T H E S I S

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THE EFFECT OF WEED GROWTH UPON SOIL MOISTURE:

THE WATER REQUIREMENT OF SPECIES OF LACTUCA AND KOCHIA.

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Submitted by

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for the Degree of Master of Science

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COLORADO AGRICULTURAL COLLEGE

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GRADUATE WORK

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY UVERNA A. DAMKE HUBBELL ENTITLED "THE EFFECT OF WEED GROWTH UPON SOIL MOISTURE: THE WATER REQUIREMENT OF SPECIES OF LACTUCA AND KOCHIA." BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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This is to certify that Mrs. Uverna Damke Hubbell has translated for me assigned passages of technical French bearing upon her graduate Botanical work.

Respectfully,

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THIS THESIS HAS BEEN APPROVED AND RECOMMENDED FOR

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The writer wishes to express to L. W. Durrell appreciation for finishing the plates and assistance with the manuscript and to Charles F. Rogers for cooperation with the experiment and assistance with the manuscript.

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INTRODUCTION

Farmers throughout the country must not only compete with the conditions of the soil and weather, but they must also battle continually against weeds. These are costly and injurious in many ways and the yield of most crops is inversely proportional to the growth of weeds. The fight against weeds is one of the routine operations on the farm and it represents a large proportion of the labor necessary to produce crops. No single feature of farming requires such universal and unceasing attention as do weeds. Weeds are to be regarded as plants out of place. Their physiological processes of absorption, conduction, and transpiration are the same as for crop plants. The primary reason why weeds are injurious to crop plants is that they rob the desirable plants of three essentials for growth; water, mineral nutrients, and light. If the weeds take part of the moisture from the soil the crop yield is reduced. There is a limited amount of mineral nutrients available during a season and if the weeds take these nutrients from the crop the desirable plants are stunted. If the crop plants have to compete with weeds for light necessary for the manufacture of food the development of the crop is hindered.

There are vast areas throughout the world in which water in the soil is the limiting factor in crop production. Whatever agents contribute to its conservation or the prevention of its loss increase the productive capacity of these areas of fertile soil. Water can best be conserved by what is commonly called a mulch. The object of mulching is to maintain a uniform degree of moisture and to hold water in the soil. The effectiveness of a mulch is brought about by diminishing the direct influence of the agencies of evaporation.

Because weeds use so much moisture it is advisable to ascertain how much water a plant of certain size uses and from what levels this water is obtained.

In the spring of 1926 an experiment on the relation of weed growth and mulching to soil moisture content was started on the Experimental Weed Plot by students in the Plant Physiology class. This experiment was continued throughout the summer for the information of the writer. In the summer of 1927 the writer became interested in the relation of cropping systems to weed growth and to the yield of fall wheat. Data were collected on the writer's farm on the problem for general information and not for college credit. In the spring of 1928 the problem that presented itself was the water requirement and root systems of special weeds encountered in previous work. At this time the data seemed to be of such interest and value as to warrent its organization into a thesis.

The purpose of this thesis is (1) to determine the effect of weed growth on soil moisture and cropping systems, and (2) to ascertain the water requirements and root systems under conditions for Lactuca spp. and Kochia spp.

PART I

The relation of mulching and weed growth to soil moisture and the relation of cropping systems to weed growth.

LITERATURE REVIEW

Effect of weeds on crop growth.

The control of weeds is one of the oldest and yet one of the most important problems connected with agriculture. Because we have always had weeds with us there is a tendency to accept the situation as inevitable and one of the necessary evils connected with farming. Consequently no sufficient general and concerted effort is being made to overcome the great loss which they cause. Observations have been made on the general relation of weeds to crop growth and on noxious weeds , but most of the literature on weeds has to do with their description, control, and eradication. The literature that deals with the effect of weeds on crop growth is much less extensive.

Pammel(25) discusses the excessive use of water and plant nutrients by weeds, the ways in which they compete with the growing crop, and the prevention of the proper cultivation of the soil.This is the same interpretation as that given by Moiser and Gustafson(21). Hunt(15) makes the assertion that weeds are harmful because they exhaust moisture from the soil. Corn plots on which he allowed weeds to grow contained less moisture than similar plots kept cultivated.

Experiments that demonstrate whether or not cultivation is a factor in conserving moisture or killing weeds have been carried on in many places. Gates and Cox (11) from the data of experiments in twenty-eight states have concluded that it is the weed factor that makes the cultivation of corn necessary, or that cultivation is not benefical except in so far as it removes the weeds.

Hansen (12) says that much "tillage loss is due to weeds". Cultivation costs about one-sixth of the total value of a farm crop. It is estimated that one-half of the cost of cultivation is incurred because of the presence of weeds. Cates(9) states that crop yields are reduced by weeds. It has been estimated that they reduce the yield of corn 10 per cent; tame hay 3 to 16 per cent; potatoes 6 to 10 per cent; spring grain 12 to 15 per cent; and winter grain 5 to 9 per cent. The extensive experiments of Moiser and Gustafson (21) in humid regions demonstrate that the killing of weeds is the most important factor in the growth of a crop of corn on a fertile soil with a well prepared seed bed. Corn plots with the same seed bed preparation, yielded 7.3 bushels per acre as an eight-year average when the weeds were allowed to grow and 45.9 bushels per acre when the weeds were kept down without cultivation. It is not to be assumed that weeds are water thieves only. Moiser and Gustafson (21) record that as a four-year average corn grown together with weeds, but irrigated to compensate for the moisture used by weeds, showed an increase of only 3.8 bushels per acre over unirrigated corn grown without weeds. "Weeds are much better foragers than most cultivated plants , and it is just as reasonable to expect a lamb to thrive with a bunch of hogs as to expect corn to compete with weeds."

At the Experiment Station of the University of Illinois (21) corn was kept free from weeds by scraping the surface of the soil, by shallow cultivation, and by deep cultivation. The scraping did not produce a mulch. On a seven-year average the yield from the scraped plots gave 97.6 per cent of that from ordinary shallow cultivation. Deep cultivation, four or five times during the season, yielded 96.9 per cent, and shallow cultivation, twelve or fourteen times ,103.6 per cent. Bakke and Plagge (2) found that when mustard and wheat were grown together in the greenhouse the "weeds retard the development of the crop with which they are associated by increasing the amount of water given off per unit area and also by decreasing the dry weight."

The effect and result of mulching has been much debated. Whether the cultivation conserves moisture by the formation of a mulch or by removing weeds is yet undecided. Wimer and Harland (37) state that cultivation for conservation of moisture is a secondary consideration. McCall (19) from experiments in Washington concludes that the soil mulch inhibits moisture absorption when the precipitation is not sufficient to penetrate the mulch, but that the soil mulch prevents the evaporation of the water already in the soil. The practice of mulching eliminates weed growth and in view of the fact that the water loss from the soil is greatest through the transpiration of plants, mulching conserves soil moisture. Leaves, manure, coarse hay, and grass clippings are commonly used for mulching in gardening operations. A mulch of loose organic material is more effective that one of fine earth, but it prevents the stirring of the land which promotes aeration. The most useful and practical mulch in dry farming is one of loose soil made by stirring the surface of the soil with any implement of tillage.

Jethro Tull (32) two hundred years ago discovered that thorough tillage of the soil produced crops that in some cases could not be obtained by the addition of manure and he came to the conclusion that "tillage is manure". In recent years we have learned the value of tillage for conserving enough moisture to enable plants to reach maturity. We may be tempted at times to believe that "tillage is moisture". Like Tull's statement this is a fallacy to be avoided, for tillage can never take the place of moisture.

From experiments carried on at Manhattan, Kansas with cultivated and uncultivated plots Call and Sewell (8) found that the mulched plots lost 1.05 inches of water whereas unmulched plots lost 1.91 inches. The next year four plots were included as follows: the first cultivated three inches deep, the second cultivated six inches deep, the third not cultivated and weeds allowed to grow, and the last not cultivated but weeds removed by scraping. The size of the plots was 12 by 25 feet. The soil was known as Marshall silt loam. Once each month soil samples for moisture determinations were taken to a depth of six feet. The bare-surfaced treatment sustained the least loss of soil moisture during the whole season. The six-inch mulch was superior to the three-inch mulch in checking evaporation. The moisture content of the bare-surfaced plot exceeded that of the deep-mulched plot during the season and was about equal to that of the shallow mulched plot. In considering the gain or loss of the water on each plot, however, the difference between loss on the bare-surface and deep-mulch treatment was 1.31 per cent in favor of the deep mulch. These authors decide that a cultivated soil is no more effective than a bare, uncultivated soil in preventing evaporation, and that cultivation conserves soil moisture by elimination of weeds and by preventing run off.

Young (38) carried on an experiment in Nebraska with three plots, the first mulched by hoeing two inches deep, the second was scraped to remove vegetation but care was taken not to produce a mulch, and the third was allowed to be cropped by volunteer vegetation. He concludes that a loose soil mulch is no more effective than an unmulched soil for retarding the evaporation of moisture that is " well established in the soil". Much more of the "established soil water" is lost through transpiration from the leaf surface of the plants than is lost by evaporation from the soil surface. Alway (1) also working in Nebraska found that the loss of water from the subsoil of dry lands under crop seemed to take place almost entirely through transpiration. In the abscence of plants the loss from the subsoil was small.

Snyder (26) says that the important problem of dry farming is the conservation of moisture and this can best be done br surface tillage and summer fallow. He defines summer fallow as the resting of the land throughout the summer months with clean cultivation and the maintainence of a shallow mulch. Widstoe (36) states that the only fallow which should be practiced by the dry-land farmer is clean fallow. Weeds use as much moisture as a crop of corn, wheat, or potatoes. A weedy fallow is a forerunner of a crop failure. Practical experience has demonstrated repeatedly that in cultivation the dry-land farmer has a powerful means of preventing evaporation and a greater loss of water through the transpiration of weeds.

According to Burr (7) summer-fallowed plots contained more moisture than plots planted to wheat. He found that the yield of wheat was greatly affected by summer fallow. In 1913 on land that had been summer fallowed in 1912 wheat yielded 26.8 bushels per acre and in an adjacent field where continous cropping was practiced the yield was 2.2 bushels per acre. He concluded that under normally favorable conditions growing vegetation is a greater factor than surface evaporation in removing soil moisture and that weeds are most active in using available water and in preventing the storage of water.

A. Relation of mulching and weed growth to soil moisture.

Methods.

On April 26, 1926 an experiment in Plant Physiology was started on the Experimental Weed Plot to discover the relation of mulching to the evaporation of water from the soil. Three students started the experiment and carried it on for five weeks, one student started a week later so that the results from Section 2 show one less reading than Sections 1 and 3. At the end of the five weeks the writer was so interested in the outcome that she secured consent from the Botany Department to continue the study throughout the summer months. The following methods were used:

An area twenty by sixty feet was separated into three sections, each of which was divided into four plots ten feet square and given different treatments. The plots were arranged as shown by the chart in Figure 1. Plot A was cropped and mulched, Plot B was uncropped and mulched, Plot C cropped and unmulched, and Plot D uncropped and unmulched. The individual plots were not arranged in a uniform order. The arrangement compensated to a certain degree the effects of the different treatment in adjacent plots. The experiment extended from April 26 to August 17, 1926.

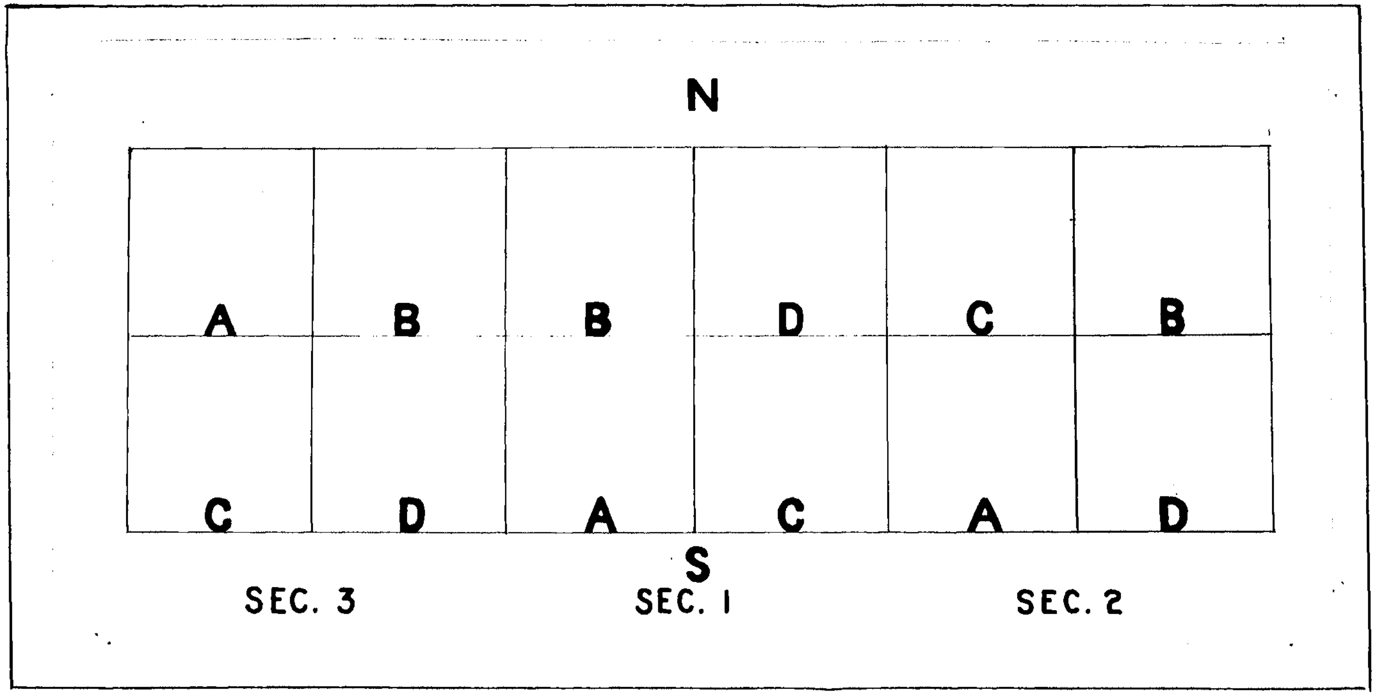


Fig. 1. Arrangement of plots for determining the relation of transpiration to the soil moisture content.

Plot A-cropped and mulched
Plot B-uncropped and mulched
Plot C-cropped and unmulched
Plot D-uncropped and unmulched

Six rows of weeds were allowed to grow across the cropped plots and in this thesis are considered as the "crop". The weeds were Chenopodium album, Convolvulus arvensis, and Kochia scoparia and other species. The Kochia spp. were most abundant. Figure 2 shows the cropped and uncropped areas. The soil on Plots A and B was mulched by hoeing to a depth of three inches each week or oftener, if a crust was formed by rain. The unmulched plots were kept free from weeds by scraping once a week with a hoe. Each week a one-hundred gram sample of soil was taken from the centarl part of each plot with a nine-inch soil cylinder. The material from the cylinder was divided into two samples and moisture percentages taken in duplicate. The percentage was calculated on the dry weight of the soil.

Fig.2. Plots A and B of Section 3, showing the appearance of the cropped mulched plot and the uncropped mulched plot.

Experimental Data.

At the end of the experiment the data were compiled into Tables I, II, and III. Each Table shows the reading of the plots in one section and the average moisture content for the period of the experiment. Table I gives the percentage of moisture in Section 1. It shows a difference of 1.28 per cent between the clean mulched and clean unmulched in favor of the mulched treatment. Table II is a record of the percentages in Section 2. The difference here is 1.24 per cent, again in favor of the mulched treatment. Table III , of Section 3 shows only 0.14 per cent in favor of the mulched treatment. The difference between the cropped mulched and unmulched is less. In Table I there is only 0.2 per cent difference in favor of the unmulched, Table II shows 0.63 per cent in favor of the mulched, and in Table III the moisture content of the cropped mulched and cropped unmulched is identical. The variation in the cropped plots can be attributed to the unevenness of the weeds upon the plots. The greater loss of moisture from the cropped plots is probably through the transpiration of the weeds. Alway (1) believed that the loss of water from dry lands was almost entirely through transpiration.

Table I

Percentage of moisture content for Section 1

Week No.	Week Ending	Plots D Clean Unmulched	B Clean Mulched	A Cropped Mulched	C Cropped Unmulched
1.	Apr. 26	23.44	23.27	23.04	22.07
2.	May 3	21.29	20.20	19.02	19.02
3.	" 10	23.71	19.99	21.02	20.22
4.	" 17	22.49	20.08	21.39	20.20
5.	" 23	18.63	19.92	17.85	19.48
6.	" 31	22.18	21.81	17.37	19.51
7.	June 7	22.57	22.36	17.75	18.22
8.	" 15	24.59	24.05	21.95	20.84
9.	" 21	22.81	14.85	19.31	18.63
10.	" 28	23.49	22.99	17.90	17.57
11.	July 6	27.50	19.47	13.35	14.82
12.	" 12	12.67	12.07	19.40	15.63
13.	" 19	17.16	15.90	13.31	15.75
14.	" 27	18.27	13.60	12.35	12.72
15.	Aug. 2	13.43	15.85	14.05	12.52
16.	" 9	10.46	12.78	11.71	13.70
17.	" 17	9.92	13.93	11.39	11.95
Average		19.68	18.41	17.59	17.79

Table II

Percentage of moisture content for Section 2

Week No.	Week Ending	Plots D Clean Unmulched	B Clean Mulched	A Cropped Mulched	C Cropped Unmulched
2.	May 3	22.65	20.47	17.06	21.26
3.	" 10	24.24	23.18	21.50	19.09
4.	" 17	21.90	22.40	20.76	24.97
5.	" 23	20.81	20.72	18.76	19.85
6.	" 31	22.83	21.85	20.87	21.39
7.	June 7	22.96	20.77	18.83	18.50
8.	" 15	25.09	22.65	28.25	18.07
9.	" 21	23.46	22.56	20.29	19.02
10.	" 28	21.02	21.66	18.64	17.00
11.	July 6	22.15	14.37	20.13	14.45
12.	" 12	17.32	17.72	15.96	16.40
13.	" 19	15.07	14.58	12.60	12.85
14.	" 27	14.70	13.71	13.03	13.49
15.	Aug. 2	14.83	13.74	6.38	10.49
16.	" 9	12.03	11.21	12.60	11.60
17.	" 17	13.23	12.88	11.93	10.21
Average		19.64	18.40	17.35	16.72

Table III

Percentage of moisture content for Section 3

Week No.	Week Ending	Plots D Clean Unmulched	B Clean Mulched	A Cropped Mulched	C Cropped Unmulched
1.	Apr.26	23.30	23.60	24.00	23.00
2.	May 3	22.40	13.30	24.50	22.10
3.	" 10	20.50	20.40	21.50	19.80
4.	" 17	22.50	25.40	20.80	22.60
5.	" 23	20.50	20.60	19.20	22.20
6.	" 31	19.74	18.33	16.75	13.79
7.	June 7	19.79	22.03	17.14	21.93
8.	" 15	23.23	22.33	16.96	16.99
9.	" 221	22.43	24.86	19.35	20.47
10.	" 28	21.59	21.54	18.33	16.79
11.	July 6	21.41	18.70	14.12	17.17
12.	" 12	22.47	20.70	16.10	16.89
13.	" 19	16.03	17.64	10.35	11.56
14.	" 27	15.74	15.00	13.16	9.46
15.	Aug. 2	13.63	16.28	13.70	13.83
16.	" 9	11.66	11.79	13.28	11.63
17.	" 17	10.79	13.74	13.71	12.78
Average		19.27	19.13	17.23	17.23

Discussion of results.

The final average computed from all the plots was compiled in Table IV. The averages of the weekly results of the three sections are also recorded in this Table. It is advisable to use the average of the readings because of the range of moisture content, as no accurate results can be drawn from single observations. Table Iv shows that the average of the clean mulched is 19.53 per cent and that of the clean unmulched is 18.64 per cent. The difference is 0.89 per cent in favor of the mulched treatment. This is 0.42 per cent less than that found by Call and Sewell (8) in a similar experiment where the mulched plot exceeded 1.31 per cent. The plots cropped to weeds and unmulched ,and that cropped to weeds and mulched show a moisture content in favor of the mulched plot, but by a much lower per cent . The average of the cropped mulched is 17.39 per cent and the cropped unmulched 17.24 per cent. The mulched exceeds the unmulched 0.15 per cent. The difference between the cropped and clean plots is much more pronounced. There is no doubt from the evidence that weeds remove moisture from the soil.

Table IV

percentage of moisture content

Averages of all Sections

Section No.	Clean Mulched	Clean Unmulched	Cropped Mulched	Cropped Unmulched
1.	19.68	18.41	17.59	17.79
2.	19.64	18.40	17.35	16.72
3.	19.27	19.13	17.23	17.23
Average	19.53	18.64	17.39	17.24

The data in Tables I, II, and III are represented graphically in Figures 3 to 8. Each unit on the abscissae represents a period of seven days, and on the ordinates each unit represents 2 per cent of the soil moisture content based on the dry weight of the soil. The histogram records the weekly precipitation and each unit represents a tenth of an inch of rainfall. The broken line in each figure shows the moisture content of the unmulched plots and the continous line that of the mulched plots.

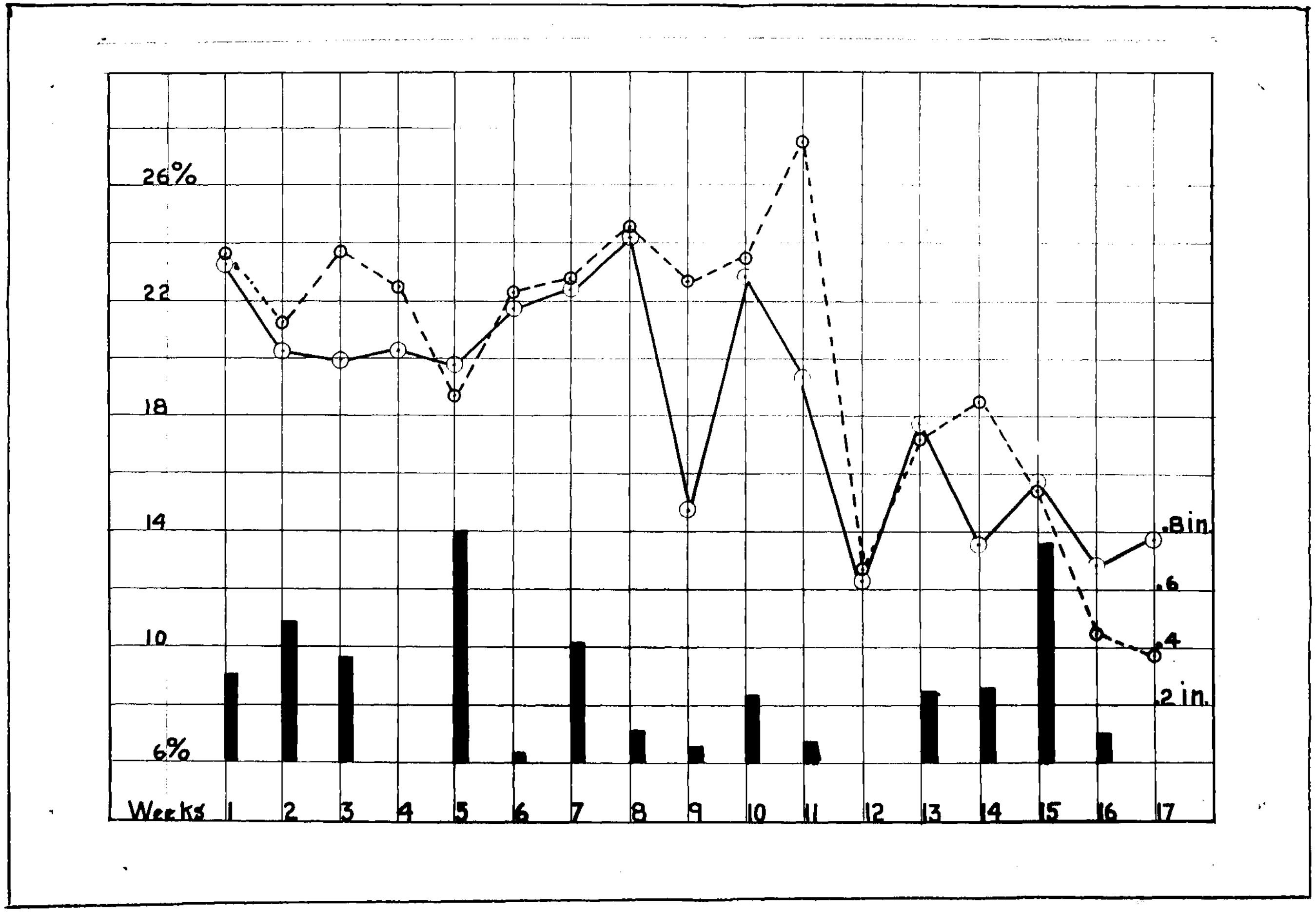


Fig. 3., Section 1, clean mulched and unmulched plots.
-------moisture content of unmulched plots.
_______moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

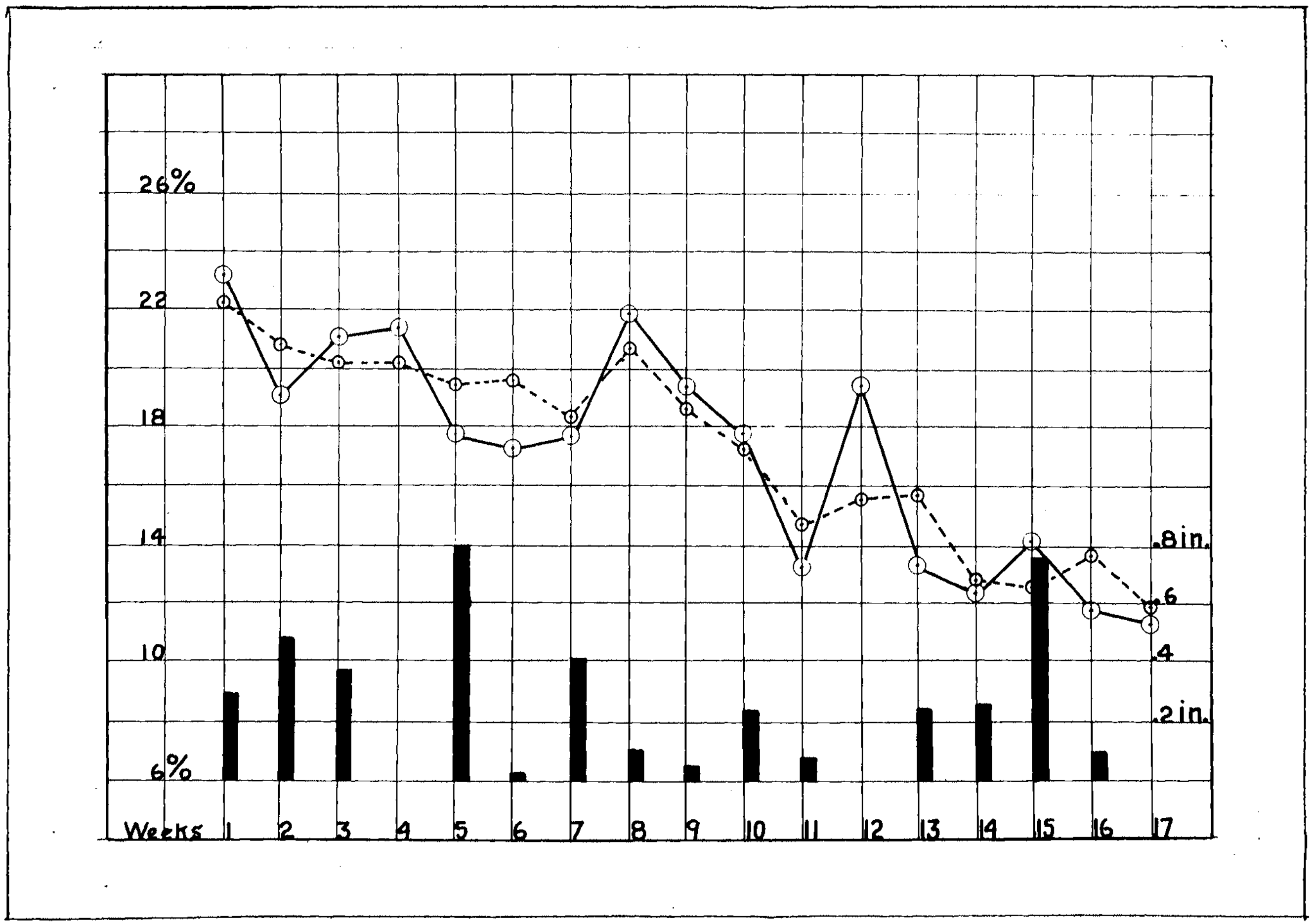


Fig. 4, Section 1, cropped mulched and unmulched plots.
--------- moisture content of unmulched plots.
——— moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

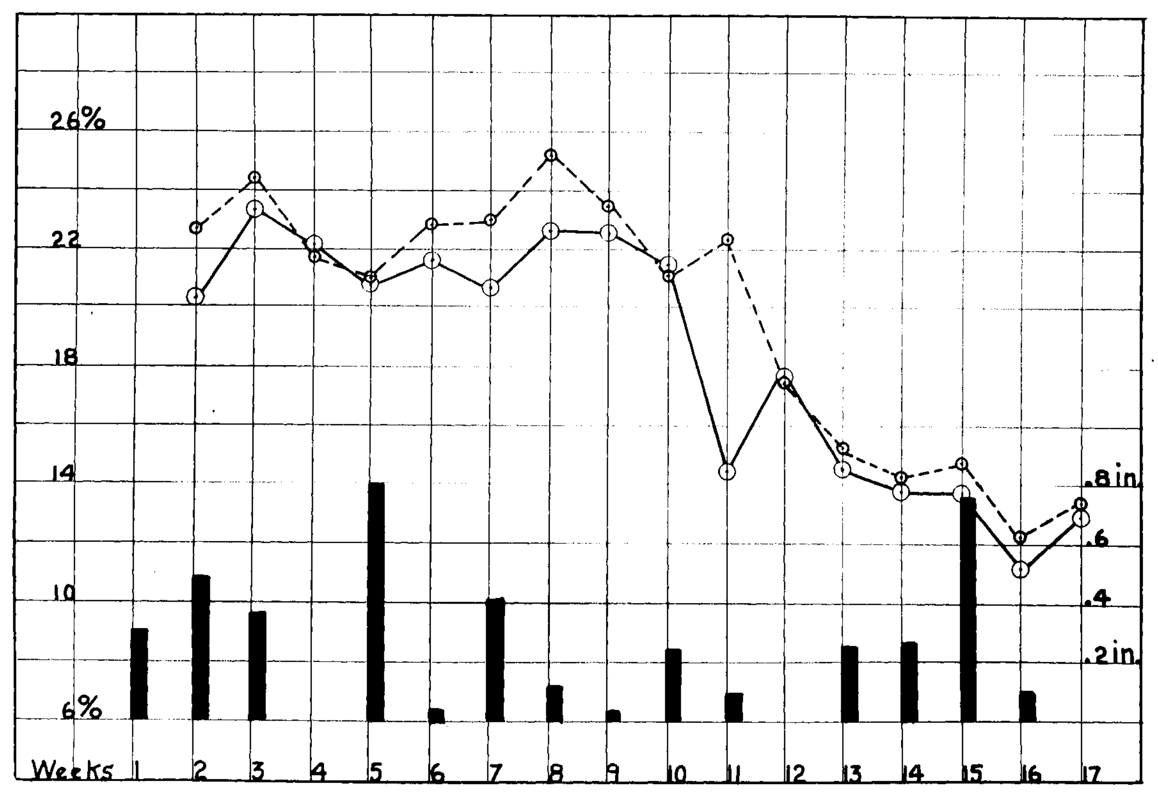


Fig. 5, Section 2, clean mulched and unmulched plots.
------- moisture content of unmulched plots.
_______ moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

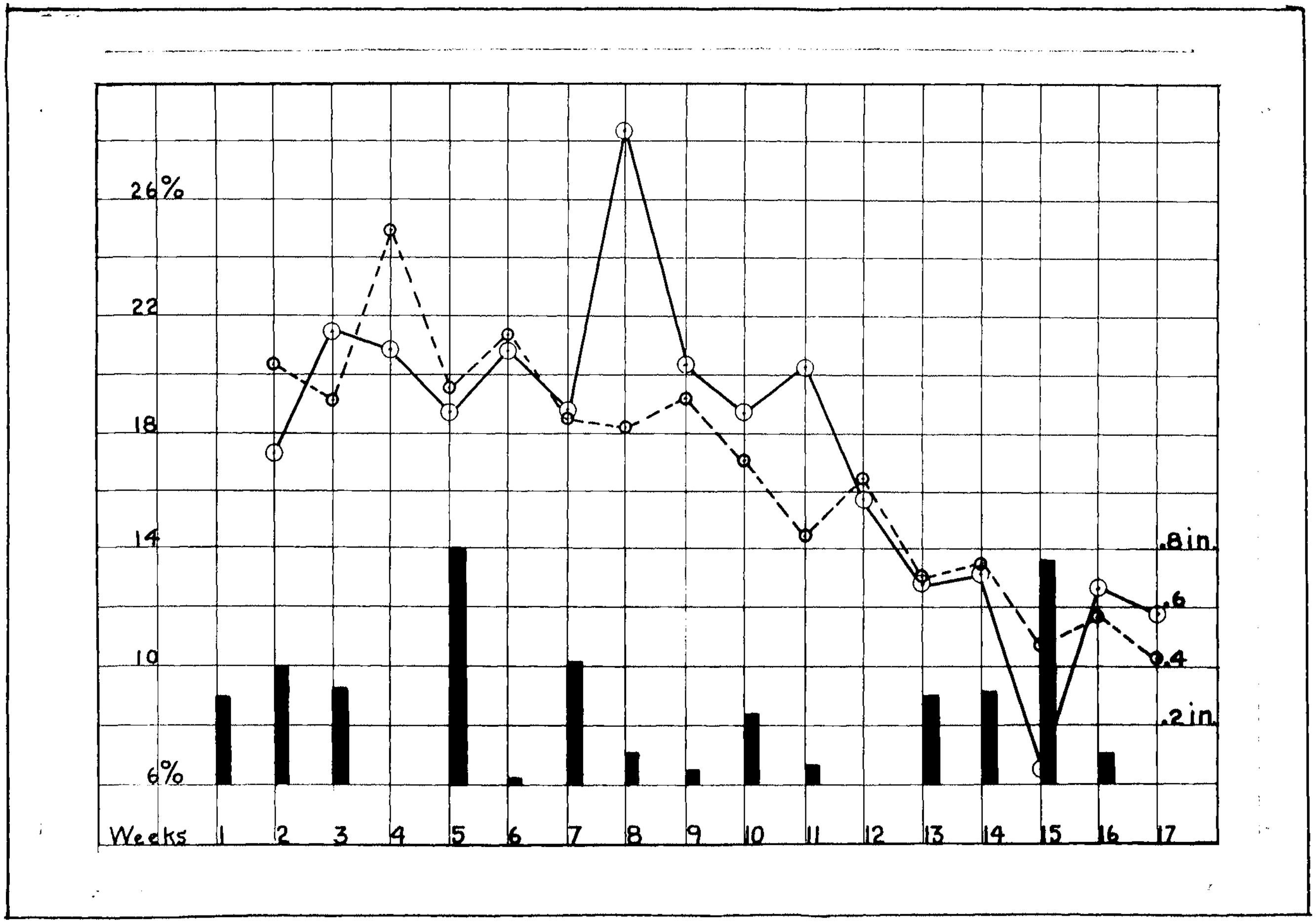


Fig. 6, Section 2, cropped mulched and unmulched plots.
-------- moisture content of unmulched plots.
________ moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

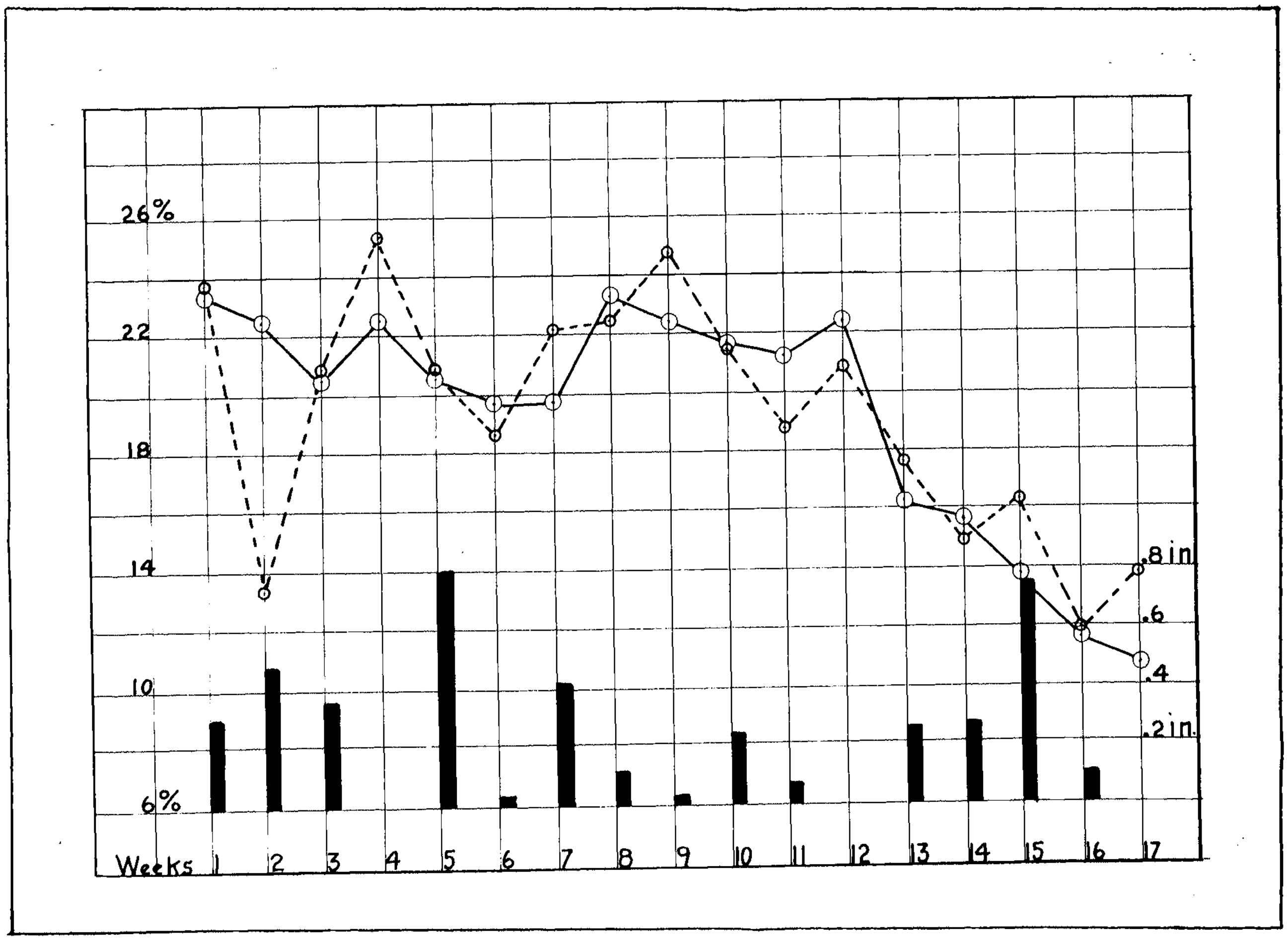


Fig. 7. Section 3, clean mulched and unmulched plots.
------- moisture content of unmulched plots.
_______ moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

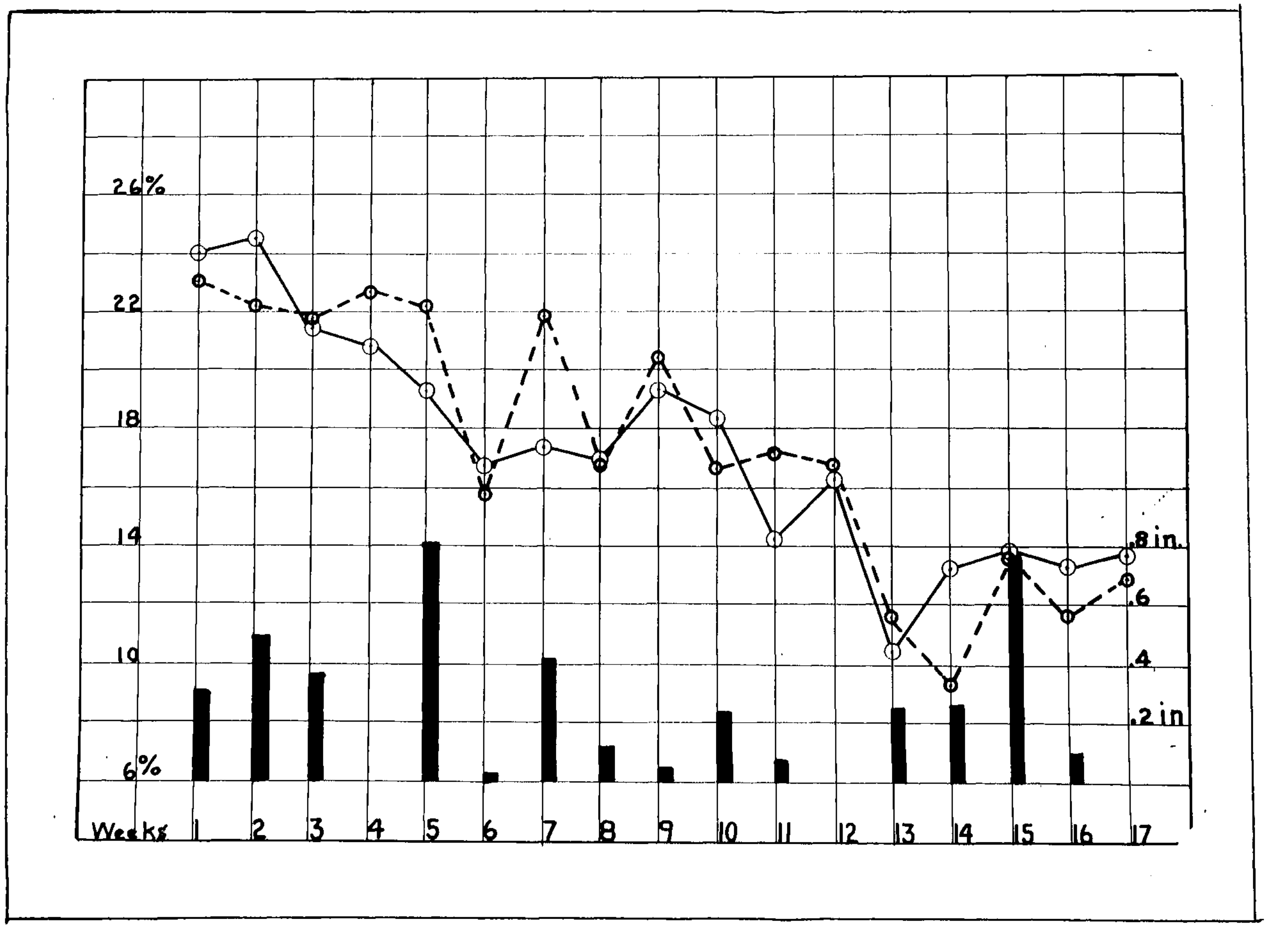


Fig. 8, Section 3, cropped mulched and unmulched plots.
-------- moisture content of unmulched plots.
________ moisture content of mulched plots.
The histogram records the weekly precipitation in inches.

The plots that were mulched, whether cropped or clean, show a higher moisture content which means a smaller loss of moisture. The curves in Figures 3, 5, and 7 of the clean mulched and unmulched plots are consistent. Figure 5 shows the least variation as shown by the smoother curve, these have an appreciably higher moisture content in the mulched plots and the results agree with those obtained by Call and Sewell (8) in Kansas and by Young (38) in Nebraska. Figures 4, 6, and 8 are of the cropped mulched and unmulched plots. They show a consistent curve, but with a lower moisture content than that of Figures 3, 5, and 7. Here again there is a slightly higher moisture content in the mulched plots.

The effect of the weather conditions on the different plots must be considered before drawing conclusions. Records of the humidity of the air, the mean temperature, the wind velocity, and the precipitation for the period of the experiment was secured from the nearest meterological station, which was one-fourth mile southeast of the plots. Table V gives the average wind velocity, temperature, and precipitation for each week. Figure 9 represents graphically the average weekly temperature for the duration of the experiment. Each unit on the abscissae represents a period of seven days, and each unit on the ordinate two degrees Fahrenheit.

Table V

Average wind velocity, temperature, and

precipitation per week for the duration of the experiment.

Week No.	Week Ending	Wind Velocity Miles per day	Temperature Degrees F.	Precipitation Inches
1.	April 26	37.2	54.3	.3
2.	May 3	38.5	53	.49
3.	" 10	37.7	50.1	.37
4.	" 17	31.2	58.7	.00
5.	" 23	35.7	60.1	.8
6.	" 31	43.1	62.8	.03
7.	June 7	25.4	65.	.41
8.	" 15	23.	61.5	.12
9.	" 21	44.	62.	.05
10.	" 28	19.6	65.7	.24
11.	July 6	25.9	65.	.07
12.	" 12	29.2	66.7	.00
13.	" 19	17.7	67.	.25
14.	" 27	22.	64.1	.26
15.	Aug. 2	25.3	63.5	.76
16.	" 9	18.7	68.	.1
17.	" 17	26.5	64.	.00

Fig. 9. Temperature curve for the duration of the experiment .

Table V shows that for the week ending May 17 there was no precipitation and the wind movement at 18 inches above the ground was 31.7 miles per day. During this week according to Tables I, II, and III in five out of six cases the moisture content was lower in the mulched than in the unmulched plots. This can readily be seen in Figures 3 to 8 for in all except Figure 4 the broken line is higher than the continous line. For the week ending July 12 with no precipitation and an average temperature of 66.7° F. and a wind movement of 29.2 miles per day the mulched had less moisture content than the unmulched in three out of six cases. (See Tables I, II, and III and Figures 3 to 8.) The mulch had not succeeded in conserving the moisture already held in the soil. From May 17 to 23 with 0.8 inch precipitation, five unmulched plots had a higher moisture content than the mulched plots. During the first week of August with 0.76 inches precipitation, three unmulched plots had a higher moisture content and in two cases the moisture content was almost identical in the mulched and unmulched plots. In only one case does the mulched plot show a higher moisture content. In two cases out of twelve a three-inch mulch increases the moisture content after a rain. (See Tables I, II, and III and Figures 3 to 8).These results agree with those obtained by McCall (19) who found that when a mulch was kept, light rains could not penetrate through and the water held in the upper layers of the mulch was lost to the air directly and completely.

Figure 9 gives the temperature curve for the duration of the experiment. As the temperature increased the percentage of moisture content decreased, although the precipitation and the wind velocity remained fairly constant from week to week. If the temperature curve is superimposed upon the curves of the soil moisture contents of the various plots, the relation between the moisture content and the temperature can easily be seen. With minor exceptions when the temperature rises the soil moisture content is lowered, and as the temperature falls the amount of water held in the soil increases. Temperature seems to effect the percentage of soil moisture more than does the amount of precipitation or the wind movement.

Mulching the clean plots does not result in a decided increase in the percentage of soil moisture and the clean scraped plots which require less labor have almost the same moisture cotent. This bears out the statement of Gates and Cox(11) that cultivation is benefical because it destroys weed growth. Hansen(12) agrees that much "tillage loss" is incurred by weeds. The scraped plots absorbed more of the rain than those that were mulched. Of the cropped plots , both the mulched and the unmulched showed small differences in moisture contents, but varied perceptibly from the clean plots. The moisture had not been lost to the air by evaporation from the surface of the soil but had been used by the weeds, which caused great transpirational loss of soil moisture.

It was planned to carry this experiment on the following year to determine the effect of the treatments on crop yield and the relation of cropping systems to weed growth, but the plots were flooded in the fall and again in the spring by waste irrigation water and the writer was forced to look for a new location for the experimental work. A field on the author's field contained the three cropping systems and it was decided that the readings from this location would be of interest and value.

B. The relation of cropping systems to weed growth.

In order to find the relationship of weed growth to three cropping systems , data were secured in 1927 on summer fallow, crop rotation, and on a repeated crop. The summer fallow had been given the treatment defined by Snyder (26) and kept free from weeds as suggested by Widstoe (36). A field of wheat on Section 32, Township 6, Range 69, Larimer County, Colorado, was an example of the three methods of cropping: wheat after summer fallow, wheat after corn, and wheat following wheat. The marked variation of the differences could be readily distinguished, before harvest, by the height of the grain; and after harvest by the density of the stubble and the prevalence of weeds.(Fig. 18, 19, and 20).

Methods.

Wheat was cut on the 18th of July by hand from plots one by 1.5 meters from three locations in each of the three cropping systems. Triplicate samples were taken. Soil samples were taken for the determination of the moisture content. The bundles were dried in the curing shed on the Agronomy Experimental Farm and threshed on August 24th by the Station's separator.

Experimental Data and Discussion.

In comparing the results of this type of work it is simpler and more accurate to use photographs. They show the relationship of the cropping systems to growth and development. Figure 10 is a photograph of the representative cutting from each method of cropping. The difference in height, abundance of straw, and yield is evident. Figure 11 shows the three cuttings from each method of cropping and the variation. No great variation occurs between cuttings from similar treatments although wheat following wheat shows the greatest irregularity. The height and size of the bundles are almost uniform when wheat follows summer fallow. There is uniformity in the size of bundles cut from the corn ground, but the grain cut from the repeated crop system varies both in the height of the straw and in the amount cut from the same areas. This suggests that the stand was patchy and that the grain was thin and uneven.

Fig. 10. Representative bundle from each method of cropping. Left to right, wheat following wheat, wheat following corn, and wheat after summer fallow.

Fig. 11. Bundles cut from each method of cropping. Left to right: wheat following wheat, wheat following corn, and wheat after summer fallow.

The amount of moisture in the soil influenced the growth of the wheat. The summer-fallowed land, after producing the best crop had an average moisture content of 7.14 per cent, whereas the crop of wheat after wheat was inferior in quality and quanity, and the soil had an average of only 5.46 per cent moisture. This leaves little doubt but that moisture can be stored in the soil by clean fallow and that when wheat is planted after wheat the weeds have not been killed by summer fallow and the moisture content is reduced. Corn ground contained 6.09 per cent or 0.63 per cent more than soil planted repeatedly to wheat. The relative variation between the moisture held in summer-fallowed land and the repeated crop systems was 0.047 for the summer fallow, and 0.100 for the repeated crop. (See Table VI). The variation of the soil moisture content between plots of similar cropping systems can be correlated with the uneven growth of the wheat within the same treatment. The weeds in the wheat after wheat was doubtless responsible for the low moisture content of the soil under that treatment.

Five average heads of wheat were selected from each method of cropping. Figures 13, 14, and 15 show their diversity of length and plumpness. The representative heads of wheat from the fallow land (Figure 13) are the most uniform of the three groups. They are well filled and on strong stems. The heads of wheat from the corn ground (Figure 14) are of fairly uniform size and development. The heads of wheat that followed wheat (Figure 15) were small and poorly filled. Some were very short with few mature grains, whereas other heads were of moderate size and well filled. None were as large as those on summer fallow and few as large as those on corn ground. This indicates that the yield was uneven. In Figure 16is shown the wheat obtained from the five heads of each group. The grains of wheat from the repeated crop method were small, shriveled, and irregular. Many grains were affected with yellow berry, a disease of malnutrition. The wheat from the corn ground had less yellow berry,(14) was more uniform in size and color, and slightly larger. That from the summer-fallowed land was a healthy color and yellow berry was practically absent. The grains were uniform, large, and plump. Figure 17 shows the sacks of grain threshed from the bundles photographed in Figure 11. The bundles from the summer-fallowed land yielded 6892 grams, over four times that of wheat after wheat, which was 1652 grams and 2.6 times that from corng ground which was 2755 grams. These results bear out the work done by Burr (7) who found the yield on summer fallow to be 26.8 bushels per acre and on c continous cropping 2.2 bushels per acre.

Fig. 13. Representative heads of wheat after summer fallow.

Fig. 14. Representative heads of wheat after corn.

Fig. 15. Representative heads of wheat after wheat.

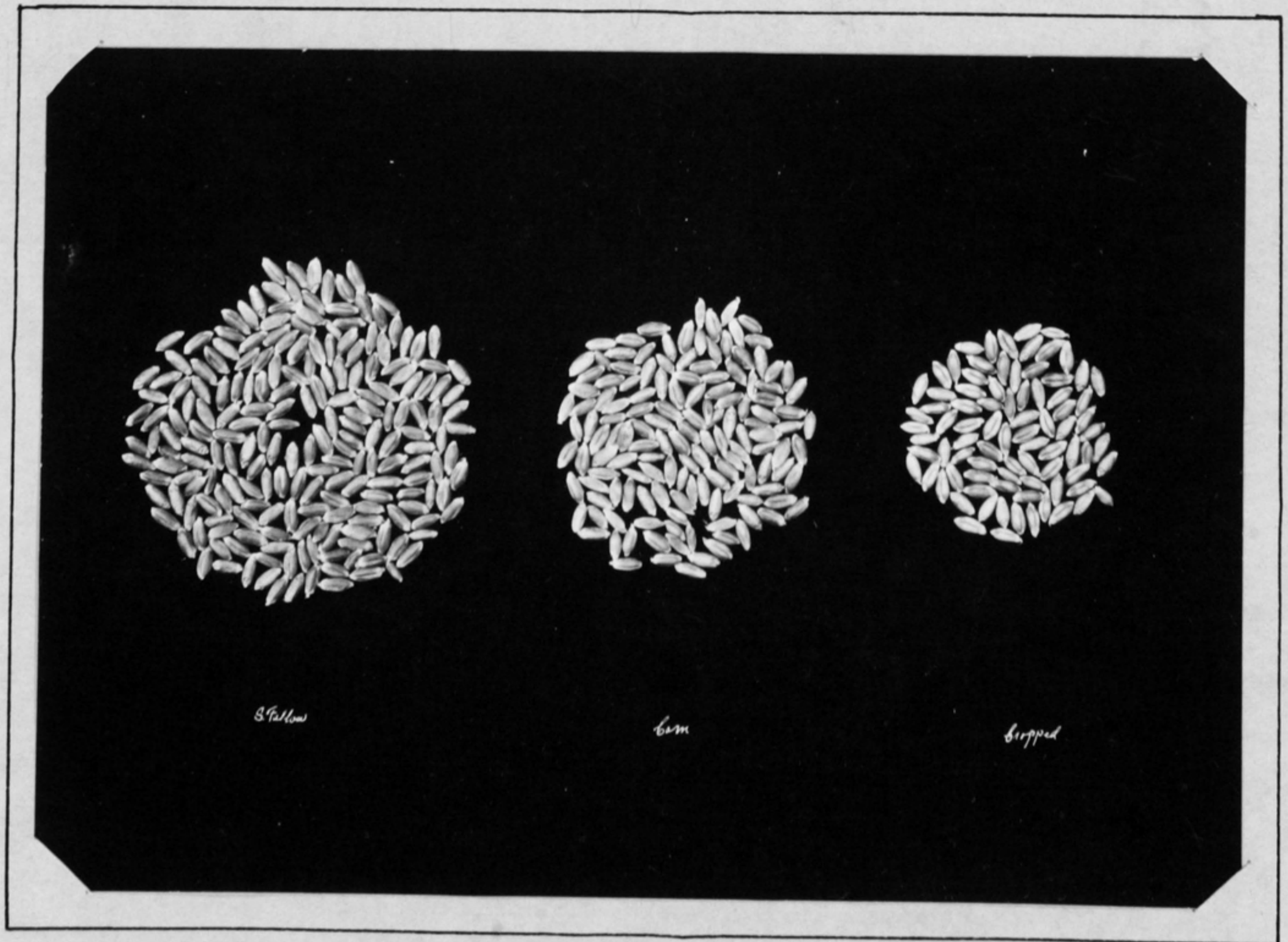


Fig. 16. The wheat from the heads shown in Fig. 13, 14, and 15. Note that the grain from wheat after whaat is not as uniform as wheat after fallow or wheat after corn.

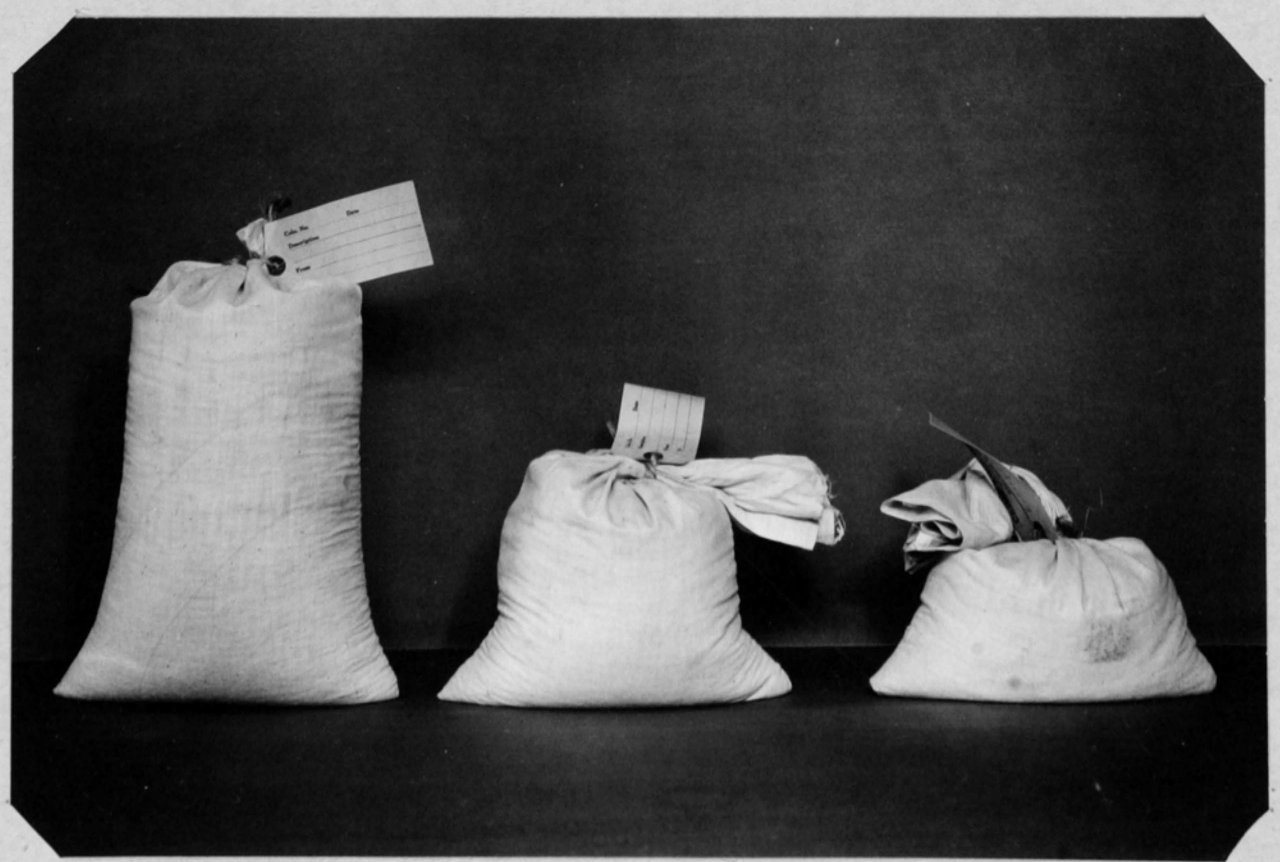


Fig. 17. The wheat threshed from the bundles photographed in Fig. 11
From left to right: summer fallow, 6892 grams; wheat after corn, 2755 grams; wheat after wheat, 1652 grams.

Each sample of grain was weighed after it had become air dried. This weight included that of the straw and the grain. After threshing the grain was cleaned and reweighed. The yield from each cutting was weighed separately and the total weight of all the samples from each method of cropping was also taken. At the time of cutting soil samples were taken for the determination of soil moisture content. These were dried in an electric oven 48 hours at 110° C. and the percentages of moisture content computed on the dry weight of the sample. All the measurements were collected in Table VI. The variation of each measurement from the average and the relative variation is given. The relative variation is the ratio of the difference of an individual variation to the average.

Table VI
The relation of cropping systems to weed growth

Method	Test	Grain and straw Weight grams	Grain and straw Variation from average	Grain Weight grams	Grain Variation from average	Moisture content Per cent	Moisture content Variation from average
Summer Fallow	A	5778.3	415.4	2381	84	7.24	.10
	B	5098.5	264.4	2210	87	6.62	.52
	C	5211.8	151.1	2301	4	7.55	.41
	Ave.	5362.9	276.9	2297	58.3	7.14	.34
Relative Variation			.0516		.025		.047
Corn Ground	A	2312	220	976	58	5.25	.84
	B	2285	93	923	5	5.98	.11
	C	1980	212	856	62	7.05	.96
	Ave.	2192	141.6	918	41.2	6.09	.63
Relative Variation			.064		.045		.103
Wheat after Wheat (weedy)	A	1573	237	649	98.5	511	.35
	B	1365	29	557	6.5	6.32	.86
	C	1070	266	446	104.5	5.02	.44
	Ave.	1336	177	550.5	67.8	5.46	.55
Relative Variation			.132		.123		.100

Table VII

Summary of Table VI giving only the average results

Treatment	Height cm.	Grain and Straw		Grain		Moisture Content	
		Weight grams	Relative Variation	Weight grams	Relative Variation	Per cent	Relative Variation
Summer Fallow	137	5362.9	.0516	2297.	.025	7.14	.047
Corn Ground	102	2192.	..064	918	.045	6.09	.103
Wheat after wheat(weedy)	91.4	1336.	.132	550.5	.133	5.46	.100

From Table VI of the recorded data the relative variation in the weight of the grain and straw is 2.6 times as great as for the wheat upon the fallowed land, although the relative variation of the wheat after corn is 1.2 times that of wheat after summer fallow. This again suggests that the condition of the field was not uniform and that the stand of grain was uneven as may be observed from Figure 11. The relative variation of the yield from the three cropping systems show a marked difference. On summer fallow it was 0.025 but on corn ground it was 0.045, and when wheat followed wheat it was 0.123, almost five times that of the fallow. This also indicates the irregularity and patchiness of the field.

Table VII summarizes Table VI giving only average results. The height of the grain upon the three cropping systems is given. The wheat upon the fallowed ground was 137 cm. tall, half again as high as the wheat following wheat which was 91 cm. in height. Wheat from the corn ground was 102 cm., approximately 11 per cent greater than that from the repeated crop system. Bakke and Plagge (2) state that weeds retard development. The variation in height is partially due to weed growth.

Figures 18 and 19 are photographs of the stubble. The stubble of the wheat after wheat (Figure 18) is thin and there are many wild lettuce plants. The stubble of the wheat on fallowed land is free from weeds.(Figure 19). There was a marked difference in the density of the stubble and the number of weeds upon the ground. The position of the various treatments in the field could be determined after harvest by the condition of the stubble and the prevalence of weeds. The line of demarcation between the stubble of the wheat upon fallow and of the wheat after wheat is evident at the left in Figure 20. The increase in the number of weeds ia apparent from Figures 19 and 19. The background in Figure 20 gives a clear idea of the location of the field in relation to the foothills.

The abundance of weeds upon the repeated crop system reduced the soil moisture content and robbed water from the growing wheat. Without the toll taken by the weeds the soil could have produced a somewhat higher yield. With weeds the moisture content was 5.46 per cent and without weeds on summer fallow it was 7.14 per cent. In previous years when the repeated crop ground had been summer fallowed it produced good crops and was free from weeds. Cates(9), Moiser and Gustafson (21), and Hunt (15) agree that crop yields are greatly reduced by weed growth. Pammel (25) states that weeds use excessive amounts of water and mineral nutrients that would otherwise be used by crop plants. The relation of cropping systems to weed growth and the difference in yield in the systems correlate with the statements of these workers.

Fig. 18. Stubble of wheat after wheat. Note the thin stand and the abundance of wild lettuce plants.

Fig. 19. The stubble of wheat after summer fallow. Note the density of stubble and freedom from weeds.

Fig. 20. The wheat field containing the three cropping systems. The line of demarcation at the left shows the junction of the stubble of the wheat that followed wheat and the stubble of the wheat after summer fallow. Note the position of the field in relation to the foothills.

In the first part of this study it was found that the greatest difference in soil moisture content of the plots was between the uncropped mulched plots and the cropped unmulched plots. This leads to the conclusion that the value of cultivation lies in the eradication of weeds which remove soil moisture by transpiration. Summer fallow,a special kind of cultivation results in the conservation of soil moisture and provides an excellent method of eliminating weeds.

The results of the two preseding experiments open up a new field in relation to weed growth: What is the amount of water actually used by weeds and what is the relation of the root systems of weeds to the amount of water used? In Part II these questions will be discussed.

PART II

Water requirement and root systems of Lactuca spp. and Kochia spp. under different envåromental conditions.

The most prevalent weed on the experimental plots of 1926 was Kochia spp.and ån the summer of 1927 on the writer's farm it was found that wild lettuce, Lactuca, was practically the only weed in wheat after wheat or corn. The work of 1926 proved that the reduction of soil moisture was due more to transpiration from the weeds that to evaporation from the surface of the soil. On a properly kept summer fallow weeds never mature and the greatest transpirational water loss is through young plants. It is necessary therefore to ascertain the amount of water that is used by young Kochia and Lactuca during the early part of their growth. This can be done through a study of the water requirement of these plants.

Transpiration is closely connected with the water requirement of plants. Montgomery (22) defines water requirement as the ratio of the weight of water absorbed by the plant during its growth to the weight og dry matter produced. The water requirement of plants differ under varying climatic conditions and these should be taken into consideration in finding the water requirement of Kochia and Lactuca.

In the study of the weeds the parts both above and under ground and their functions must be considered. The relation of roots of weeds to the roots of crop plants has not been adequately studied. The type of root system determines the level at which the plant removes moisture from the soil. The relation between the root systems of wheat and of the weeds is a factor in determining the stunting of wheat because of lack of moisture. The water and mineral nutrients which would otherwise go to a useful plant are used by weeds. A study of the root systems of <u>Kochia</u> and <u>Lactuca</u> will reveal to what extent the competition between the weeds and the wheat is for water and mineral nutrients and to what extent for sunlight. If the roots absorb water at levels different from those of the crop plants the competition is negilible, but if they both absorb water at the same level the competition underground will be as keen as that above ground for sunlight.

LITERATURE REVIEW

The literature on the water requirements of plants is varied and has no relation to the literature on root systems of plants. Because of this diversity the two subjects will be treated separately in the following review.

Water requirement of weeds

The necessity for making the greatest possible use of the limited annual precipitation in regions where dry farming is practiced and the equally important of making the most economical use of water in irrigation, demands that the factors which influence the water requirement of plants be more completely understood.

Khankhoje (16) states that it is well known that water is essential to plant growth, but the exact role of water is not yet fully understood, nor is the practice of its application yet perfected. The problem "water requirement of plants" from the scientific viewpoint has a two-fold significance, theoretical and economical. By careful observation Montgomery (22) proved that transpiration was closely connected with the water requirement of plants. Boyoucos (3) ststes that it has been found that the amount of water usually transpired by the different plants varies from about two to six acre-inches per ton of dry substance produced. According to Briggs and Shantz (5) the earliest water requirement measurements were made by Woodward in 1699. Lawes in 1850, however, was the first to extend his experiments to include the entire growing period of annual crop plants.

Each worker om water requirements of plants has his own list of factors which influence transpiration. Thom amd Holtz (30) undertook experimental research with the view of determining the relative amounts of water used by different crops and the factors influencing the plants under various climatic and soil conditions. They believe that relative water requirement depends upon two kinds of factors, namely, conditions surrounding the plant and the ability of the plant to adapt itself to its enviromment. The results of their investigations indicate "that any condition which disturbs the normal life processes, be it soil, atmospheric, or pathological, increase the water requirement to just such a degree as it depress the normal functionings of the plant."

Briggs and Shantz (5) state that the effect of soil moisture content on the water requirement of plants was first investigated by Il'enkov in 1865. Buchwheat was planted in five flower pots containing garden soil, and seven plants were grown in each pot. The pots were exposed in a window of a room which received the sun at midday. The experiment was continued for 57 days and the water requirement ratio was based on the water added to each pot instead of on the amount actually used. They cite Fittbogen in 1873, Hellriegel in 1883, Maercker in 1896, Schroeder in 1896, Von Seelhorst in 1899, Wilm in 1899, and Fortier in 1903 as workers who investigated the effect of different soil moisture contents on the water requirements of various plants.

Fortiers(10) results show that about 22 per cent irrigation water added to the soil gives the lowest water requirement for oats. Widstoe (35) grew four crops in 10 per cent, 15 per cent, and 20 per cent moisture content based on the degree of saturation, but only corn showed any preference to a high moisture content and the otherc crops fluctated from year to year. Montgomery (22) states that the more normal the conditions of water and fertility, the less the water requirement of the plant. When the water is excessive or deficient the requirement is usually greater than when the water is optimum. As a general rule the lowest water requirement is secured at about 60 per cent saturation. Morgan (24) says that the moisture content of the soil influenced the amount of dry matter produced per gram of transpiration. This is evident from the fact that in the low moisture series a fertilizer increased the production of dry matter, whereas in the medium and high moisture contents the transpiration was increased by the fertilizer. He found the water requirement of oats to be 776 in 17.6 per cent moisture, 869 in 29 per cent, and 815 in 42.3 per cent. All the moisture contentswe were calculated on the dry weight of the soil. Harris (13) grew wheat seedlings in soils of eight different moisture contents. In the 11 per cent the water requirement was 731, in the 13 per cent it was 696, and in the 37.5 per cent it was 864. Kiesselbach (17) obtained a water requirement for corn of 293 in low- moisture content, 317 in the medium and 343 in the high-moisture content soil. In Russia Tulaikov (31) found that a soil moisture content equivalent to 60 per cent of the water holding capacity of the soil was optimum in field and greenhouse conditions.

Briggs and Shantz (5) list Marie-Davy (1875), Liebscher (1895), King (1905), Von Seelhorst (1906), Widstoe (1909), and Leather (1910,1911) as workers on the influence of types of soils on the water requirements. They agree that the water requirement is affected by the type of soil. The factor influencing the water requirement seems to be mineral nutrients rather than the type of soil. The water requirement will be higher in a poor soil, whether it is sand or clay, than in a good soil. The data did not indicate that the water requirement was affected by the soil texture alone when the plant nutrients were equally available in the different soil types.

Briggs and Shantz (5) further state that the effect of temperature on the water requirement of plants does not appear ever to have been investigated under controlled conditions. The investigations which have been made on this subject have only a qualitative bearing. It is well recognized that sunlight is an important factor in increasing transpiration. It is also known that in ordinary sunlight more solar energy is received than is necessary for photosynthesis. It seems evident, therefore, that an increase in insolation would cause an increase in the rate of loss of water from the plant without changing the rate of carbon dioxide fixation. In all work done on this factor no intensity of sunlight or shade is given, so it is not possible to draw specific conclusions from the work done although all data indicate that shading produces an increase inthe water requirement. The results of the work in this thesis agrees with these findings.

Montgomery and Kiesselbach (23) grew corn in a greenhouse kept artifically humid, and compared results with corn grown in a greenhouse with the normal humidity of a greenhouse. The difference in humidity was about 20 per cent. The plants in the humid air required about half as much water for a given dry weight.

In order to determine the effect of small pots on water requirements ordinary drinking glasses were used by Khankhoje (16) as soil receptacles. Each glass contained one plant and were sealed with paraffin. They were weighed once each week and the loss taken as the amount of transpiration. The experiments continued for two and one-half months. The results obtained from the small receptacles were similar to those obtained from large pots.

The following is a list of factors influencing the water requirements of plants compiled from those given by Thom and Holtz (30), Khankhoje (16), Montgomery (22), Montgomery and Kiesselbach (23), and Boyoucos (3): soil moisture, soil fertility, soil types, the concentration and chemical nature of the soil solution, the species and variety of plant, the previous crop, the temperature of the soil and air, the humidity of the air, the light intensity, the wind velocity, the altitude and the cultivation.

Kiesselbach(17) states that cultivation is one of the most practical treatments that a farmer can give his crops for the reduction of weeds, because they require water and mineral nutrients in proportion to their number and size, and when there is a shortage of moisture the crop is certain to suffer. His experiments show that wild sunflowers consume as much moisture individually as an entire hill of three large corn plants.

Briggs and Shantz (4) state that the water requirement of small grains grown in a cool humid region is much lower than that of the same crops grown in a dry region, such as the western part of the Great Plains, where they are subjected to high winds and a greater insolation. In their work at Akron, Colorado, they used four plants that grow without cultivation. One was a native plant, Artemisia frigida, false sage brush. The other three were weed pests, Salsola pestifer, the Russian thistle; Amaranthus graecizans, a tumble weed; and Amaranthus retroflexus, the common redroot or pigweed. They found that the water requirement for Artemisia frigida was high, 65 per cent higher than Kubanka wheat and 157 per cent higher than Red Amber Sorghum. Only alfalfa and Canada field pea had a higher water requirement. For an equal production of dry matter the Russian thistle required about the same amount of water as Dwarf milo; the redroot about the same amount as the Northwestern Dent corn; and the tumble weed approximately the same quanity as the Blackhull Kafir. Probably more water is needlessly lost through the growth of these and similar weeds than from any other cause. When soil moisture is available thy make a rapid and luxuriant growth, and the water consumed by them is a complete loss, except in so far as they contribute organic matter to the soil. Sorghum, corn,or millet could take the place of these weeds with no greater consumption of soil moisture,

In 1912 Briggs and Shantz (6) included Grindelia squarrosa, the common gum weed , in their measurements at Akron, Colorado. The water requirement for this common weed was found to be 468 ± 18. In 1913 (6) these authors grew a number of weeds to determine their water requirements. Sunflowers which had a water requirement of 705 ± 8 use three times as much water as alfalfa. Table VIII gives the other weeds grown and their water requirements.

Table VIII

Water requirement of weeds grown by Briggs and Shantz. (6)

Purslane, Portulaca oleracea	292 ± 11
Pigweed, Amaranthus retroflexus	320 ± 7
Cocklebur, Xanthium commune	432 ± 13
Narrow leaved sunflower from sand hills Helianthus petiolaris	570 ± 11
Annual sunflower, Helianthus annuus	705 ± 8
Narrow leaved sunflower from near Akron Helianthus petiolaris	774 ± 20
Lamb's Quarter, Chenopodium album	801 ± 41
Fetid marigold, Boebera papposa	881 ± 26
Western ragweed, Ambrosia artemisifolia	948 ± 66

From Table VIII Purslane and Pigweed appear to be exceptionally efficient plants, their water requirement being only slightly higher than that of Krusk millet and practically the same as the sorghums. It is evident thatt common weeds differ in water requirements. A growth of weeds in a crop or on a summer fallow represents a tremendous loss of moisture. A thousand pounds of dry matter per acre of the most efficient weeds represent a loss of at least 1.5 inches of stored rainfall, or a loss of 4 to 5 inches of stored rainfall in the case of weeds having a higher water requirement. The latter represents about the maximum amount of moisture that can be stored in fallow land. It is easy therefore to understand how the whole of the stored moisture supply may be lost through the growth of a moderate crop of weeds. The varieties having a high water requirement are especially to be guarded against.

Root systems and methods of studying

If the activities of plants are to be studied the functions and morophology of all parts must be taken into consideration. The roots must receive the same attention as the growth above ground. Root systems are divided into two classes, fibrous root systems and tap root systems. The type of root system of a plant determines at what level the plant removes water and mineral nutrients from the soil. In the study of the competition of weeds with crop plants the root systems should not be neglected. Weaver (34) states that the variations in root habits under different climatic conditions are very pronounced. Root systems of plants within the same field have definite differences as the result of competition. Many roots are capable of adjusting themselves to different soil environments, others are much less susceptible to change.

Studies of root systems were made in the early part of the twentieth century, but the methods were crude and unsatisfactory. In 1916 Miller (20) isolated the root systems to be studied by digging a trench two and one-half feet wide around prisms of soil 15 to 18 inches in thickness. After the isolation of a prism of soil a wooden framework of light material was fitted snugly over it. Ordinary wire fencing with a four to six-inch rectangular mesh was placed on two sides of the prism. The plant stubs and root crowns were held in place by wiring them to narrow strips of boards which were nailed crosswise to both sides of the framework. Numerous cross wires were pushed through the soil to hold the roots in place. The soil was then washed away with a stream of water. This is almost the same method as that used in earlier years by King (18), and Ten Eyck (27), (28), and (29) in studying root systems of farm crops.

Weaver (33) says that a knowledge of root development under different natural and cultural conditions is not only of much practical value, but it also finds numerous scientific applications. In his experiments a trench was dug to the depth of about five feet and of convenient width beside the plant to be examined. This afforded an open face into which one could dig with a hand pick furnished with a cutting edge, and make an examination of the root system. Upon excavating the roots detailed notes and careful measurements were made. Drawings of the root systems were made in the field on a large drawing sheet with a pencil and later traced with India ink. They were made simultaneously with the excavation and always by exact measurements.

A. The water requirement of Lactuca and Kochia under different environmental conditions.

Methods

From the list of factors given by authors in the literature review four were chosen to be controlled and one to be modified in determining the water requirement of Lactuca and Kochia. These were type of soils, wind velocity, percentage of moisture, intervals of addition of water, and two light intensities.

Ordinary drinking glasses were selected as soil receptacles. Glass tubes 13 cm. in length were placed in each glass to provide a method of watering the plants. (Fig. 32) The glasses were weighed before filling and the weights recorded. The same amount of air dried soil was placed in each glass. On July 2nd small plants were taken from the Experimental Weed

Plot and three plants planted in each glass. The measured amount of water to make the correct percentage of moisture content was added. On July 3rd small pieces of cotton were wrapped around the base of each plant to protect it from a warm mixture of paraffin and vaseline which was poured on top of the soil to prevent evaporation from the surface. The new weight was recorded as the constant weight for the period of the experiment.

The first readings were made on July 5th. It was found that the wax had been added too hot on some of the glasses and the plants were killed. These were transplanted on the 9th of July, brown paper was wrapped around each plant to protect it from the wax. This method was more effective than the cotton and no plants were lost by the addition of wax.

Each glass had a key number typed on a label and shellaced upon it. Table IX gives the key to the factors used. Thirty-two conditions were maintained for each kind of weed and these were run in triplicate.The Experiment ran for forty days.

Table IX

Key to labels on glasses

Series-Kind of plants
- A.<u>Kochia</u>
- B.<u>Lactuca</u>

Treatment
1. Wind velocity 19 miles per day
2. Wind velocity 0 miles per day
3. Sandy loam soil
4. Clay soil
5. Shade
6. Sunlight
7. Sixty per cent moisture
8. Thirty per cent moisture
9. Water added every second day
10. Water added every fourth day

1-3-5-7-9-	equals	a	2-3-5-7-9-	equals	(a)
1-3-5-7-10	"	b	2-3-5-7-10	"	(b)
1-3-5-8-9-	"	c	2-3-5-8-9-	"	(c)
1-3-5-8-10	"	d	2-3-5-8-10	"	(d)
1-3-6-7-9-	"	e	2-3-6-7-9-	"	(e)
1-3-6-7-10	"	f	2-3-6-7-10	"	(f)
1-3-6-8-9-	"	g	2-3-6-8-9-	"	(g)
1-3-6-8-10	"	h	2-3-6-8-10	"	(h)
1-4-5-7-9-	"	i	2-4-5-7-9-	"	(i)
1-4-5-7-10	"	j	2-4-5-7-10	"	(j)
1-4-5-8-9-	"	k	2-4-5-8-9-	"	(k)
1-4-5-8-10	"	l	2-4-5-8-10	"	(l)
1-4-6-7-9-	"	m	2-4-6-7-9-	"	(m)
1-4-6-7-10	"	n	2-4-6-7-10	"	(n)
1-4-6-8-9-	"	o	2-4-6-8-9-	"	(o)
1-4-6-8-10	"	p	2-4-6-8-10	"	(p)

Test in triplicate
- I-II-III

Glass
- 1-192

Example of key
- A-a-I-1

Interpertation of key number
- A-<u>Kochia</u>
- a-moving air
  - sandy loam
  - shade
  - sixty per cent moisture
  - water added every second day
- I-first test in triplicate
- 1-number of glass

In order to determine the dry weight of the plants used, fifty plants of each species of a representative height were selected from the field. These were oven dried, weighed and the average weight for each plant computed.

A mechanical analysis of the two types of soils selected was made by the Roads Material Laboratory at the Colorado Agricultural College. The report is given in Table X. The classification according to Trilinear soil was Sandy loam and Clay.

Table X

Roads Materials Laboratory report on soil samples

	Sample No. 1	Sample No. 2
Passing No. 10 Sieve	99.9%	100.0%
" No. 20 Sieve	90.7%	97.4%
" No. 60 Sieve	62.4%	91.0%
" No. 100 Sieve	46.8%	82.4%
" No. 200 Sieve	37.9%	72.9%
Silt	18.8%	31.4%
Clay	19.1%	41.5%

Classification according to Trilinear soil Classification chart: Sample No. 1, Sandy loam; Sample No. 2, Clay. Tested by I.R.R.

A ten year average of the wind velocity 18 inches above the ground for July and August was secured from the Meterological station. This was found to be 19 miles per day. To maintain this rate of wind velocity in the greenhouse two electric fan blades were mounted on shafts and rotated continually throughout the experiment by a small electric motor. The wind velocity was tested with a Short and Mason anemometer for thirty minutes. Alleys were made of unbleached muslin to prevent the spread of the wind and to maintain the same velocity over all the plants. See Fig. 21.

The effect of shading was included as one of the environemntal factors. The two intensities were obtained by shading one series of plants with two layers of unbleached muslin, one oiled with linseed oil and one unoiled. See Fig.21.

The water holding capacity of the two types of soils was determined. The capacity of the clay soil was found to be 60 grams of water for each 100 grams of soil, and the sandy soil held 36 grams for each 100 grams of soil. The two percentages of moisture chosen for <u>Lactuca</u> were 60 per cent and 40 per cent of the water holding capacity of thesoil, and for <u>Kochia</u> 60per cent and 30 per cent. The amount added for each 100 grams of soil is given in Table XI. Sixty per cent was chosen for both plants because it was given by Tulaikov (31) as the optimum moisture content.

Table XI

Amount of water added to each type of soil to obtain the correct percentage of moisture

Type of soil	Percentage of moisture maintained	Water added to each 100 grams of soil
Clay	60%	36 grams
"	40%	24 "
"	30%	18 "
Sandy loam	60%	21.6 grams
" "	40%	14.4 "
" "	30%	10.8 "

The glasses were weighed every second day between 6 and 8 o'clock A.M. The weight lost and the amount of water added was recorded. One series of glasses were brought back to the original weight at each weighing. The other series were brought back to the original weight every fourth day. The water was added from a siphon placed above the scales. See Fig. 22.

Fig. 21. Arrangement of plants in the greenhouse

1.Plants in still air and sunlight
2.Plants in moving air and sunlight
3.Plants in moving air and shade
4.Plants in still air and shade

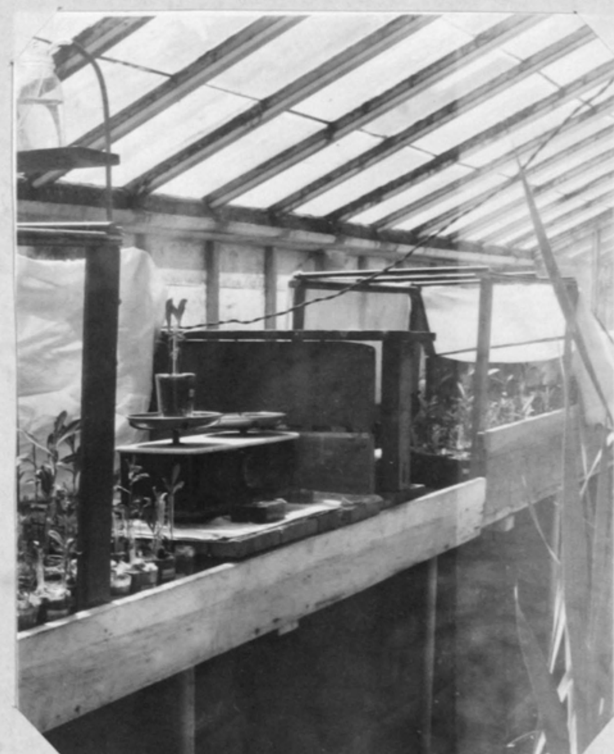


Fig. 22. Photograph of balance and siphon where plants were weighed and water added.

At the end of forty days the plants were taken from the glasses and the roots washed from the soil by an abundance of water. These were oven-dried and weighed. The increase in the weight of the plants was used as the amount of dry matter produced.

The average water requirement was calculated and the mean deviation computed. The mean deviation is the variation of the individual readings from the average.

Experimental data and discussion

The purpose of determining the water requirement of plants according to Khankhoje (16) is two-fold,for practical applications and theoretical generalizations. The term "water requirement" is used in this paper in much the same way as it is used by Montgomery (22): the ratio of the water absorbed to the amount of dry matter produced. Only the water transpired by the plants is taken into consideration. The water requirement of Lactuca and Kochia under environmental conditions maintained in the experiment are presented in Tables XII and XIII.

The group letters " a,b,c,..... " are used in the Tables to denote the conditions under which these plants were kept. (See Table XIV). Only the small letters which represent groups are given in this Table. The groups in parenthesis were in still air, those without parenthesis were in moving air. The groups from "a-h" were in sandy loam and from"i-p" in clay; groups "a-d" and "i-l" were in the shade, whereas the groups "e-h" and "m-p" were in the sun; groups "a,b,e,f,j,k,m and n" had 60 per cent moisture content and the remaining groups 30 per cent for Kochia and 40 per cent for Lactuca. Gropps "a,c,e,g,i,k,m, and o" were watered every second day and the other groups every fourth day.

It can be seen from Tables XII and XIII that the variation in the water requirements of these groups is so great that no definite correlations are possible. There is no closer correlation between the groups than between any other random arrangement. If any correlation could be made it is apparent that the mean deviation is so great that no significance could be attached to the comparison. The data are all quanitative, but some trends are evident and these will be discussed in the combinations of still aie with moving air, the types of soils, the intensity of shading, the percentage of soil moisture, and the time of watering.

The water requirement for Lactuca in Table XII for plants in still air ranged from 153 to 923 with a variation in the mean deviation of from 14 to 247. The water requirement in moving air is more consistent ranging from 365 to 715. The variation in the mean deviation, however, is greater, ranging from 58 to 426.

The water requirements for Kochia in Table XIII shows a marked difference under different conditions. There is a wide range in the mean deviation when the water requirement is low in moving air and the results are consistent, in still air there is no apparent consistency. In moving air the soil does not have the same effect on the water requirement as it has in still air, but in both cases the plants in the clay has a tendency to have a higher requirement. The water requirement tends to be higher in the shade than in the sun.

Table XII

Water requirement of <u>Lactuca</u> under environmental conditions.

Wind velocity 0			Wind velocity 19 miles per day		
Key No.	No. of trials	Water Requirement	Key No.	No. of trials	Water Requirement
a	3	466 ± 108	(a)	3	825 ± 312
b	2	571 ± 92	(b)	3	497 ± 137
c	2	419 ± 14	(c)	2	923 ± 426
d	2	538 ± 92	(d)	3	305 ± 113
e	2	454 ± 59	(e)	2	643 ± 178
f	3	365 ± 157	(f)	3	487 ± 109
g	3	440 ± 100	(g)	2	459 ± 154
h	3	451 ± 77	(h)	3	153 ± 58
i	3	483 ± 105	(i)	3	463 ± 72
j	3	572 ± 122	(j)	2	819 ± 151
k	2	614 ± 224	(k)	3	813 ± 193
l	3	563 ± 247	(l)	3	568 ± 132
m	3	636 ± 132	(m)	2	177 ± 67
n	3	715 ± 127	(n)	2	227 ± 91
o	3	415 ± 49	(o)	3	416 ± 56
p	3	409 ± 112	(p)	3	483 ± 160

Table XIII

Water requirement of Kochia under envitomental conditions.

Wind velocity 0			Wind velocity 19 miles per day		
Key No.	No. of trials	Water Requirement	Key No.	No. of trials	Water Requirement
a	Failed to establish		(a)	2	644 ± 322
b	Failed to establish		(b)	1	680
c	3	1387 ± 501	(c)	2	199 ± 36
d	2	995 ± 485	(d)	2	459 ± 3
e	3	359 ± 26	(e)	3	631 ± 289
f	1	253	(f)	2	347 ± 36
g	2	297 ± 8	(g)	1	336
h	2	333 ± 38	(h)	2	322 ± 52
i	2	1544 ± 1005	(i)	1	4720
j	1	1300	(j)	1	717
k	1	1766	(k)	Failed to establish	
l	1	695	(l)	1	1575
m	2	512 ± 58	(m)	2	702 ± 100
n	Failed to establish		(n)	3	496 ± 201
o	1	702	(o)	3	4408 ± 2061
p	1	448	(p)	2	1717 ± 407

Table XIV

Group letters which denote the conditions under which the plants were kept.

Letter	Wind	Sand	Clay	Shade	Sun	60%	30%	2nd day	4th day
a	x	x		x		x		x	
b	x	x		x		x			x
c	x	x		x			x	x	
d	x	x		x			x		x
e	x	x			x	x		x	
f	x	x			x	x			x
g	x	x			x		x	x	
h	x	x			x		x		x
i	x		x	x		x		x	
j	x		x	x		x			x
k	x		x	x			x	x	
l	x		x	x			x		x
m	x		x		x	x		x	
n	x		x		x	x			x
o	x		x		x		x	x	
p	x		x		x		x		x

Letters in parenthesis indicate the series in still air.

Air Movement

The water requirement of the plants, both Lactuca and Kochia, show similar variations in still and moving air. The plants in the still air required more water. (See Tables XII and XIII). This was probably caused by the difference in temperature for in the sunlight without wind the temperature was on the average 4°C. higher than under the same conditions in wind. The temperature of still air in shade was 2°C. higher than in moving air. Temperature probably affects the water requirement more than does the movement of the air. In all the photographs of the plants (Fig. 23 to 35) the three glasses at the left were in still air, and the three at the right were in the controlled velocity of the wind.

Types of Soils

The effects of the soils on the water requirement of Lactuca are conflicting, but the Kochia plants in the clay had a higher water requirement in practically every case. The variation of Lactuca agrees with the statement of Briggs and Shantz (5) that the available mineral nutrients have more influence on the water requirement than soil types. The clay probably had more available mineral nutrients than the sandy loam. No direct comparisons can be made from the pictures of Lactuca, but the plants in Fig. 23 and 24 were grown in sandy loam and those in Figures 25, 26, and 27 were in clay. Direct comparisons can be made from the Kochia,

Fig. 28 shows plants growing in sandy loam and Fig. 34 plants under identical conditions except that they are in clay. Similar comparisons can be made from the plants in Fig. 32 and 35. The former is in sandy loam and the latter in clay. The plants in sandy loam in both cases were almost dead when the experiment was half finished.

Shade

For both *Kochia* and *Lactuca* the plants shaded had a uniformly higher water requirement than those in the sunlight. Briggs and Shantz (5) state that all available data indicate that shading increases the water requirement of plants. Comparisons of the growth of *Lactuca* can be made from Figures 25 and 27, and for *Kochia* from Figures 28 and 30; and Figures 29 and 32. The plants in the sunlight did not mature as well as those in the shade.

Moisture content of the soil.

The data on the moisture content of the soil for the *Lactuca* indicate that the higher the percentage of moisture the higher the water requirement. This agrees with the work done by Morgan (24), Harris (13), and Kiesselbach (17) when working with oats , wheat, and corn. The same conditions with *Kochia* give such varying results that no conclusions can be drawn. Comparisons of the plants in Figures 28 and 29, Figures 30 and 32, and Figures 31 and 33 show that the plants in sixty per cent moisture grew more before they died.

Intervals of adding water.

Water was added to one series every second day and to the other series every fourth day. No conclusive results were obtained for either weed. This may be seen from the Kochia in Figures 30 and 31; and in Figures 32 and 33, also in the Tables XII and XIII when the series "a,c,e,g,i,k,m and o" are compared with "b,d,f,h,j,l,n, and p".

General conclusions

The average water requirement of Lactuca under all environmental conditions is 513, and the average for Kochia 1019. Kochia had a higher requirement than any weed given by Briggs and Shantz (6) as shown in Table VIII. The water requirement for Lactuca and Kochia was determined for young plants only during a part of their growth. This probably accounts for the great variation under different environmental conditions for the young plants were not thoroughly established and the data indicate that the more vigorous the plant the lower the water requirement. These plants were allowed to grow only forty days and the data give the water requirement for young plants, not for the entire growing period. The Tables XII and XIII show that the water requirement of Lactuca is more consistent under all conditions maintained, but Kochia shows a great variation. This suggests that *Lactuca* has a greater capacity to survive widely different environmental conditions than has *Kochia*. The writer draws the same conclusion on the effect of environmental conditions to the water requirement as Thom and Holtz (30): That any condition that disturbs the normal life processes of the plant increases the water requirement to just such a degree as it depresses the normal fuctionings of the plant.

Fig. 23. Lactuca
Sandy loam
Shade
60% moisture every fourth day
Three tests to left in still air
Three tests to right in moving air

Fig. 24. Lactuca
Sandy loam
Sunlight
30% moisture added every second day
Two tests to left in still air
Three tests to right in moving air

Fig. 25. Lactuca
Clay
Shade
60% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

Fig. 26. Lactuca
Clay
Shade
30% moisture added every fourth day
Three tests to left in still air
Three tests to right in moving air

Fig. 27. Lactuca
Clay
Sunlight
60% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

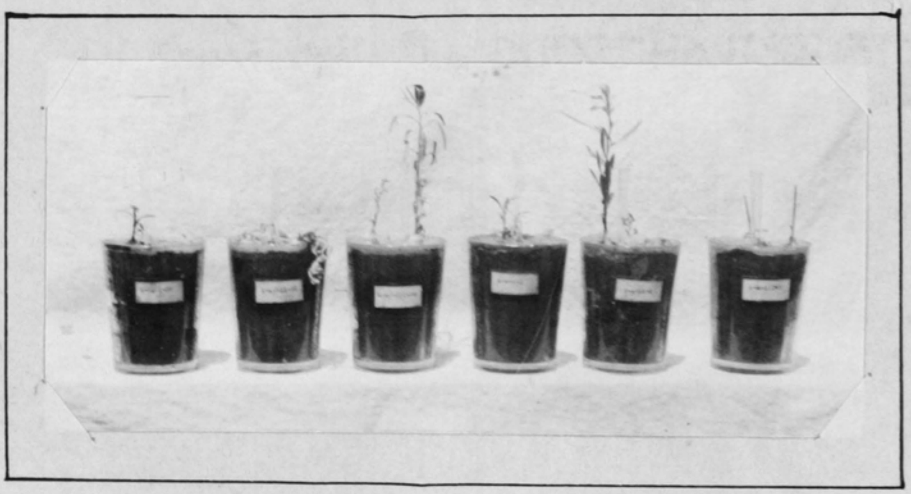


Fig. 28. Kochia
Sandy Loam
Shade
60% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

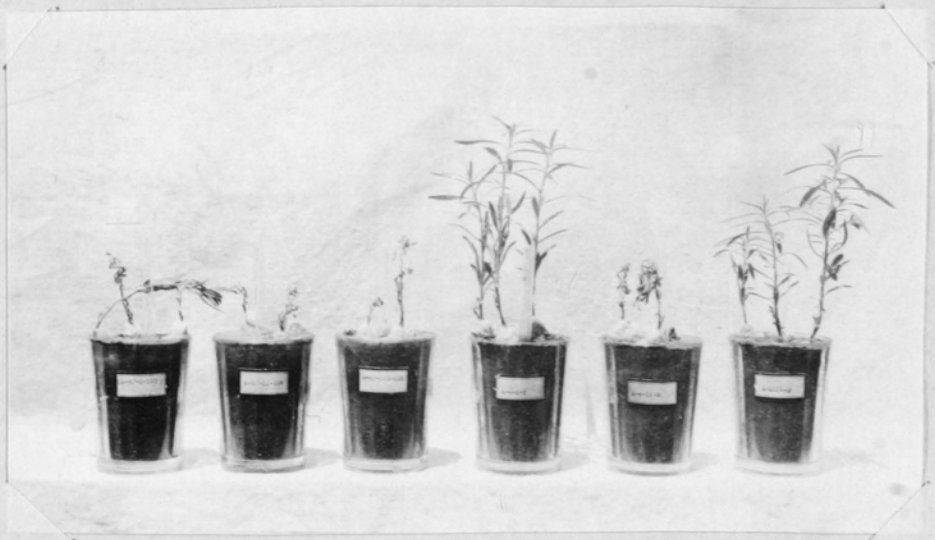


Fig. 29. Kochia
Sandy loam
Shade
30% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

Fig. 30. Kochia
Sandy loam
Sunlight
60% moisture every second day
Three tests to left in still air
Three tests to right in moving air

Fig. 31. Kochia
Sandy loam
Sunlight
60% moisture added every fourth day
Three tests to left in still air
Three tests to right in moving air

Fig. 32. <u>Kochia</u>
Sandy loam
Sunlight
30% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

Fig. 33. Kochia
Sandy loam
Sunlight
30% moisture added every
fourth day
Three tests to left in still air
Three tests to right in moving air

Fig. 34. Kochia
Clay
Shade
60% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

Fig. 35. Kochia
Clay
Sunlight
30% moisture added every second day
Three tests to left in still air
Three tests to right in moving air

B. Root Systems of *Lactuca* and *Kochia*.

Roots in semi-arid conditions are of interest to the dryland farmer because the type of root determines at what level a plant takes water from the soil. To find the relation of the weeds and crops underground the root systems must be traced.

Methods

In order to determine the best method of investigating root systems the manipulation of previous workers was considered. The method used by Weaver (33) appeared to be more satisfactory than that used by Miller (20), King (18), and Ten Eyck (28), (29), (27). Trenches were dug about five feet deep and of convenient width. A plant was selected a little distance back from the face of the trench and the roots carefully excavated with an ice pick. Water was used to wash off the dirt clinging to the roots and to soften the ground so that no small rootlets would be broken. Detailed notes, careful measurements, and drawings were made simultaneously with the excavation. Measurements of the growth of the plant above ground were made and soil samples were taken at different depths to determine the moisture content at that level.

Experimental data and discussion

Two small and one large specimen, each under different environments, were selected of each weed for the study of the root systems. One small and the large plant were in a crowed pure stand whereas the other small plant was isolated from all other plant growth. The root systems of the small plants of Lactuca and Kochia are shown in Plates I, II, IV, and V, and of the large plants in Plates III and VI. Plates I, II, IV, and V are natural size and Plates III and VI are one-fourth natural size. Both Lactuca and Kochia have tap root systems. The moisture contents of the soil at different depths are given in Table XV.

Table XV

Percentage of moisture content of the soil at different depths

Plant				
<u>Lactuca</u>	30 cm.	60 cm.	120 cm .	165 cm.
I	8.52			
II	7.17			
III	8.00	7.33	12.18	13.68

<u>Kochia</u>	30 cm.	90 cm.	150 cm.	210 cm.	255 cm.
IV	7.56				
V	7.66				
VI	4.93	7.18	9.35	10.90	13.16

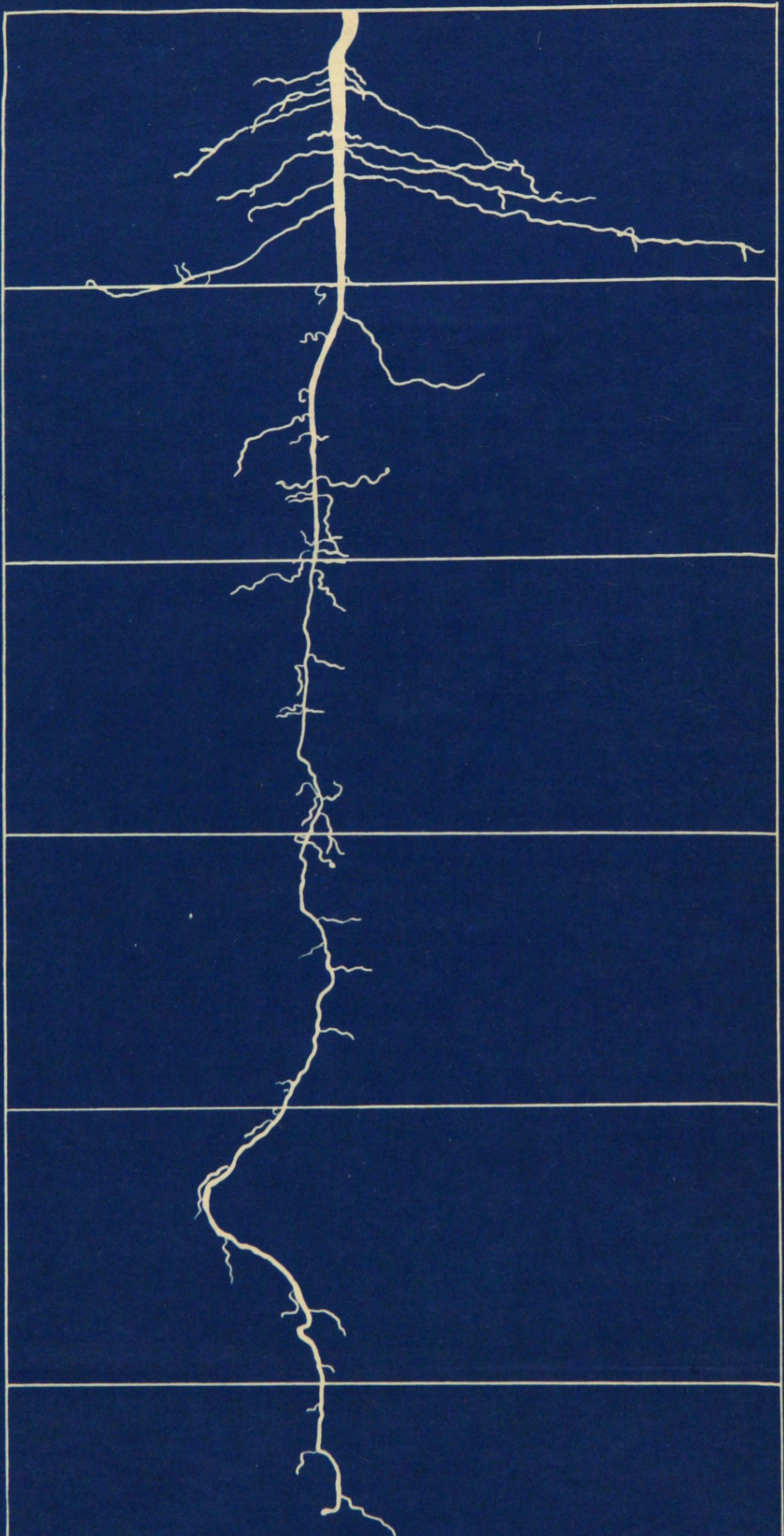
The small isolated plants had a main tap root with only a few laterals. The _Lactuca_ (Plate II) reached down 16 cm. and the plant was 14 cm. high. The laterals were practically all in the upper 5 cm. of soil. The soil moisture content at a depth of 30 cm. was 7.17 per cent. The _Kochia_ (Plate IV) was 8.5 cm. high and the root extende 17 cm. in the ground. The percentage of soil moisture was 7.56. All _Kochia_ plants have a peculiar bend in the root just below the surface of the soil.

The roots of the small plants in the dense pure stand extend deeper into the soil and have more laterals than the isolated plants. The _Lactuca_ (Plate I) was 17 cm. high and extended down 28 cm., the root ended abruptly but the root cap was intact. The decided curve about 22 cm. down was caused by a stone and the root grew around it. The moisture content of the soil at this level was 8.52 per cent. The _Kochia_ (Plate V) plant was 17.5 high and the moisture content of the soil was 7.66 per cent , almost identical with the other small _Kochia_. The greater depth and the increased number of laterals on both the _Lactuca_ and _Kochia_ indicate that competition with other plants and a lower availability of moisture leads to more rootlets to absorb water from the soil.

The large plants were chosen from dense pure stands. The hard pan extended from 30 cm. to 90 cm., the moisture content was low throughout this region and very few rootlets branched from the main roots. The large Lactuca chosen was 120 cm. high and was almost in bloom. The root (Plate III) extended 180 cm. in the ground and for a part of this distance it followed the path of an old dead root. All Lactuca plants have many laterals near the surface of the soil with only a few rootlets on the rest of the root. Soil moisture percentages were computed for the different depths as shown in Table XV. The young wheat plant has many laterals near the surface of the soil so that Lactuca and the wheat are in competition when grown together. If both plants absorb moisture from the same level, neither has a fair chance in dry-land soils of low moisture content. The large Kochia chosen was 83 cm. in height. The root system (Plate VI) extended 240 cm. into the ground. At the surface the root was 16 mm. in diameter and very irregular with many indentations. Soil samples (See Table XV) were taken to show the influence of increased moisture on root growth. Many rootlets were found at a depth of 150 cm. where the moisture content increased. The soil was sandy with numerous pebbles and this in part accounts for the irregularities in the downward growth of the root. The great depth of the Kochia root shows that the plants are able to absorb moisture from the soil at levels at which the water might be stored. The systems given in the Plates are representative of the plants studied and indicate that both Lactuca and Kochia are able to absorb moisture from great depths.

PLATE I

Root system of small Lactuca , in dry unirrigated soil and in thick pure stand. The plant was 17 cm. high. (Natural size)



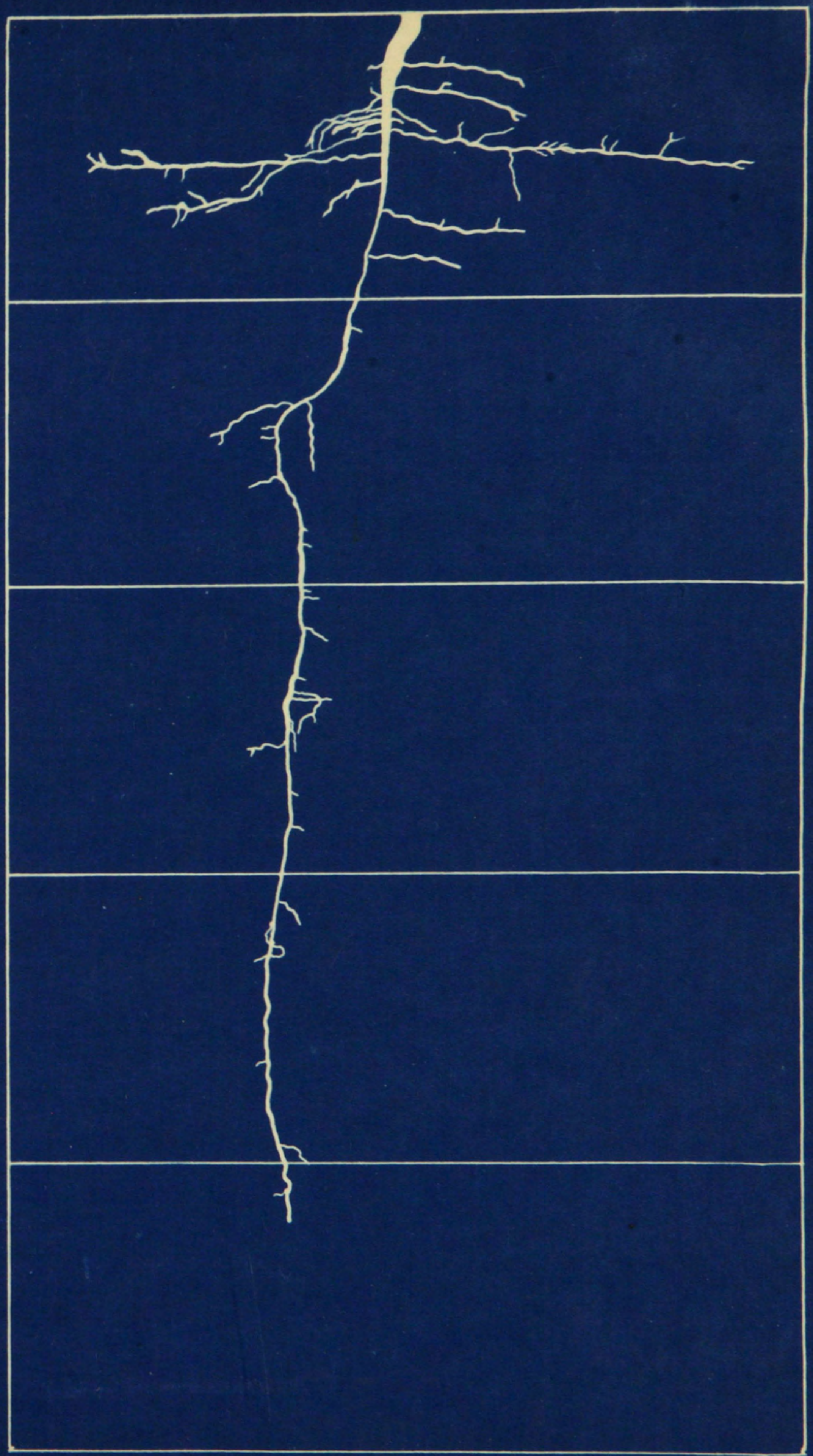


PLATE III

Root system of large *Lactuca*, in dry unirrigated soil and in thick pure stand. The plant was 120 cm. high. (.25 natural size)

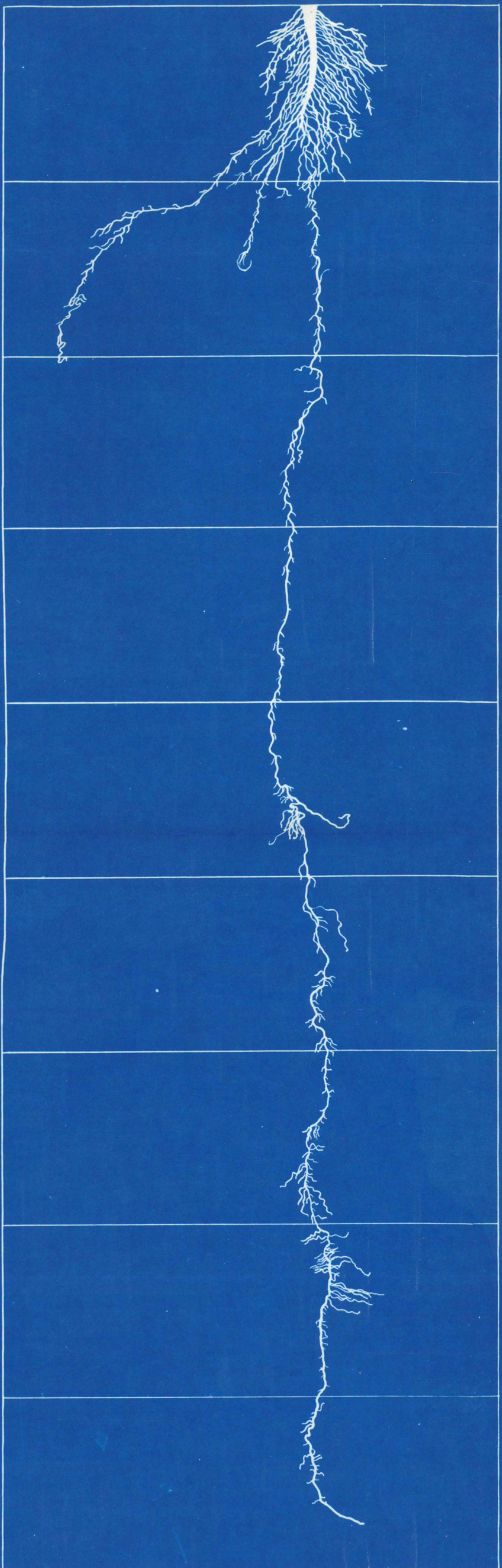
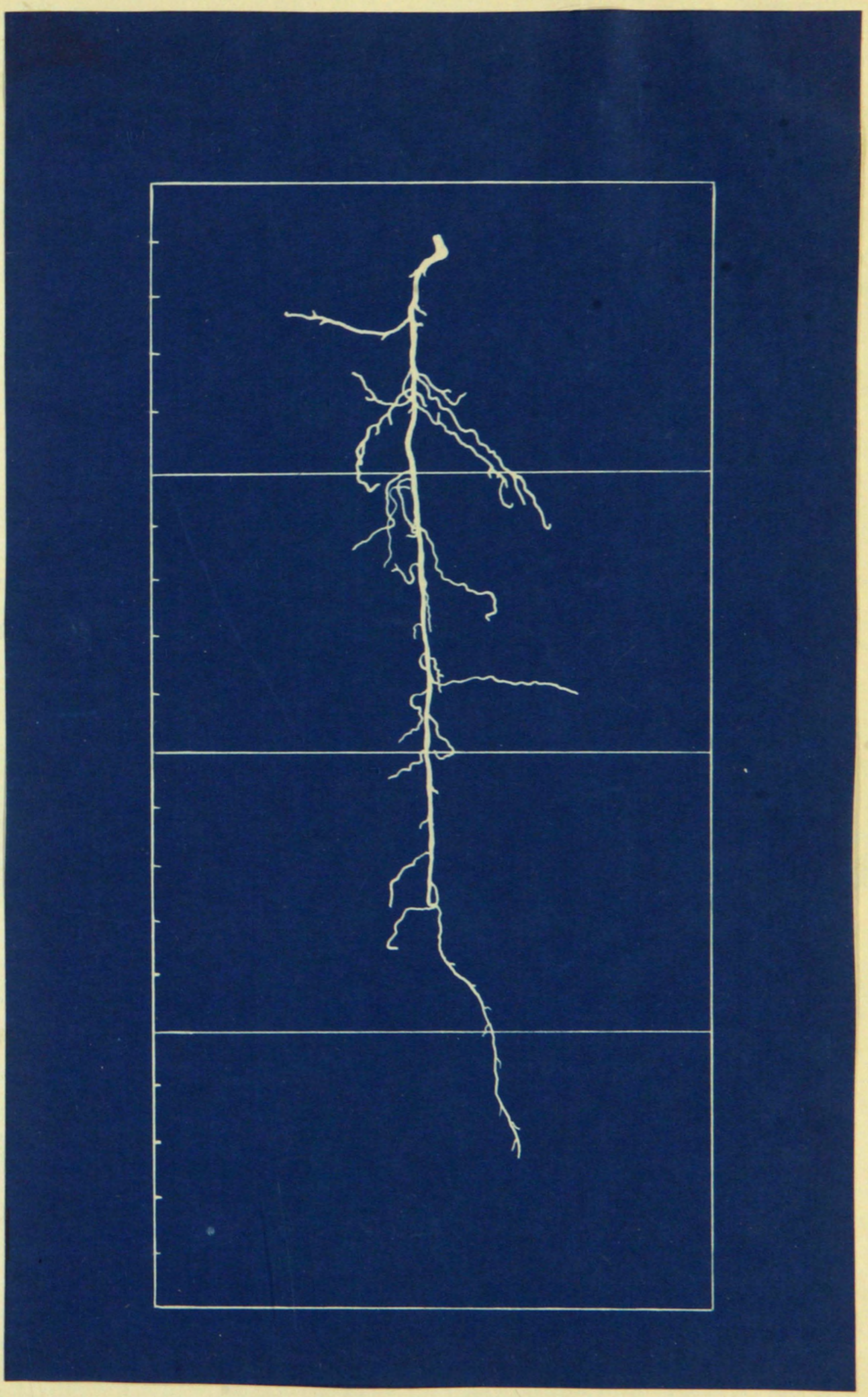
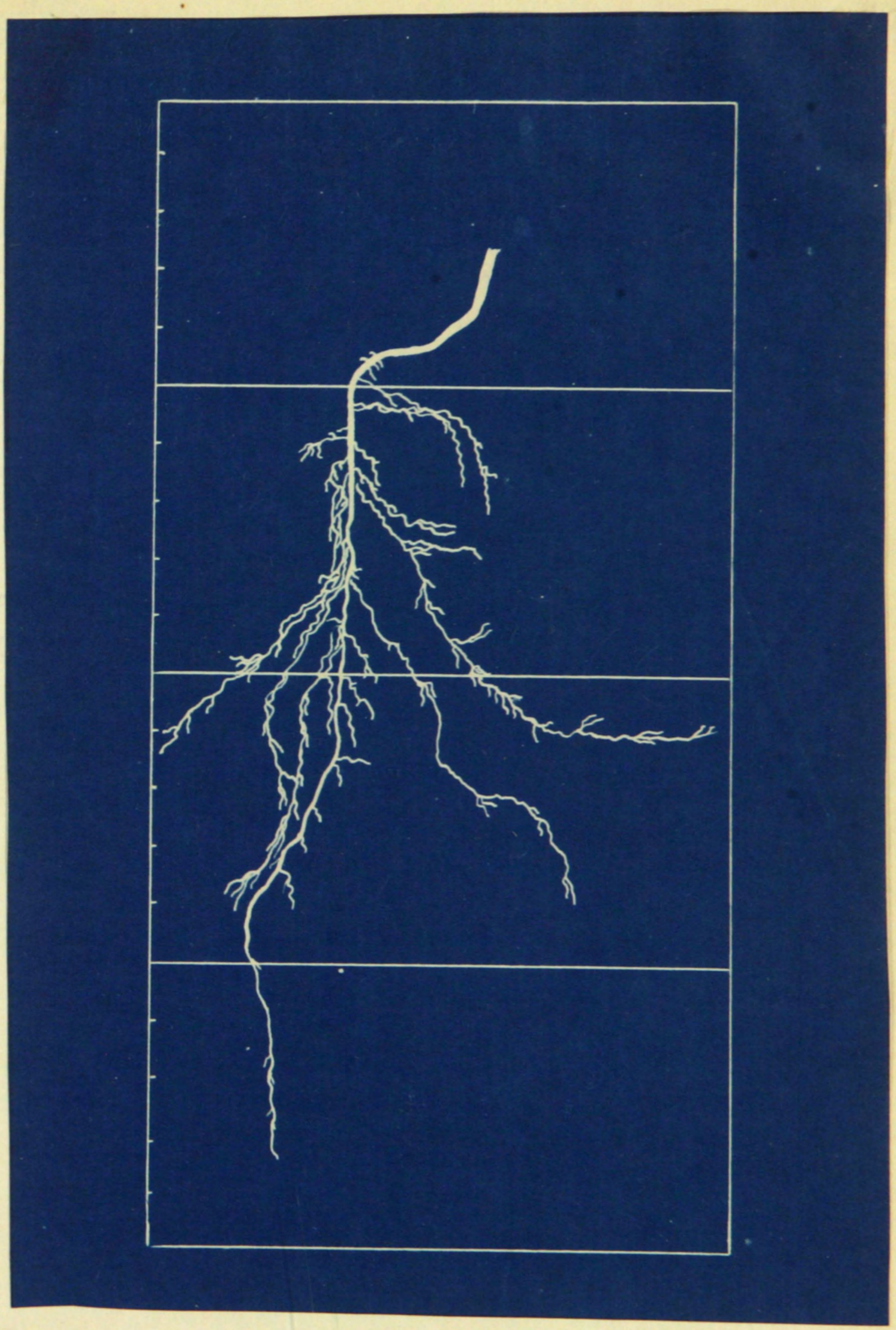
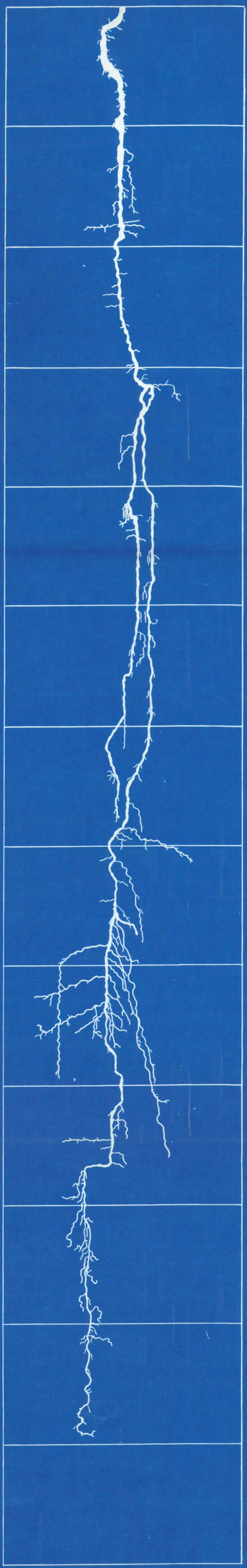


PLATE IV

Root system of small *Kochia*, in dry unirrigated soil isolated from other plant growth. The plant was 8.5 cm. high. (Natural size)







Summary and Conclusions

The purpose of this thesis has been (1) to determine the effect of weed growth on soil moisture and (2) to ascertain the water requirements and root systems of Lactuca and Kochia under different conditions.

In the spring of 1926 plots were established to determine the relation of weed growth to the loss of moisture from the soil. Four conditions were maintained: Plot A was cropped and mulched, Plot B was uncropped and mulched, Plot C cropped and unmulched, Plot D uncropped and unmulched. It was found that the loss of moisture from the soilwas greater through the transpiration of plants than through evaporation from the surface of the soil, and that the elimination of weeds is a greater factor in the conservation of soil moisture than the maintainence of a mulch.

It was planned to continue this experiment during the following year to determine the effect of the treatments on crop yield and the relation of croppind systems to weed growth, but the plots were flooded in the fall and again in the spring with waste irrigation water and the writer was forced to look for a new location for the experimental work. A field on the writers farm contained the three cropping systems and it was decided that readings from this location would be of interest and value. Weed growth was more abundant on wheat after wheat than on either wheat after summer fallow or wheat after corn. The yield and soil moisture content were higher on the summer fallow in the absence of weeds than on the wheat after wheat where the weeds were numerous.This led to the conclusion that the chief value of cultivation lay in the eradication of weeds which removed soil moisture by transpiration.

The results of the two preceding experiments opened up new fields in relation to weeds growth, the amount of water actually used by weeds and the relation of root systems of weeds to the water used.

Because the most prevalent weed on the experimental plots of 1926 was Kochia spp.and because Lactuca spp. were practically the only weed in wheat after wheat or corn rotation on the writers farm these two were chosen for the determination of water requirements under different environmental conditions. It was found that the water requirement showed a great variation but that it increased in proportion as the normal life processes of the plant were disturbed.

The root systems of these two plants were traced at the Experimental Weed Plot. It was found that competition increased the depth to which the roots went and the number of laterals upon them. Weeds in competition with wheat or other farm crops rob moisture from the growing crop and reduce the crop yield.

The results of this thesis substantiate the commonly held idea that clean cultivation improves crops by eliminating the weeds and increasing the proportion of rainfall available to crop plants by the removal of competing vegetation the root systems of which rob the crop plants of moisture and mineral nutrients.

BIBLIOGRAPHY

1. Alway, F. J.
1913. Studies on the relation of nonavailable water of the soil to hygroscopic coefficient. Nebraska Agric. Exp. Sta. Res. Bull. 3:1-122.

2. Bakke, A. L. and H. H. Plagge
1926. The extent to which weeds modify the transpiration of cereals. Iowa Agric. Exp. Sta. Res. Bull. 96: 209-239.

3. Bouyoucos, G. J.
1911. Transpiration of wheat seedlings as affected by soils, by solutions of different densities, and by various chemical compounds. Proc. Amer. Soc. Agron. 3:130-191.

4. Briggs, L. J. and H. L. Shantz
1913. The water requirement of plants. I. Investigations in the Great Plains in 1910 and 1911. U. S. D. A. Bur. of Plant Ind. Bull. 284:1-49.

5. Briggs, L. J. and H. L. Shantz
1913. The water requirement of plants. II. A review of the literature. U. S. D. A. Bur. of Plant Ind. Bull. 285:1-96.

6. Briggs, L. J. and H. L. Shantz
1914. Relative water requirements of plants. Jour. Agric. Res. 3:1-65.

7. Burr, W. W.
1914. The storage and use of soil moisture. Nebraska Agric. Exp. Sta. Res. Bull. 5: 1-88.

8. Call, L. E. and M. C. Sewell
1917. The soil mulch. Jour. Amer. Soc. Agron. 9:49-61.

9. Cates, H. R.
1917. The weed problem in American agriculture. U. S. D. A. 1917 Yearbook. pp.205-215.

10. Fortier, S.
1902. Soil moisture in relation to crop yield. Montana Agric. Exp. Sta. 9th Ann. Rpt. pp.101-107.

11. Gates, J. S. and H. R. Cox.
1912. The weed factor in the cultivation of corn. U. S. D. A. Bur. of Plant Ind. Bull. 257:7-23.

12. Hansen, A. A.
1921. The toll of weeds in Indiana. Proc. Indiana Acad. Sci. 31:105-109.

13. Harris, F. S.
1914. Effects of variation in moisture content on certain properties of a soil on the growth of wheat. New York (Cornell) Agric. Exp. Sta. Bull. 352:805-868.

14. Headden, Wm. P.
1915. Yellow berry in wheat, its cause and prevention. Colorado Agric. Exp. Sta. Bull. 205:1-38.

15. Hunt, Thomas F.
1907. The importance of nitrogen in the growth of plants. New York (Cornell) Agric. Exp. Sta. Bull. 247: 223-250.

16. Khankhoje, Pandurang
1924. Some factors which influence the water requirement of plants. Jour. Amer. Soc. Agron. 6:1-23.

17. Kiesselbach, T. A.
1916. Transpiration as a factor in crop production. Nebraska Agric. Exp. Sta. Res. Bull. 6:1-214.

18. King, F. H.
1891. Natural distribution of roots in field soils. Wisconsin Agric. Exp. Sta. 9th Ann. Rpt. pp.112-120.

19. McCall, M. A.
1924. The soil mulch in the absorption and retention of m moisture. Jour. Agric. Res. 30:819-831.

20. Miller, Edwin C.
1916. Comparative study of the root systems and leaf areas of corn and the sorghums. Jour. Agric. Res. 6:311-332.

21. Moiser, J. G. and A. F. Gustafson
1915. Soil moisture and the tillage of corn. Illinois Agric. Exp. Sta. Bull. 181:565-586.

22. Montgomery, E. G.
1911. Methods of determining the water requirements of crops. Proc. Amer. Soc. Agron. 3:261-283.

23. Montgomery, E. G. and Kiesselbach, T.A.
1912. Studies in water requirement of corn. Nebraska Agric. Exp. Sta. Bull. 128:1-15.

24. Morgan, J. O.
1911. The effect of soil moisture and temperature on the availability of plant nutrients in the soil. Proc. Amer. Soc. Agron. 3:191-249.

25. Pammel, L. H.
1923. The weed flora of Iowa. Iowa Geological Survey, Bull. 4.

26. Snyder, W. P.
1907. Crop production in Western Nebraska. Nebraska Agric. Exp. Sta. Bull. 95:1-34.

27. Ten Eyck, A. M.
1899. A study of root systems of wheat, oats, flax, corn, potatoes and sugar beets, and the soil in which they grew. North Dakota Exp. Sta. Bull. 36:333-362.

28. --------------
1900. A study of root systems of cultivated crops grown as farm crops. North Dakota Exp. Sta. Bull. 43:534-560.

29. ---------------
1904. The roots of plants. Kansas Exp. Sta. Bull. 127:199-252.

30. Thom, C.C. and H. F. Holtz.
1917. Factors influencing water requirement of plants. Washington Agric. Exp. Sta. Bull. 146:1-64.

31. Tulaikov, N. M.
1926. The utilization of water by plants under field and greenhouse conditions. Soil Sci. 21: 75-91.

32. Tull, Jethro
1829. Horse Hoeing Husbanding. Cobbett's Edition, London, William Cobbett. xxiv plus 466 pp.

33. Weaver, J. E.
1925. Investigations on the root habits of plants. Amer. Jour. Bot. 12:502-509.

34. Weaver, J. E.
Root development in grassland formations. Carnegie Inst. of Washington Publ. 292:1-172.

35. Widstoe, J. A.
1909. Irrigation investigations. Factors influencing evaporation and transpiration. Utah Agric. Exp. Sta. Bull. 105:1-64.

36

36. Widstoe, J. A.
1913. Dry Farming. New York: The MacMillan Co. xxii plus 445 p.

37. Wimer, D. C. and M. B. Harland
1925. The cultivation of corn. Illinois Agric. Exp. Sta. Bull.259:175-195.

38. Young, H. J.
1911. Soil Mulch. Nebraska Agric. Exp. Sta. 5th Ann. Rpt. p.124-128.

THE EFFECT OF WEED GROWTH UPON SOIL MOISTURE: THE WATER REQUIREMENT OF SPECIES OF LACTUCA AND KOCHIA.

BY

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Summary and Conclusions

The purpose of this thesis has been (1) to determine the effect of weed growth on soil moisture, and (2) to ascertain the water requirement and the root systems of _Lactuca_ and _Kohia_ under different conditions.

In the spring of 1926 plots were established to determine the relation of weed growth to the loss of moisture from the soil. Four conditions were maintained: Plot A was cropped and mulched, Plot B was uncropped and mulched, Plot C cropped and unmulched, and Plot D uncropped and unmulched. It was found that the loss of moisture from the soil was greater through the transpiration of plants than through the evaporation from the surface of the soil, and that the elimination of weeds is a greater factor in the conservation of soil moisture than the maintenance of a mulch.

It was planned to continue this experiment during the following year to determine the effect of the treatments on crop yield and the relation of cropping systems to weed growth, but the plots were flooded in the fall and again in the spring by waste irrigation water and the writer was forced to look for a new location for the experimental work. A field on the writers farm contained the three cropping systems and it was decided that readings from this location would be of interest and value. Weed growth was more abundant on wheat after wheat than on either wheat after summer fallow or wheat after corn. The yield and soil moisture content were higher on the summer fallow in the absence of weeds than on the wheat after wheat where the weeds were numerous. This led to the conclusion that the chief value of cultivation lay in the eradication of weeds which removed soil moisture by transpiration.

The results of the two preceding experiments opened up new fields in relation to weed growth: the amount of water used by weeds and the relations of root systems of weeds to the water used.

Because the most prevalent weed on the experimental plots of 1926 were Kochia spp. and because Lactuca spp. were practically the only weed in wheat after wheat or corn rotation on the writers farm these two were chosen for the determinationso of water requirements under different environmental conditions. It was found that the water requirement showed a great variation but that it increased in proportion as the normal life processes were disturbed.

The root systems of these two plants were traced at the Experimental Weed Plot. It was found that competition increased the depth to which the roots went and the number of laterals upon them. Plates I- VI give the details of the roots. Weeds in competition with wheat or other farm crops rob moisture from the growing crops and reduce the crop yield.

The results of this thesis substantiate the commonly held idea that clean cultivation improves crops by eliminating the weeds and increasing the proportion of rainfall available to crop plants by removal of competing vegetation the root systems of which rob the crop plants of moisture and mineral nutrients.