a preliminary trial, some of the ground was brought into as good condition for potatoes as was practicable with buffalo-grass sod. Of course, it was not like old ground in good tilth. Four strips were planted to potatoes and treated exactly alike, except as to the proportion of water applied by irrigation. A full amount of water for maximum growth was given one plat ; the second plat received less water; the third still less ; the fourth was not irrigated. Every two days a sample was taken from each of these four plats, and the percentage of moisture determined.

It was a part of the plan of the experiment to note the character of the growth of the potatoes, the yield, and the quality, and by comparing these for several years it was hoped that conclusions might be drawn as to the water content of such a soil required by the crop and of the effects of proportion of water upon the quality of the product. A mechanical and perhaps a chemical study of the soil would be an adjunct. Incidentally, it was thought that we might control the quality of potatoes, and perhaps improve the Kansas product. Although we have considerable data, procured this first year of the experiment, the details will not now be published, as the experiment has necessarily been abandoned. Some of the data may at some future time have value in connection with other similar work.

EXPERIMENTS AT THE STATION GROUNDS.

In planning the experiments upon soil moisture at the Station, the attempt was made to obviate as much as possible errors due to dissimilar condition and preparation of soil, and those due to ill-considered sampling. The piece of soil available had a gentle slope toward the southeast, and had been used for sugar beets for four years. It was subsoiled in 1891, *i.e.*, four years before. Previous to preparing for these experiments it had been plowed twice during the season. It was again plowed, disked and harrowed August 17, 1895. The night of the 19th, 5.91 inches of rain fell. This soaked the ground to super-saturation and packed it down well. A sample taken August 22 contained 22.5 per cent. of moisture. August 23 the ground was thoroughly raked to as nearly level a state as possible, and without tramping the portions to be used in subsequent moisture tests. Small plats were staked off, and were of such size and proportion that all parts could be reached without entering them.

In taking samples for determination of moisture, Professor Whitney's sampling tube was used. This consists of a brass tube 15 inches long and three-fourths inch in diameter. One end is given a smaller diameter by soldering within it a short ring of brass. just fitting the main tube. This end is then sharpened to a cutting edge, and samples are taken by driving the tube into the soil to a depth of one foot. The cutting edge being of less diameter than the tube is above, the core cut out usually slides up into the tube readily, unless the soil be very wet and sticky.

To note the change in moisture of the several plats, we deemed it advisable to take the successive samples from a given plat from as nearly the same place as was feasible. To this end, whenever a sample was taken the hole was filled with soil of similar moisture, packed in to a similar degree. The object was to prevent drying out through the hole, and also to prevent water running in, in case of rain, which would then soak into the surrounding parts, giving them a different. water content, undoubtedly, from the adjacent portions. The point was marked by a small stick each time, so that we could easily take subsequent samples from near the same place, and at the same time run no risk of getting too near, or actually cutting out the filling of a hole. The plats were sampled every two days. Six were worked upon, but the results of but four are exhibited in plate V. Of the two omitted, one was a “nothing” plat, *i.e.*, one untreated in any way save to keep weeds in check without stirring the soil, and the other was another cultivated plat. These gave results so entirely similar to the ones shown, that it seemed unnecessary to complicate the plate by including them

Plat 1 was untreated. Plat 2 was cultivated to a depth of about five inches, with a hoe. Plat 3 was mulched with green grass to a depth of three or four inches after settling. Later a light covering of sorghum bagasse was added, to prevent the wind blowing the dried grass off. Plat 5 had its surface raked to a fine condition, to a depth of an inch or more. Plat 6 was sown thickly to sorghum, broadcast. In this the soil would be protected from the direct rays of the sun by the shade of the crop, but would be subject to losses from its water requirements.

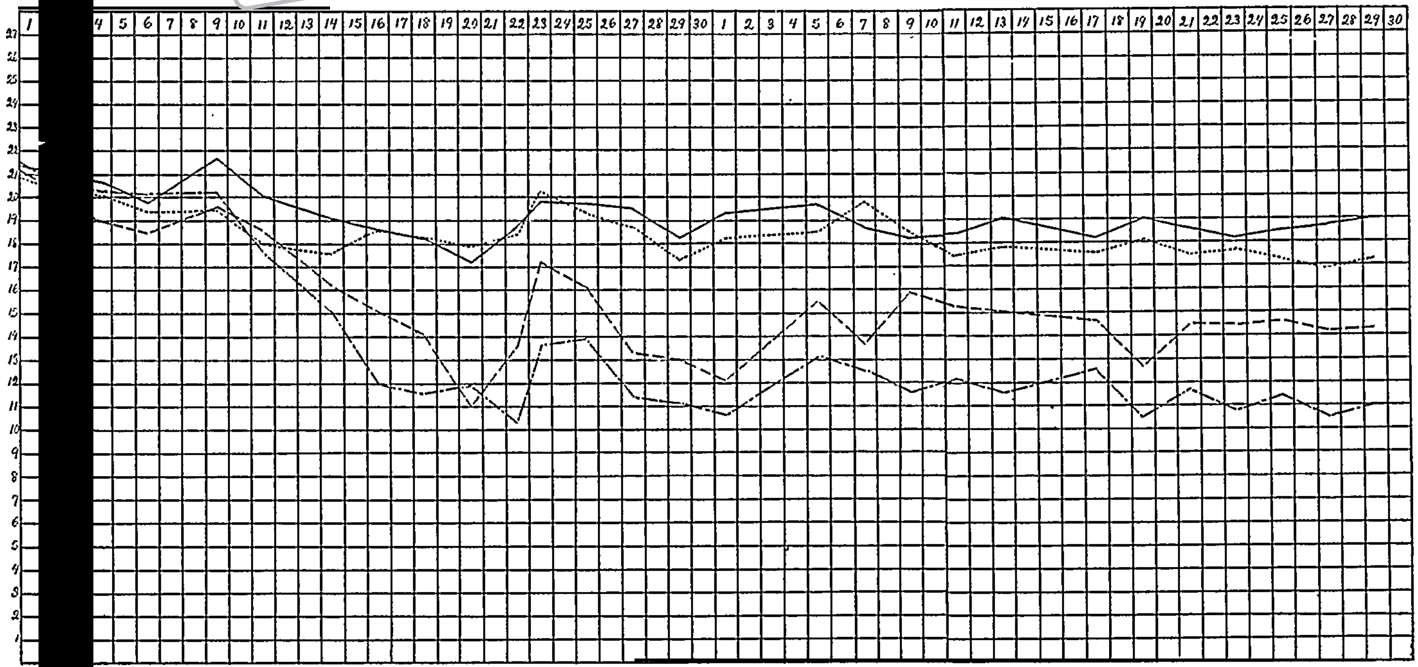
The mulch was applied to plat 3 August 24, but the cultural experiments were not begun until August 31, after several light intervening showers had put the surface into such condition as to make such experiments of possible value. The cultivation was repeated weekly. Before the cultivation was done, a stake was driven into the ground at the point around which samples were to be taken, and a mark made at the level of the soil. The loosening of the soil caused by cultivation necessarily raised the surface, but this was allowed for in sampling by driving the sampling tube in to a point 12 inches below the original height of the surface as shown by the marked stake.

The sorghum was killed by a heavy frost September 30. Rain fell during the progress of the experiment in the following amounts, on the dates named: .12 inch, September 6; .25 inch, September 8; .65 inch, September 22; .34 inch, October 3; .04 inch, October 5. A rain October 30 terminated the experiment.

Plate V shows how effective are the mulch and the cultivation in preserving moisture. The cultivated soil is practically as moist through the period as that covered by a good mulch. The dust blanket formed by the cultivation is in fact a mulch. This dry dust mulch was included as a part of the sample taken by driving the tube down, and of course lowered the apparent moisture. Had a 12-inch sample been taken below the dust mulch, as it was below the grass mulch, a higher percentage of moisture would have been found. Although the 12 inches of the sample were measured from the surface of the soil, it is obvious that it is really the moist part below the dust mulch that constitutes the medium in which the plant roots expand, and from which they must draw sustenance, whether water or solid plant food in solution.

The effect of the cropping with young sorghum upon moisture content is plainly shown by the chart. This ground was not cultivated after planting, as the sorghum was sown broadcast. There was a thick stand of sorghum. The difference between this soil and that neither cultivated nor cropped is plainly due to the ready loss of water from the soil through the plants. Had the weather been as

Plate V.



[redacted] Cultivated .... Untreated — — — Mulched ——— Cropped — - — -

warm as in midsummer, the young sorghum would doubtless have shown strong evidence of distress during the later portion of the trial. The soil samples were dry, or, to sight, did not appear to contain water. The proportion of water was probably reduced to about the lowest limit for plant growth, if not actually deficient even during the autumn temperature.

The presence of about 4 per cent. more water in one soil than another may not at first thought seem to be of any consequence, but a further consideration will show the importance of this amount. The percentages upon the chart are calculated upon the weight of the soil as taken, which includes both the soil proper and the water it contains. If the difference were calculated as percentage of the water present, it would be much more apparent. If one soil contains 14 per cent. of water and another 17½ per cent., the latter has about 25 per cent. more water than the former. In a close, retentive soil, such as the one under trial, crops will often suffer when the proportion of water is reduced as low as 10 or 11 per cent., because moisture cannot move through the soil to the roots of plants fast enough to supply the water evaporated from the plant. When this is the minimum below which plants will suffer, there is twice as much available water in the soil when it contains 17½ per cent. as when it contains 14 per cent. This is really the proper view of the matter. The practical question is, What. is the relative amount of water that any given soil can furnish plants rapidly enough for their needs? Another question is, How can the soil be so manipulated that it will contain in the time of need a greater supply of available water? Since the cultivated soil had about twice as much available water as the uncultivated, the efficiency of this method of saving moisture is apparent. These experiments measure in figures for this soil the truth that has been learned by experience and by other direct experiments.

EXPERIMENTS WITH SOIL IN POTS.

In plat experimentation it is practically impossible to get soil that will be perfectly uniform. The chemical composition will vary, and the physical state will be liable to much variation, even if the chemical composition be practically the same. Inequalities of surface, inequalities of subsoil, variations in pulverization, unequal packing by the unavoidable tramping by man and team, will all bring about variations in the deportment of the plats toward moisture, which interfere with accurate testing by designed variations of treatment. In studying the effect of chemicals, the difficulty of uniform application, so essential to accurate sampling subsequently, is very great. In the field of fertilizer experimentation this was recognized many years ago, and the difficulties largely surmounted by Prof. Paul Wagner, in his celebrated fertilizing experiments, using specially prepared soil and growing the plants under experiment in pots. Under his conditions a degree of accuracy was reached approaching that of quantitative chemical analyses. It was with a view to greater accuracy in our work upon soil moisture that the experiments about to be described were undertaken.

The experiments were conducted in galvanized-iron pails of uniform size, 9¼ inches deep, and 10½ inches in diameter at the top. These pots were weighed, and the weight of each stamped upon it, to facilitate adjustments of soil and water at any subsequent time. The soil used was a good quality of ordinary field soil. It was sifted and mixed with the utmost care by many hours of systematic shoveling. The water content was determined and enough of the prepared soil weighed into each pot to give 10 kilograms (22 pounds) of dry soil. In the cases where other solids were added to the soil, these were made a part of the 10 kilograms weight, so that each pot contained the same weight of dry matter. The soil of pot 5 contained, thoroughly incorporated, 100 grams of finely powdered lime, equal to 1 per cent. Pot 6, in like manner, contained 100 grams of finely powdered gypsum. Pot 7 contained 1 gram of common salt, which was added by dissolving it in the water which was given the soil. Pot 8 received, in a similar manner, a quantity of crystallized magnesium chloride, equivalent to 1 gram of the anhydrous salt. Pot 9 contained 5 kilograms of the dry soil and 5 kilograms of dry sand, well intermixed.

The quantities of lime and gypsum added were much in excess of what would ordinarily be applied to a soil. Gypsum in that amount would have no injurious effect on vegetation, and lime would so soon lose its causticity by the action of the carbon dioxide of the soil that the quantity taken would probably not prove injurious if crops were not actually growing on the soil, and perhaps not even then.

The quantity of salt added was such as would begin to be injurious to most crops if the water content of the soil were reduced to 10 per cent. The magnesium chloride would probably exert an effect upon plants somewhat similar to that of salt. The object in view in using it was to test the influence of a highly hygroscopic substance. It seemed probable that the tendency of magnesium chloride to absorb water from the air might be manifested in power to prevent evaporation from the soil to a certain extent.

The fact that a sandy soil can be worked sooner after a rain than one less sandy is well known. Whether this is due entirely to better drainage and the scouring action of sand, or whether evaporation actually takes place more rapidly from a sandy soil, was the point that was to be investigated by means of pot 9.

The quantities of soil taken filled the pots to a depth of nine inches, except the one containing the sand, which was about eight inches deep. Each pot, after being charged with soil, had added to it one-fourth as much water, viz., 2,500 grams. The moist soil then consisted of 80 per cent. dry soil, and 20 per cent. water. This is about the amount of water that common soils hold after a hard rain. After the water had been added, the soil in pot 4 was covered with a mulch of cut blue-grass hay two inches thick, held in place by a covering of mosquito bar.

The pots were exposed to the sun and wind at the south side of the laboratory, but were protected from rain by a glass roof. The pots were therefore open to the wind on three sides, but protected on the north and above. They stood on a table about 30 inches high, and were separated from each other enough to expose the sides equally to the sun. After standing two days, the surface of No. 2 was stirred and finely pulverized to a depth of about three-fourths of an inch. No. 3 was loosened up coarsely to about the same depth. Except as heretofore stated, all were treated alike. To recapitulate: Pots 1, 2, 3 and 4 contained the soil unmixed with other substances. No. 1 was not treated in any way; No. 2 had the soil surface finely pulverized; No. 3 had the soil surface coarsely pulverized; No. 4 was mulched. Pots 5, 6, 7, 8 and 9 were like No. 1, except that No. 5 contained 1 per cent. of lime ; No. 6, 1 per cent. of gypsum; No. 7, one-hundredth of 1 per cent. of common salt; No. 8, one-hundredth of 1 per cent. of magnesium chloride; No. 9,50 per cent. of sand.

In addition to the above pots, we had one numbered 13, which contained soil as in No. 1, but was supplied with water at the bottom by means of a cistern inclosing the bottom of the pail. This cistern was soldered to the pail, could be filled by means of a hole which was closed by a rubber stopper, and communicated with the bottom of the soil through numerous holes over which lay a sheet of blotting-paper. The object of this experiment was to observe the rate of evaporation from a soil kept wet by a continuous water-supply. Later, we added still another, No. 15, which was like No. 9, that is, half sand and half soil, except that it had the continuous water-supply as described above. The object in this case was to test further the rate of evaporation from a sandy soil compared with one much less sandy.

The loss of water was determined by weighing the pots with their contents daily, thus obviating the error that must be inherent to a less or greater degree in any method of field sampling.

The losses of water from pots Nos. 1 to 9 during the first month are exhibited graphically in plates VI and VII. The time is measured on the horizontal lines, and percentages of water lost are measured on the vertical lines. The percentages are calculated on the amount of water originally in the soil, and not on the weight of the dry soil or the soil as sampled, as is usually the case. An example will make the distinction clearer. Our pots contained 10,000 grams of dry soil and 2,500 grams of water. Of the total 12,500 grams, therefore, 20 per cent. was water. The soil, if it were sampled as soils usually are, should show 20 per cent. of water. If this pot be dried until one-half of the water has evaporated, that is, 50 per cent. of it, the remaining soil and water together would weigh 11,250 grams, of which the water would be 1,250 grams, or 11.1 per cent.

After the experiment had continued a month the water content had become nearly constant, and the pots were brought back to their original weight with water and the experiment repeated during another month. The results of the second trial are shown in plates VIII and IX. As pot 1 contained the prepared soil untreated, except with water, it may be taken as the standard from which to observe variations, and it is therefore included in all the plates.

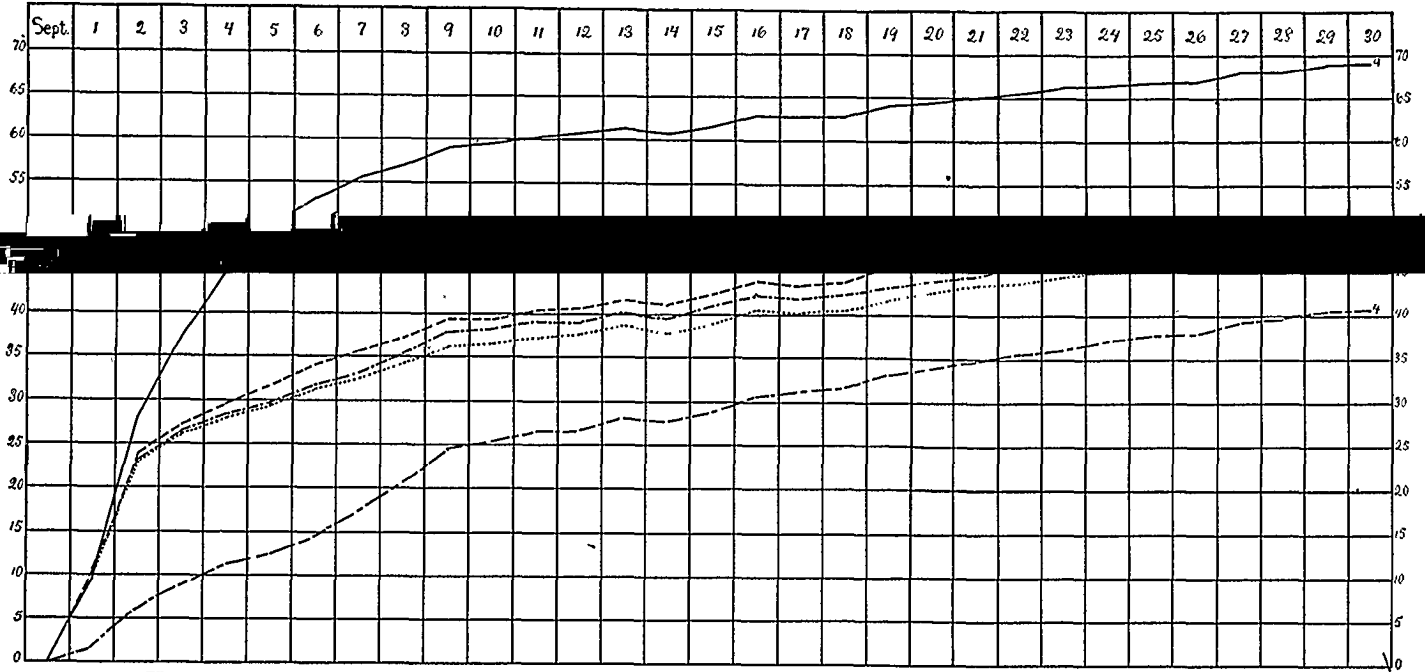
In plates VI and VIII we have exhibited the curves showing the variations in loss of moisture due to different modes of treatment of the soil. In plates VII and IX we show the effects due to additions of chemicals to the soil.

The first noteworthy point may be seen in all, that is, that where the soil is bare the evaporation takes place with very much greater rapidity during the first few days. This was to be expected; but it would not, perhaps, have been anticipated that as much would evaporate during the first two days of September as during the remaining 28 days. In the October trial, about one-half the total loss took place during the first three days. The soil in all the pots became very dry, yet it actually contained about one-half as much water as it had to begin with, when it was nearly saturated.

When we attempt to trace any effect due to the application of chemicals we find little encouragement. The first month pot 1 lost slightly more than the treated pots, and the second month it lost slightly less. In each month the limed soil lost least of the five. The differences are so slight as to be insignificant, however. We shall continue this line of investigation, not only with these but also with other substances added to the soil.

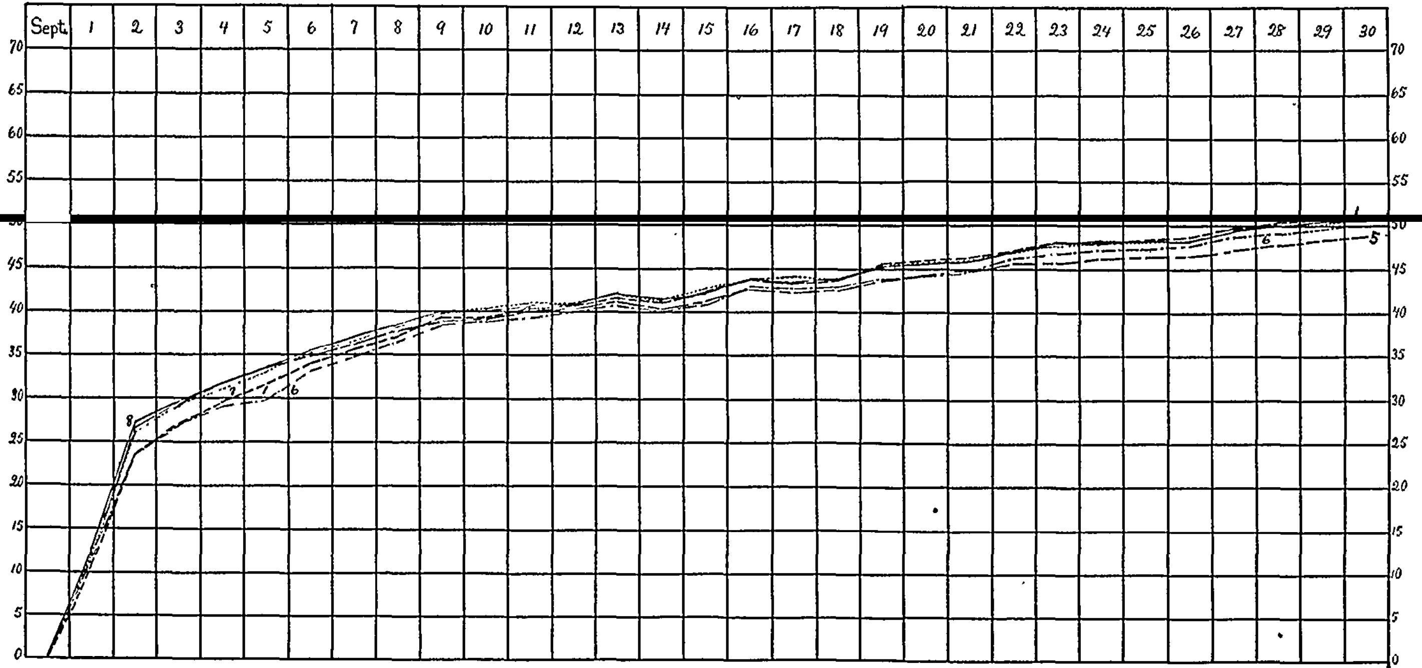
The effect of mulching is strikingly shown in both months' observations. The loss was much more regular, and at the end of the month the soil still contained enough moisture to prevent suffering

PLATE VI.



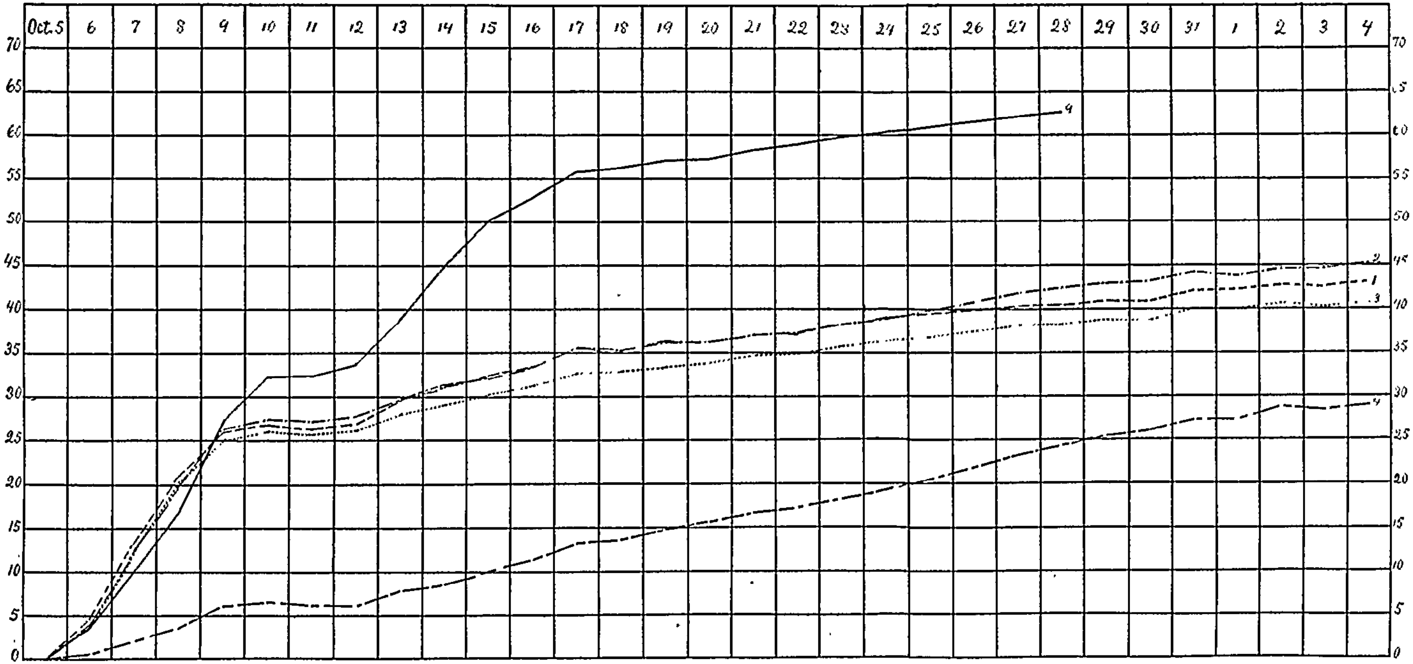
1, Untreated .... 2, Surface finely pulverized —·—·— 3, Surface loosened coarsely ....
4, Mulched — — — — 9, Half sand ————

Plate VII.



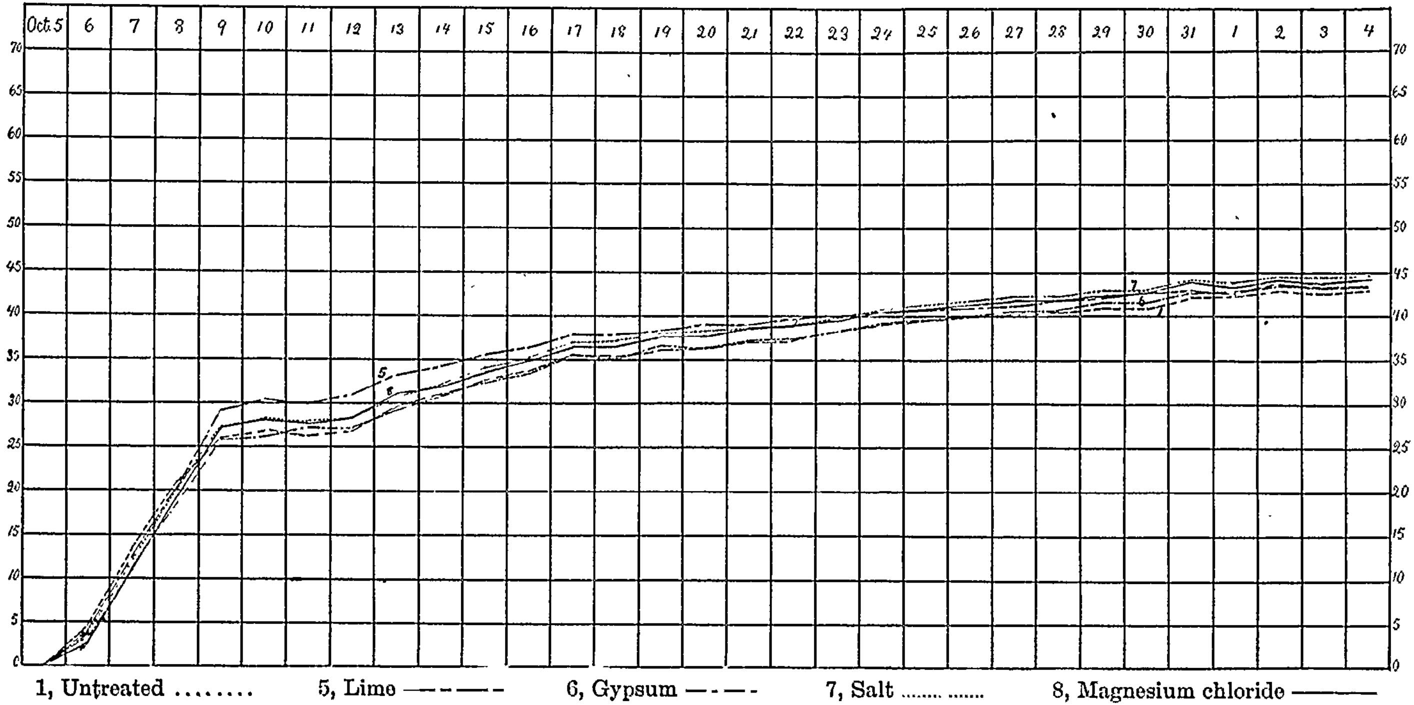
1, Untreated .... 5, Lime ——————— 6, Gypsum —·—·— 7, Salt .... 8, Magnesium chloride ————

PLATE VIII.



1, Untreated .... 2, Surface finely pulverized —-—- 3, Surface loosened coarsely ....
4, Mulched —-—— 9, Half sand ————

PLATE IX.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of crops. The rapid drying observed during the first two days where the soil was bare leads to the suggestion that, where mulching is practiced for the sake of conserving moisture, the mulching should follow the rain immediately.

The effect of tillage on the soil in pots 2 and 3 is seen to have been very slight. Evidently a mulch of loose earth of that thickness is not sufficient. In subsequent experiments of this kind we shall increase the thickness of the pulverized layer, and by varying the thickness learn the minimum that is effective.

The sandy soil lost water far more rapidly than pot 1, and became much drier at the close. These facts are probably due to the greater coarseness of the particles. At the beginning of the experiment the sandy soil was relatively much more highly saturated, and so would lose more easily. Later its holding power would be less because of the less surface possessed by its particles.

Pot 13 was the prepared soil kept saturated by a cistern at the bottom. The results obtained with it are not shown in the plates, and it is scarcely worth while to print the record of daily losses. The total loss the first month was 7,029 grams, varying from 72 to 540 grams per day. During the second month it lost from 17 to 381 grams per day, the total being 5,240 for 30 days. As the sandy soil lost so much more rapidly than the ordinary soil, it seemed desirable to have a pot similar to 13, but containing sandy soil, to see if with constant water-supply to both there would be a difference in evaporating power manifested. This comparison was begun October 16 and continued one month. During this time pot 13, containing the prepared soil, lost 4,925 grams, while pot 15, which contained soil one-half sand and the other half like 13, lost 4,367 grams. Taking the loss in pot 13 as 100, pot 15 lost 88.6.

The comparison of pots 13 and 15 not being wholly satisfactory, a second experiment was conducted with them indoors during the months of March and April, to test, under as nearly exactly the same conditions as possible, the rate of evaporation from a very sandy soil as compared with that from an ordinary one.

The pots stood side by side on a table in the northwest corner of a room which is not heated directly. The room is a large inner one, lighted from above mainly, and has only 10 feet of outside wall, and this is over 40 feet from the corner used for the experiment. Weights were made every day as a rule, and the positions of the pots reversed, although no one could have anticipated that there would be any difference due to position. The experiment continued 64 days, each pot occupying each position 32 days. During this time the pot containing ordinary soil lost 4,013 grams, while the very sandy soil lost 3,735 grams. Taking the greater loss as 100 per cent., the other lost 93 per cent. The difference is not very great but is in the same direction and to nearly the same extent as was shown by the out-of-doors test.

It was noticed, as the experiment progressed, that the pot standing nest the west wall almost always lost more than the other, no matter which one it was. The average shows that pot 13 actually exhibited a greater rate of evaporation than pot 15, and it should be expected that this would be sufficient to offset many times the greater tendency to evaporate from the west side in those cases where pot 13 occupied the less favorable north wall. So, too, when pot 13 stood nest the west wall its rate of evaporation must be more than 7 per cent. greater than the other in order to show an excess in favor of the west wall. Examining the daily losses, and introducing a correction on account of this point, we find that in 70 per cent. of the observations the greater evaporation took place from the pot standing nest the west wall. During the 32 days that pot 13 stood nest the west wall it lost 2,021 grams; during the same days pot 15 stood next the north wall, and lost only 1,794 grams, that is, about 89 per cent. as much. During the 32 days that pot 13 stood next the north wall it lost 1,992 grams, while at the same time pot 15, next the west wall, lost 1,941 grams, or about 97 per cent. as much. It will be seen that, if the precaution of reversing the positions of the pots at each weighing had not been taken, the conclusion arrived at would have been erroneous. These details have been given to emphasize the fact that exact identity of conditions in experimentation is very difficult to obtain, and that checks and balances should be planned for wherever possible.

SUMMARY.

In this bulletin the following experiments are described—all of them are to be regarded as preliminary and not carried to a conclusion:

1. A study of the difference in the condition of moisture of soils which differ only by the preparatory tillage they have received. In these trials, the undisturbed prairie sod, as compared with that which had been brought under cultivation, was much drier in all cases, except following a heavy rain. In this case, the part sampled of the sod, the upper portion, was about as wet as the plowed ground; but it rapidly dried out again. The plowed ground, not cropped nor cultivated during the season, was more uniform in its water content than the sod, and was persistently in better condition.

2. A comparison at the close of the season of the moisture content of ground that had been prepared in the spring by shallow plow-

ing, by deep plowing, and by subsoiling. The soils were sampled at different depths. No essential difference could be observed in the soils.

3. A trial to see whether soils to which salt and gypsum have been applied are more moist because of any direct or indirect effects of these chemicals. The results are negative.

4. A comparison of the loss of water from soil that was treated as follow: Cultivated, but not cropped; mulched, but not cropped; cropped, but not cultivated; untreated. The cropped soil dried out most rapidly. Next, the untreated soil. Surface cultivation to a depth of four or five inches was about as effective in conserving moisture as a good mulch.

5. Experiments with soil in galvanized-iron pots, under well-controlled conditions, showed: That a layer of finely pulverized soil three-fourths inch thick had no marked influence on the rate of evaporation; that a hay mulch two inches thick checks evaporation most effectively, but that evaporation proceeds at so rapid a rate from bare soil that a mulch, to be most useful, must be promptly applied; that the rate of evaporation from a sandy soil is less than that from one less sandy when both are kept constantly wet, but if allowed to dry, the sandy soil becomes much drier; that neither salt, gypsum, lime, nor magnesium chloride exerts any beneficial effect in checking evaporation from the soil, the evaporation being practically the same as from untreated soil.