THE CONSUMPTIVE USE OF MOISTURE BY GRAIN SORGHUM AND THE SUITABILITY OF AN ALLUVIAL SOIL FOR FIELD EXPERIMENTS

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INTRODUCTION

In irrigation farming, it is necessary to know the amount of water a particular crop needs to produce the highest and most economical yields. It is also important to know the rate at which the crop uses water at various stages of growth so it can be irrigated before drought has caused any appreciable decrease in yields. In some crops, wilting for only one day will cause definite reduction in yield. In planning an irrigation system, it is necessary to know the amount of water that may be stored in the soil for plant use, the time of peak use and the amount of water used during this period.

Consumptive use studies of water for various crops have been carried out for several years in other parts of the United States, but little work of this type has been done in Oklahoma or under the climatic conditions found here. There is an increased demand for consumptive use data in Oklahoma as more and more land is developed for irrigation. One of the objectives of this experiment was to determine the consumptive use of water of grain sorghum in Central Oklahoma.

Before initiating fertility experiments, it is necessary to have some idea of the homogenity of the experimental site. If the plots within a site are not alike before treatments are initiated, it is impossible to measure the comparative effects of treatments made on different plots. A five year grain sorghum fertility experiment was contemplated for the site on which this experiment was conducted.

The second objective of this experiment was to determine whether or not the site was sufficiently uniform in productivity to be used for a fertility experiment.

REVIEW OF LITERATURE

Definition of Terms:

Some of the terms to be used in this paper are defined by Young (26)* as follows:

Irrigation requirement: The quantity of water, exclusive of precipitation, that is required for crop production. It includes surface evaporation and other economically unavoidable wastes. It is usually expressed in depth for any given time (volume per unit area for a given time).

Water requirement: The quantity of water, regardless of its source, required by a crop in a given period of time, for its normal growth under field conditions. It includes surface evaporation and other economically unavoidable wastes. It is usually expressed as depth (volume per unit area for a given time).

Consumptive use (evapo-transpiration): The total water used from all sources. It includes rainfall during the growing season, the irrigation water applied during the growing season, and the difference between the moisture in the soil at the beginning and at the end of the growing season. The consumptive use may be expressed in acre-inches per acre or depth in inches, or acre-feet per acre or depth in feet.

Transpiration: The quantity of water absorbed by the crop that

*Figures in parentheses refer to Literature Cited.

is transpired and used directly in the building of plant tissue in a specified time. It is expressed as acre-feet or acre-inches per acre or as depth in feet or inches.

Field capacity: The moisture percentage, on a dry weight basis, of a soil after drainage has taken place following an application of water. This moisture percentage is reached approximately two days after irrigation.

Permanent wilting point: The moisture content of the soil at which the plants wilt and do not recover unless water is added. It is expressed as percentage of moisture on the oven-dry weight of the soil.

Available moisture: The quantity of water in the soil that is available for plant use, as limited by the field capacity and the permanent wilting percentage. It is expressed as depth of water in inches per foot depth of soil.

Moisture percentage: The percentage of moisture in the soil based on the weight of the oven-dry material.

Apparent specific gravity (volume weight): The ratio of the weight of a unit volume of oven-dry soil of undisturbed structure to that of an equal volume of water, under standard conditions.

Soil moisture: The water in unsaturated soil. It is expressed as a percentage on a dry weight basis or in inches per foot depth of soil.

Methods of Determining Consumptive Use:

There are several methods of determining consumptive use of water. Some are more accurate than others but are impractical on large areas. Some of the various methods used by engineers to determine consumptive use of agricultural crops are described by Blaney (2) as follows:

I. Soil moisture studies on plots:

This method is usually employed to determine the consumptive use of irrigation. The depth of ground water is such that it will not influence the soil moisture fluctuations within the root zone. (Soil samples are taken by means of a standard soil tube before and after each irrigation, with some samples taken between irrigations. The samples are in 6 inch sections in the major root zone and thereafter in 1 foot sections.) Usually, a great number of samples are taken.

Standard laboratory practices are used in determining the moisture content of the soil samples. The samples are weighed and dried in an electric oven at 110° C. and the dry weight determined. The water content of a sample is expressed as a percentage of the oven-dry weight of the soil. From the moisture percentage thus obtained the quantity of water in acre-inches per acre (inches) removed by evaporation and transpiration from each foot of soil is computed by using the formula $D = PVd/100$.

P = The moisture by weight.

V = The apparent specific gravity (volume weight).

d = The depth of soil in inches.

D = The equivalent depth of water in inches lost by the soil (acre inches per acre).

II. Tanks and lysimeter experiments:

The practicability of determining consumptive use by means of tanks or lysimeters is dependent on the accuracy of reproduction of natural conditions. In most consumptive use studies, tanks 2 to 3 feet in diameter and 6 feet deep are used. It has been found that all tank vegetation must be protected from the elements by surrounding growth of the same species. Soil tanks equipped with suitable supply tanks have been used successfully in evapo-transpiration measurements from water tables at various depths.

III. In flow-outflow measurements:

This method is used on large areas such as valleys. It includes the measurements of the amount of water flowing in, precipitation, and change in ground water storage.

Valley consumptive use is equal to the amount of water that flows into the valley during a 12 month period (I) plus the yearly precipitation on the valley floor, (R), plus the water in ground storage at the beginning of the year, (Gs) minus the amount of water in ground storage at the end of the year, (Ge) minus the yearly outflow (O). All amounts are measured in acre-feet. This can be expressed in the following equation $U = (I + R) + (Gs - Ge) - O$. The difference between the storage of capillary water at the beginning and end of the year is considered negligible. It is also assumed that stream measurements are made on bed-rock controls and there is little or no subsurface flow.

IV. Integration method:

This method determines consumptive use by the summation of the products of consumptive use for each crop, times its area, plus the consumptive use of natural vegetation times its area plus water surface evaporation, times surface area, plus evaporation from bare land times its area.

Before using this method it is necessary to know unit evapo-transpiration of water, and the areas of various classes of agricultural crops, natural vegetation, bare land, and water surfaces.

V. The Hedke heat consumptive use method:

This method is the application of a linear relation between the consumptive use of water and the heat available for production of crops each month, and for the season.

VI. Blaney and Criddle empirical formula (3):

Blaney and Criddle devised an empirical formula by correlating climatological data and irrigation data. By using climatological data and experimental results from various locations, they derived this consumptive use formula that appears to be reasonably accurate. With this formula, consumptive use can be determined without running expensive water requirement studies. The formula is U = KF.

U = Consumptive use of crops in inches for any period.

F = Sum of the monthly consumptive-use factors of the period.

f = t times p/100 = monthly consumptive use factor.

t = The monthly temperature.

p = the monthly percent of daytime hours of the year.

K = An empirical consumptive-use coefficient determined by the formula K = U/F.

u = Monthly consumptive-use in inches = kf.

Factors Affecting Consumptive Use:

Climate undoubtedly has the greatest influence on the amount of water used by growing crops in an area.

Wind movement (3):

Evaporation of water from land and plant surfaces takes place much more rapidly when the air is moving across a surface than under calm air conditions. Hot dry winds and other unusual wind conditions during the growing period will affect the amount of water consumptively used. Russell (21) found that with a 14.7 mph wind the evaporation was as high as .568 inches per day.

Growing season (3):

It is frequently considered to be the period between killing frosts, but for many annual crops it is shorter than the frost free period. For most perennial crops, growth starts as soon as the maximum temperature stays well above the freezing point for an extended period of days, and continues throughout the growing season in spite of later freezes. The hardier crops survive temperature fluctuations during the spring and fall when the temperature drops one or two degrees below 32^{o} F., and continues to grow unharmed during the few hours of subfreezing temperature.

Precipitation (3):

The amount of precipitation may have a pronounced effect on the amount of water consumptively used during any summer. Under certain conditions, precipitation may be a series of frequent, light showers during the hot summer. Such showers may add little or nothing to the soil moisture for use by the plants through transpiration. The precipitation may be largely lost by evaporation directly from the surface of the plant foliage and the land surface. Some of the precipitation from heavy storms may be lost by surface runoff. Other storms may be of such intensity and amount that a large percentage of the precipitation will enter the soil and become available for plant transpiration. Such a condition may materially reduce the amount of irrigation water needed and the consumptive use.

Temperature (3):

The rate of consumptive use of water by crops in any particular locality is probably affected more by temperature than any other factor. Abnormally low temperatures may retard plant growth and unusuually high temperatures may produce dormancy. Consumptive use may vary widely even in years of equal accumulated temperature because of deviations from the normal seasonal distributions since transpiration is influenced not only by temperature but also the area of leaf surface and the physiological needs of the plant both of which are related to the stage of maturity. During hot weather, especially when hot winds are blowing over the fields, transpiration may take place more rapidly than moisture can be absorbed by plant roots.

Harris and Hawkins (12) found that the highest consumptive use by cotton was in July and August. Whitt (24) reported, from experiments in Missouri, that the maximum use by corn was in July, (.37 inches per day, for a 12 day period) and for cotton, the last 15 days in August (.29 inches per day).

Latitude (3):

Although latitude may hardly be called a climatic factor, it does have considerable influence on the rate of consumptive use of various plants. Because of the earth's movement and axial inclination, the hours of daylight during the summer are much greater in northern latitudes than at the equator. This will allow plant transpiration to continue for a longer period each day and to produce an effect similar to that of lengthening the growing season.

Soils:

There are several factors in soils that will affect the use of water by plants. The most important one is permeability. Drainage depends directly on soil permeability. Permeability is influenced by many factors, among which are organic matter, structure, and texture.

Texture:

Texture has a dominant effect on the moisture holding capacity, wilting point, and available moisture. Crops commonly require more water when grown on light sandy soils than when grown on heavy soil, because more water percolates through sandy soil.

Shockley (23) gives some information on available moisture from different textured soils.

Texture	Available moisture in inches range	average
Fine (40% clay +) (clay, silty clay, sandy clay)	1.6-2.5	2.3
Moderately fine (27 to 40% clay)	1.6-2.5	2.2
Medium (40% or more silt)	1.6-2.5	2.3
Medium (0% to 39% silt)	1.5-2.4	1.9
Moderately coarse (more than 70% sand)	1.0-1.5	1.2
Coarse (less than 95% sand)	.8-1.0	.9

This indicates that the finer textured soils will generally have a greater amount of available moisture for crop use, although some crops are able to extract moisture from the soil under greater pressure than other crops. Bloodgood and Curry (4) quote some figures by Hilgard, who found, in soil ranging from sand to clay, that clover wilted when the sand still retained 9.53% water and the clay 13.52% water. Corn grown on the same soil wilted when the moisture had decreased to 14.17% water in sand and 11.79% water in the clay. In irrigation, however, greater importance is put on infiltration rather than the moisture holding capacity and available moisture.

Peele (19) and Hansen (11) agree that the rate of entry of water in moist soils is less than in dryer soils. Peele (19) found that the rate of infiltration on dry soil was 2 to 3 times faster than on wet soil.

Fortier and Beckett (8) found that rates of evaporation were about the same on all textured soils for the first 3 days after a 6 inch irrigation except on relatively impermeable clay loam soil which held more moisture near the surface. Clay loam lost 1.4 inches of water by evaporation in 3 days while sandy loam and other textures lost only .7 inch in the same period.

Structure and organic matter:

Structure and organic matter go hand in hand. A soil with good structure usually is medium to high in organic matter and a soil high in organic matter (excluding peats and mucks) usually has good structure. Thorne (24) quotes Soklovosky, who points out that the breakdown of soil aggregates during irrigation reduces permeability. Fuestell (6) reported that when peat was incorporated with soil, the water holding capacity was increased but the wilting point was also raised. He concluded that peat should not be recommended for the purpose of increasing the available moisture, except on a sand or a very sandy soil. Peele (19) found in an infiltration study of Cecil sandy loam, that infiltration in this soil was more than tripled by a surface mulch of 4 tons per acre of organic matter.

Application of Irrigation Water:

Application and frequency of irrigation are very important. If a heavy application of water is applied to a sandy soil, a considerable portion of the water will percolate below the effective root zone of plants and be of little use. On the other hand, if irrigations are more frequent and light applications of water are applied, more water will be held near the surface in heavy soils where evaporation is the greatest. Bloodgood and Curry (4) state that shallow rooted crops require lighter applications at shorter intervals than do the deep rooted crops which are adapted to deep and less frequent irrigations. The yield of most of the crops involved seemed to be more closely correlated to the amount of water applied than to the soil type. Fortier (7) found that it took less water to produce the same number of bushels of grain sorghum at Hayes, Kansas, on a sandy loam than at Lawton, Oklahoma, on an upland clay. It took 21 inches of water to produce 45 bushels at Lawton and 17 inches of water to produce 43 bushels at Hayes. In 1914 and 1915 Miller (15) did a considerable amount of work on sorghum root depth at different stages of plant growth. He found that sorghum roots penetrated to a depth of 6 feet at maturity.

Consumptive Use of Water by Various Crops:

Barrett and Milligan (1) determined the consumptive use requirements of various crops in Ashley and Ferron Valleys in Utah. This soil was highly alkaline. The figures in the following table are based on the frost free period.

Consumptive Use by the Soil Depletion Method, Colorado River Investigations, Utah, 1948

	Consumptive use in inches	
Crop	Ashley Valley	Ferron Valley
Alfalfa	33.0	32.3
Pasture	30.6	31.9
Corn	20.4	21.0
Wheat	21.4	23.5

Whitt (26) reported on a claypan soil in central Missouri that the average daily use by corn was .14 inches without irrigation and .23 inches under irrigation. The maximum daily use under irrigation was .37 inches for a 12 day period in July.

Consumptive Use Data on Grain Sorghum:

Several experimenters have made consumptive use studies on grain sorghum. The majority of these have been in the southwest where grain sorghum is an important cash crop.

Fortier and Young (10) reported that under conditions equally favorable throughout the semi-arid southwest, the yields of sorghum were greater when the effective rainfall was supplemented by irrigation water and that the crop required 2.5 to 3 feet of water to produce maximum yields. Marr (13) reported on grain sorghum grown in the Salt Valley of Arizona. He found that Dwarf milo, on a clay loam soil, produced a maximum yield of 3000 pounds of grain per acre with a total application of 1.65 acre feet of water applied in 4 irrigations. Fortier and Young (9) reported on Dwarf milo on Yahola fine sandy loam in the Sacramento Valley of California. They obtained a maximum yield of more than 5000 pounds of grain per acre when they applied irrigation water in amounts ranging from 1.39 to 1.93 acre feet.

Musick (16) found the peak transpiration for grain sorghum occurred during the heading stage, August 20 to September 1, at El Reno, Oklahoma. The peak use was .29 inches per day. The average daily rate for the irrigation season was .23 inches. The peak monthly rate which occurred during August was 8.60 inches. The consumptive use for the season was 21.91 inches. McDowell (14) made a five year study on water requirements of grain sorghum in the Wichita

Valley of Texas and found that for optimum yields the water requirement ranged from 23 inches to 37 inches. Fortier and Young (10) reported on the seasonal water requirement of water on kafir corn. The range was from 15.8 inches to 18.5 inches. The water requirement for milo ranged from 11.5 to 20 inches.

MATERIALS AND METHODS

Location:

The experimental area on which uniformity and consumptive use studies were conducted is located in the Lake Carl Blackwell Area, 13 miles west (on State highway 51), and 2 miles north (on State highway 86), of Stillwater, Oklahoma. The exact location of the plot is the northwest corner of Section 10, T. 19 N., R. 1 W., north of the channel of Stillwater creek.

Description of the Soil:

The soil series of this area is Port[1]. The present soil (varying from sandy loam to silt loam) covers soil that decreases in content of sand at depths of 4 feet and greater. A description of the soil in the northeast corner of replication I (see plot design, Figure I) in the dryland plot is given below. The soil is described as Port loam.

Profile:

A_1 0-10" Dark-reddish-brown (2.5 YR 4/4; 3/4, when moist)[2] loam; moderate medium granular; friable; permeable; many fine pores; pH 5.8; upper 5 inches is slightly lighter in color and is weak granular; grades to the layer below.

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[1]Personal communication or unpublished data supplied by H. M. Galloway.

[2]Munsell color chart.

AC 10-26" Reddish-brown (2.5 YR 5/5; 4/5, moist) heavy loam; moderate medium granular; friable; permeable; many worm holes and casts and fine pin holes; pH 6.0; grades sharply to the layer below.

A_{1b} 26-34" Dark-reddish-brown (5YR 4/2; 3/2, when moist) heavy silt loam much like the layer above; pH 6.0; this appears to be the surface horizon of an earlier soil which grades to the layer below.

AC_b 34-50" Dark-reddish-brown (5 YR 4/2; 3/2, when moist) clay loam; moderate medium granular; friable and permeable; pH 6.5. Below about 50 inches, the granulation is slightly stronger in a band of heavy clay loam.

All layers are somewhat hard when dry, but are friable in the moist state. There are no layers restrictive enough to cause perched water tables under irrigation. Fine sandy lenses and bands up to 4 to 6 inches thick occur within the loam in the upper three feet and there are thinner clay loam layers included. The buried soils occur from 28 to about 42 inches below the surface and average more silty and less sandy in texture. These earlier soils are probably a bit more retentive of moisture than the younger soils above.

Replication IV is of a more sandy nature and grades toward the Yahola series, but has a more loamy subsoil and is less calcareous than the typical Yahola soil.

Previous History of Soil Area:

The area was in a farmstead until 1935 when it was taken over by the United States Government. Its exact history since that time is not known. Since 1947 it has been cropped to corn and castor beans, corn being the prevalent crop. It was given to Oklahoma Agricultural and Mechanical College in 1954.

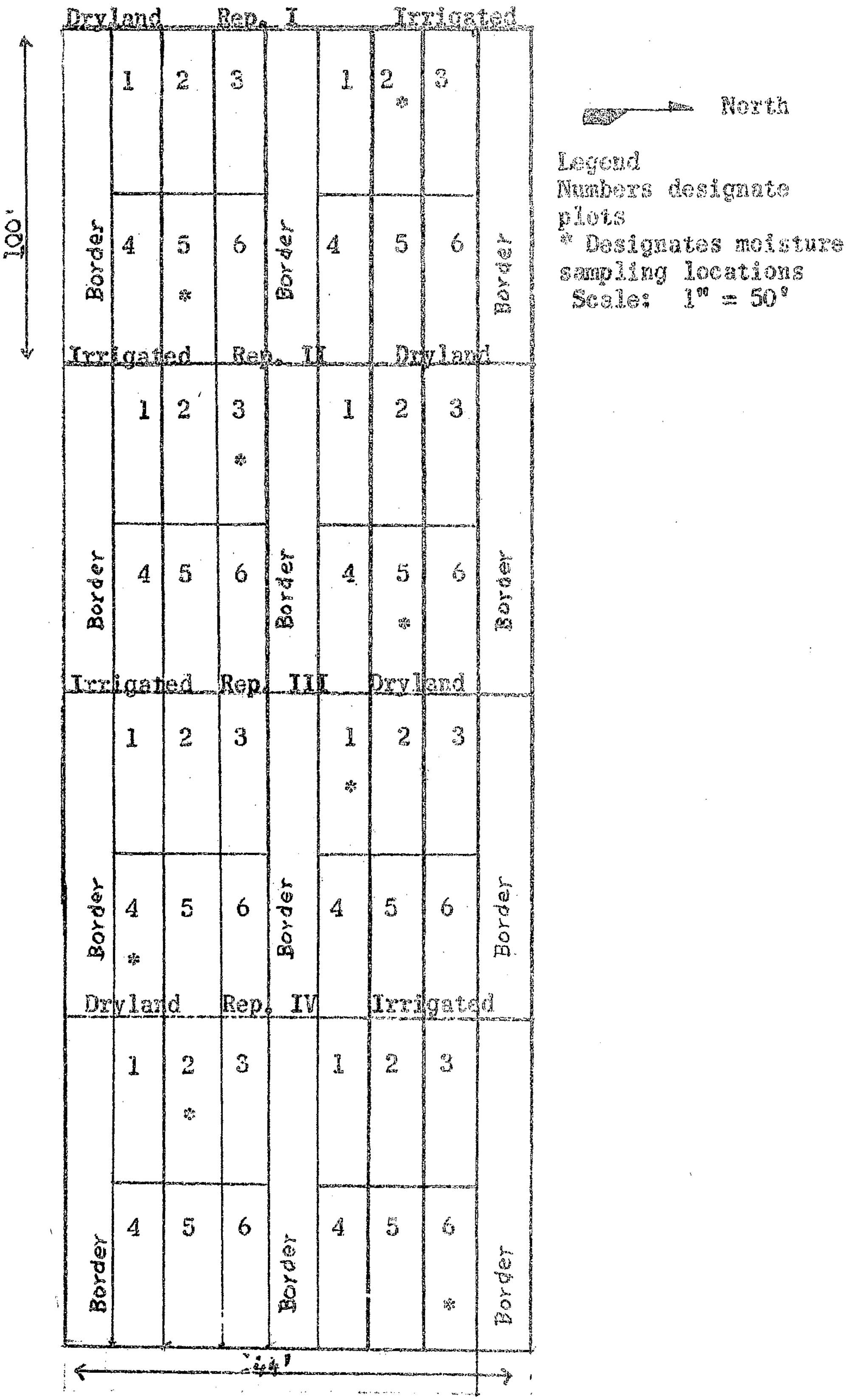


Figure 1. Plot design of the experimental site

Analysis of Soil:

Mechanical analyses were made on soils at 6 inch intervals for the first foot then at 1 foot intervals to 6 feet from all moisture sampling locations. The Bouyoucos (5) hydrometer method was used in making the mechanical analyses. Moisture equivalent, using the method described by Veihmeyer and Hendrickson (25) and moisture content at 1, 3, 5, 8, and 15 atmospheres of pressure using the pressure membrane as described by Richards (21) were determined on all soils from the same locations and depths used in making the mechanical analyses.

Soil samples were taken at 15 different locations at random over the experimental area. Available phosphorus was determined by the sodium bicarbonate extraction method (17). Nitrogen was determined by the Kjeldahl method. Potassium, calcium, and sodium were determined using the method described by Peech, et al. (18). Determinations of pH were made with the glass electrode.

Leveling and Preparation of Seedbed:

The experimental area was plowed (moldboard plow) in March, 1955. High spots were worked with a field cultivator with a chisel attachment. After chiseling, an attempt was made to move the soil from the high spots to the low areas by using an Eversman leveler. The chiseling and leveling was repeated until the field was believed to be level. It was then plowed with a two way moldboard plow.

Just before planting, the field was disked twice and harrowed twice to kill young weeds and to form a firm seedbed.

Design of Experiment:

The experiment was laid out in a randomized block split plot design with four replications. Water levels constituted the main plot treatments. Each main plot was divided into six sub-plots. The sub-plots were left untreated so that their uniformity could be studies. Main plots were 144 feet wide and 100 feet long. Sub-plots were 16 feet wide and 50 feet long. Border areas, 16 feet wide and 400 feet long were left on each side of the experiment to protect the experimental plots from any variability that might have been brought about by crops other than grain sorghum growing adjacent to the plots. Another border strip, of the same dimensions, was left through the center of the experimental area to divide the irrigated and dryland plots. The purpose of this was to do away with border effects of irrigated plots on dryland plots and vice versa. A diagram of the experimental site is presented in Figure 1.

Date and Method of Planting:

Redlan grain sorghum was planted on June 2, 1955. Planting was performed with an adjustable planter attachment mounted on an International Harvester Farmall Model C tractor. The planter was adjusted to plant 32 inch rows and calibrated to drop a seed every 4 inches. Six rows were planted on each sub-plot.

Irrigation:

Before irrigation, the sorghum was cultivated 3 times to control weeds. Previous to irrigation, furrows were deepened to provide better distribution of water and to minimize the amount of breakover of water during irrigation.

Irrigation water was pumped from Lake Carl Blackwell by means of a gasoline driven centrifugal pump. Water was pumped to the plots through

5 inch pressure pipe and distributed with 6 inch gated pipe with 32 inch orifice spacings, A "banjo type" valve on the pump discharge was used to regulate flow. It required three days to irrigate all four replications. Replication IV was irrigated first and replication I last. Moisture samples were taken 2 to 3 days after replication I had been irrigated. Irrigation water was applied four times, starting July 13, July 26, August 9, and August 25.

Irrigation water was applied when the soil contained at or near 40 percent of available moisture. The amount of moisture between the field capacity and the wilting point was determined as the available moisture.

Harvesting:

Bird damage was particularly bad in this area. Attempts were made to discourage the birds from feeding on the sorghum but it became necessary to cover the sorghum heads with paper bags. Twenty-five feet of the center two rows of each plot were bagged. On replication III and IV, damage was very heavy and it was impossible to find 25 feet of undamaged heads. In these particular plots, 25 undamaged heads were bagged from the center two rows and head counts were made from 25 feet of the same two rows.

The final moisture samples were taken September 30, 1955. The grain was left in the field to dry until October 13, 1955. Heads were harvested by hand and thrashed with a plot thrasher. All samples were weighed to the nearest .01 pound and bushels per acre were calculated. Grain samples from each plot were saved for chemical analysis.

Analysis of Grain:

Grain samples were ground with a Wiley mill and protein and phosphorus determinations were made on the 60 mesh materials. Nitrogen was determined by the Kjeldahl method. Percent nitrogen was multiplied by the factor 5.7 to obtain percent protein. Phosphorus was determined by the method of Shelton and Harper (22). Grain protein and phosphorus data were reported on a 14 percent moisture basis. (Samples were dried to constant moisture, determinations were made, and results were adjusted to a 14 percent moisture basis.)

Statistical Analysis:

Grain yields and protein and phosphorus content of the grain were analyzed statistically to aid in the interpretation of the data.

Measurements of Soil Moisture and Precipitation:

Moisture samples were taken with a standard moisture tube to a depth of 6 feet. Samples were taken just before irrigation and 2 to 3 days after irrigation, with several samples taken between irrigations. Moisture samples were taken at two locations in each replication, one on the dryland and one on the irrigated plots. These locations are designated on the plot design, Figure 1. Moisture percentages were determined by subtracting the dry weight from the wet weight to get the weight of water when dividing the weight of water by the dry weight of the soil.

An official United States Weather Bureau rain gauge was used to measure precipitation.

Determination of Volume Weight:

Volume weight was determined by using a Uhland 3 inch core sampler. Samples were taken at 3 moisture sampling locations at depths of 2 to 5 inches, 8 to 11 inches, and 13 to 16 inches. Volume weights calculated from the 3 inch Uhland core sampler were compared with volume weights taken at depths of 0 to 6 inches, 6 to 12 inches, and 12 to 18 inches using the standard moisture sampling tube used during the experiment and an Oakfield sampler. Since the volume weight obtained with the moisture sampling tube was in close agreement with that obtained with the Uhland core sampler, it was used in determining the volume weight for each replication to a depth of 6 feet. The following formula was used in calculating the volume weight:

$$\text{Volume weight} = \frac{\text{Weight of soil (oven dry)}}{\text{Volume of the soil}}$$

(calculated from the dimensions of the core sampler and the moisture sampling tube.)

RESULTS AND DISCUSSIONS

Very little fertility and water requirement information is available on grain sorghum for the Central Oklahoma Area.

The purpose of this experiment was to obtain consumptive use information on grain sorghum and to determine if the plots on the site were uniform enough to produce valid results from fertility treatments.

CLIMATIC CONDITIONS

Temperatures during June were slightly on the cool side. The average temperature for the month was 74.3° F. as compared to the normal average of 76.9° F. Precipitation for the month was 3.30 inches which was .79 inches below normal. By the end of the month the sorghum was making excellent growth.

The weather during July was hot and dry. The average temperature was 84.7° F. as compared to the normal average of 81.4° F. Rainfall for the months was 1.07 inches which was 1.68 inches below normal. The weather during the last 10 days of July was very unfavorable for the dryland sorghum and deterioration of the plants was very apparent.

August temperatures averaged near normal, 82.1° F. Rainfall for the month was .71 inches which was 2.11 inches below normal. The plants on the dryland plots suffered from severe drought.

Rainfall during September was 3.46 inches, which was 1.06 below normal. The average temperature for the month was 77.7° F. as compared to the normal average of 75.5° F. The first 2 weeks were relatively dry. Two large rains fell during the last half of the month.

Total rainfall for the growing season was 8.54 inches, 5.64 inches below normal. Temperatures during the growing season as a whole were slightly below normal. The climate was very favorable for the irrigated plants but less favorable for those grown under dryland conditions. Rainfall during the growing season is shown in Table 1.

Table 1. Rainfall, Grain Sorghum Experiment, Lake Carl Blackwell, 1955

Date June	Precipitation inches	Date July	Precipitation inches	Date August	Precipitation inches	Date September	Precipitation inches
6	.15	5	.37	4	.04	10	.06
14	.25	12	.52	8	.34	20	1.60
16	.09	19	1.8	24	.14	29	1.80
17	1.19			29	.08		
18	.60			30	.11		
19	.34						
23	.68						

Maximum and minimum temperatures and evaporation data for the growing season are plotted on a graph in Figures 1 and 2 of the Appendix.

CONSUMPTIVE USE OF MOISTURE BY GRAIN SORGHUM

Moisture Retention Curves:

Moisture retention curves were plotted from laboratory measurements of moisture retention at 1/3, 1, 3, 5, 8, and 15 atmospheres of tension. The curves in Figure 2 are average curves of the eight separate profile curves of Figures 5, 6, 7, 8, 9, 10, 11, and 12.

In conjunction with the average moisture retention curves the percentages have been placed in table form in Table 2.

The curves were used to determine the amount of available water that the soil would hold and to determine the tension with which the available water was held. These curves give a picture of the soil stratification to a depth of 6 feet which was believed to be the extent of root penetration. Soil stratification and depth have an important bearing on the response of plants to soil moisture. Deep permeable soils thoroughly filled with roots provide good water-transfer contact between the soil and the plant.

Table 2. Average Moisture Content at 1/3, 1, 3, 5, 8, and 15 Atmospheres Tension for all Profiles

	Atmospheres of tension					
Depth inches	1/3 percent	1 percent	3 percent	5 percent	8 percent	15 percent
0- 6	15.03	10.43	7.91	7.23	6.89	6.03
6-12	15.62	11.43	8.15	7.58	7.04	6.32
12-24	16.23	9.64	7.43	6.70	6.29	5.79
24-36	11.93	7.37	6.02	5.44	5.30	4.84
36-48	17.07	12.72	9.80	8.85	8.17	6.98
48-60	21.43	16.61	13.47	11.94	11.14	10.78
60-72	22.62	16.90	14.41	13.30	12.24	11.12

There were marked differences in the moisture holding properties between the different horizons of each profile and there were marked differences between like depths of different profiles but the amount of water held in each profile was about the same for the eight sampling locations.

Moisture retention curves show the relation between the moisture content and soil moisture tension in the plant growth range. In the sandy horizons, a large percentage of the available moisture was gone at the one atmosphere level, while in the finer textured soils, a large percentage of the available moisture remained. In some of the horizons, there was very little difference between the available moisture at the 3 atmosphere level and the 15 atmosphere level. In some of the indi-

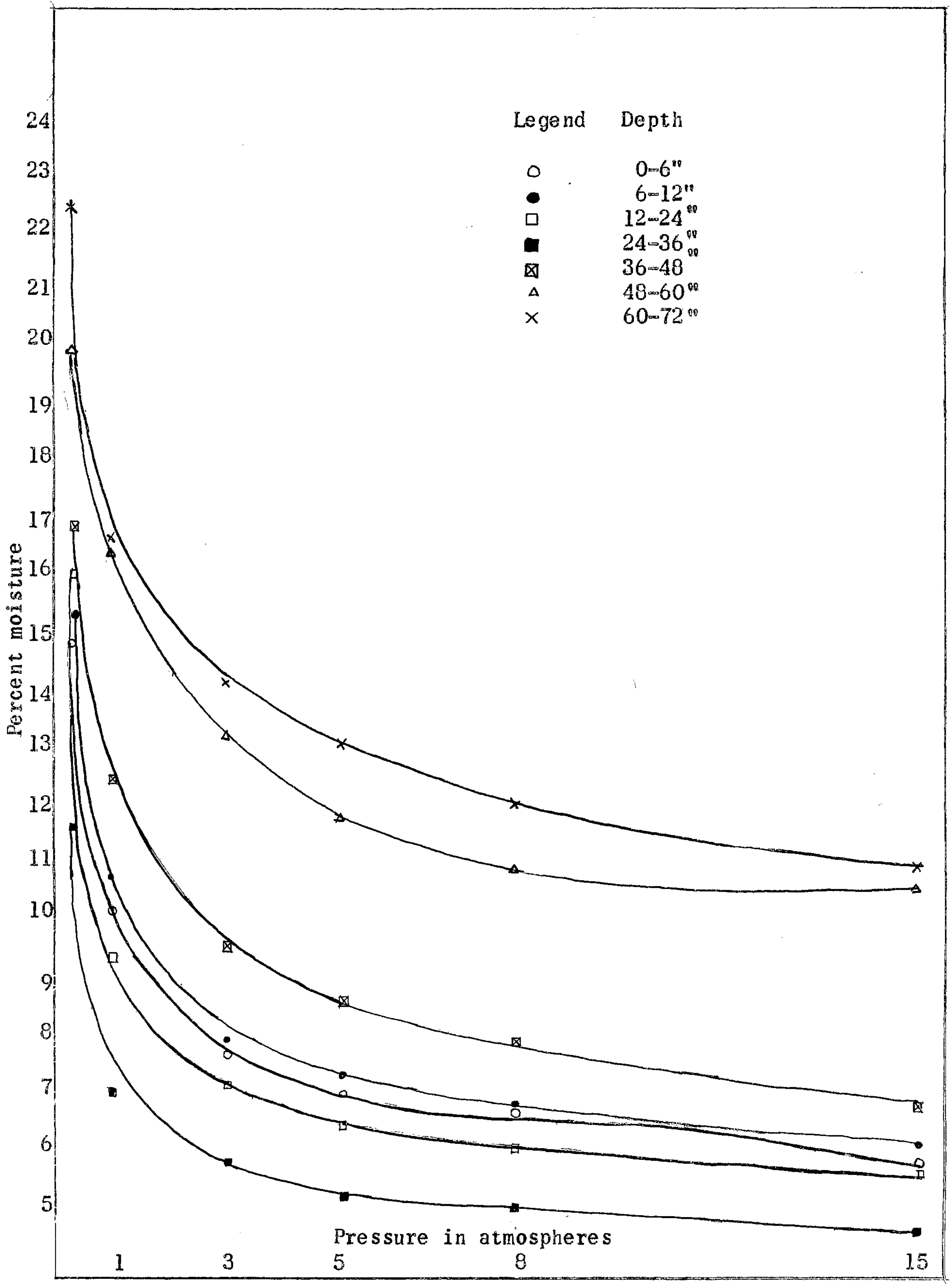


Figure 2. Average moisture retention curves from all profiles

vidual curves, especially in the third and fourth replications of the irrigated plots, there was no sharp break in the retention curve. It was still moving down at the 15 atmosphere level.

Available Moisture Holding Capacity:

One of the principal factors that available moisture is dependent upon is the texture of the soil. Available moisture, texture, and percent of sand, silt, and clay are presented in Tables 14, 15, 16, 17, 18, 19, 20, and 21.

It appears that silt or clay alone does not have a dominating influence on available moisture but there must be large percentages of each to increase the available moisture in a soil.

The average available moisture holding capacity for all the soil profiles, including both irrigated and dryland was 10.61 inches. The range was from 9.33 inches, in the second replication of the irrigated plots, to 11.69 inches for the dryland plots in replication I. The available moisture holding capacity was determined from a 6 foot soil profile. The individual soil horizons varied from a maximum of 2.47 inches, at a depth of 36 to 48 inches, to a minimum of .94 inches, at a depth of 24 to 36 inches.

The soil moisture in the first and second feet of the irrigated plots was maintained most of the time in the upper three-fifths of the available range but on a few occasions it dropped to the wilting point.

Root Growth:

Very little moisture was used from the time of the first sampling to the second which was from June 2 to June 8. Since the plants had little time to grow, it appears most of the water lost during this period was lost by evaporation.

Table 3 gives the moisture sampling depths and the time required for the roots to reach these various depths. Root penetration was determined by the moisture extraction at the various depths.

Table 3. The Time Required for Roots to Reach Various Moisture Sampling Depths in Both Dryland and Irrigated Plots

Depth in inches	Irrigated days	Dryland days	days difference
0- 6	0	0	0
6-12	10	10	0
12-24	40	34	6
24-36	50	40	10
36-48	89	46	43
48-60	97	63	33
60-72	97	78	21

Root growth in some plots penetrated to certain depths before this depth was reached by the roots in other plots but the time given was when all plots gave a definite indication of using water at that particular depth. Plant roots on all plots penetrated to a depth of 6 feet. The irrigated plots used very little moisture below the 4 foot depth whereas the plants on the dryland plots used a considerable amount of water from the fifth and sixth feet. This difference was probably due to the fact that there was available water present in the upper horizons of the irrigated plots while the upper horizons of the dryland plots were dry or at least near the wilting point.

Consumptive Use:

The total consumptive use of water on the dryland plots averaged 13.42 inches for the four replications. This water, of course, came from that stored in the soil at the outset of the experiment and that which fell as precipitation during the growing season. Precipitation during the season was 8.54 inches, thus the net usage from the soil was 4.88 inches. The data show that on August 30, 11.90 inches of water had been used, 5.08 inches of this came from precipitation thus 6.82 inches came from stored soil moisture. The available moisture at the outset was only 6.61 inches. This shows that the soil moisture in the entire 6 foot profile was .21 inches below the wilting point.

The total consumptive use of water on the irrigated plots averaged 22.65 inches. The average available moisture in the irrigated plots at the beginning of the experiment was 7.58 inches. Replication III of the irrigated plots contained nearly 3 inches more available moisture at the outset of the experiment, than the other three irrigated replications. This may have some bearing on the high consumptive use in replication III as related to the other three irrigated replications which had practically the same amount of water usage. If we assume that if this irrigated sorghum had not been irrigated, the consumptive use would have been the same as the average of the dryland plots, estimation of the irrigation requirement can be made.

22.65 inches, the average consumptive use of the irrigated plots.
-13.42 inches, the average consumptive use of the dryland plots.
9.23 inches, the amount of water applied by irrigation.

The average yield of the dryland plots was 48.2 bushels per acre. Yields in replication III and IV were about 10 bushels higher than in replications I and II. Yields on the irrigated plots averaged 90.84 bushels per acre. Measured differences in water use did not appear to influence the yields of any of the irrigated plots.

Moisture use during irrigation was taken from an average of the sampling period just before irrigation and the sampling period just after irrigation. This was calculated on a daily use basis and multiplied by the number of days between the last sampling period before irrigation and the first sampling after irrigation.

The average daily consumptive use for both irrigated and dryland plots are shown in Figure 3 and Table 4.

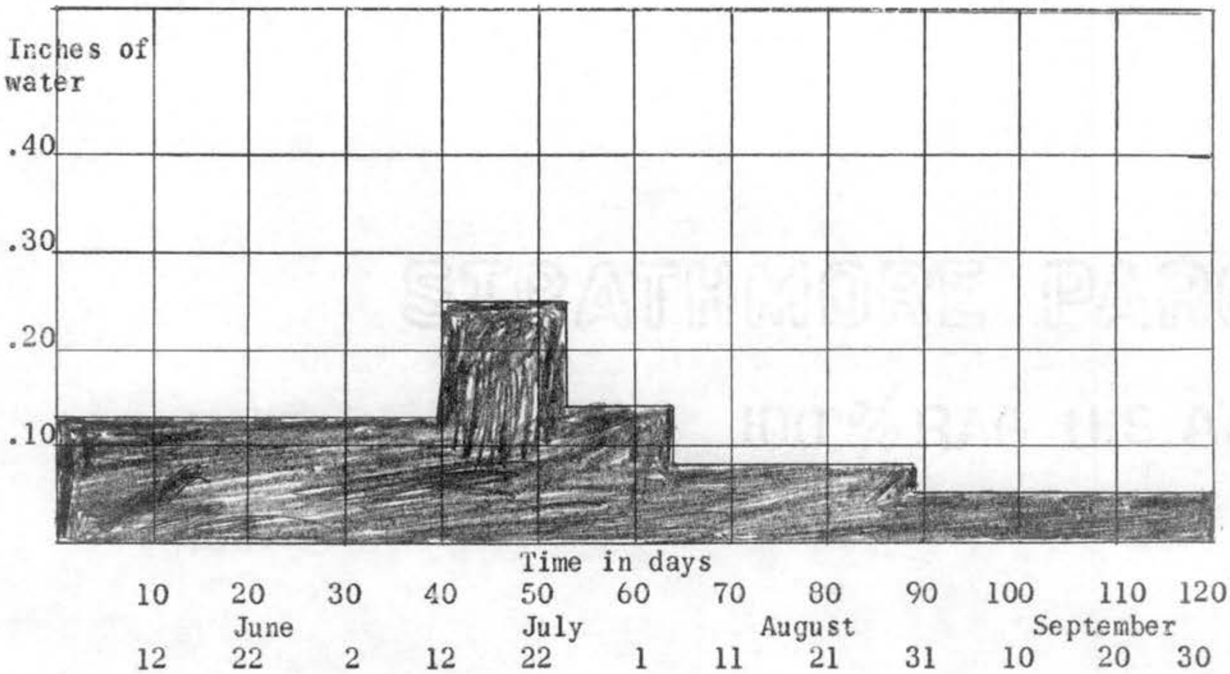
Table 4. Consumptive Use of Water for Various Periods and Average Use Per Day on Dryland and Irrigated Plots. (Average of four replications)

Irrigated				Dryland			
Period	Days	Water used (inches)	Use per day (inches)	Period	Days	Water used (inches)	Use per day (inches)
6/2-2/12	40	5.50	.14	6/2-7/12	40	5.17	.13
7/12-7/25	13	3.34	.26	7/12-7/25	13	3.26	.25
7/25-8/8	14	3.42	.24	7/25-8/4	10	1.50	.15
8/8-8/24	16	4.97	.31	8/4-8/30	26	1.97	.08
8/24-9/30	37	5.43	.15	8/30-9/30	31	1.52	.05
Total	120	22.66	.19	Total	120	13.42	.11

The graph and table for the irrigated plots are based on the periods between irrigations. Those for dryland are based on periods as near those used in the graph for the irrigated plots as the data will allow. Moisture samples were not always taken on the dryland plots at the same time they were taken on the irrigated plots. The graph and table were both drawn for periods between irrigations rather than for individual sampling periods.

The peak consumptive use for the irrigated plots occurred between August 8 and August 24. It was .31 inches per day. The average daily consumptive use for the season was .19 inches. The peak consumptive use for the dryland plots occurred between July 12 and July 25. It was .25 inches per day. The average daily consumptive use for the season was .11 inches. Consumptive use data for the individual sampling sites are given in Tables 5 and 6.

Average consumptive use on the dryland plots



Average consumptive use on the irrigated plots

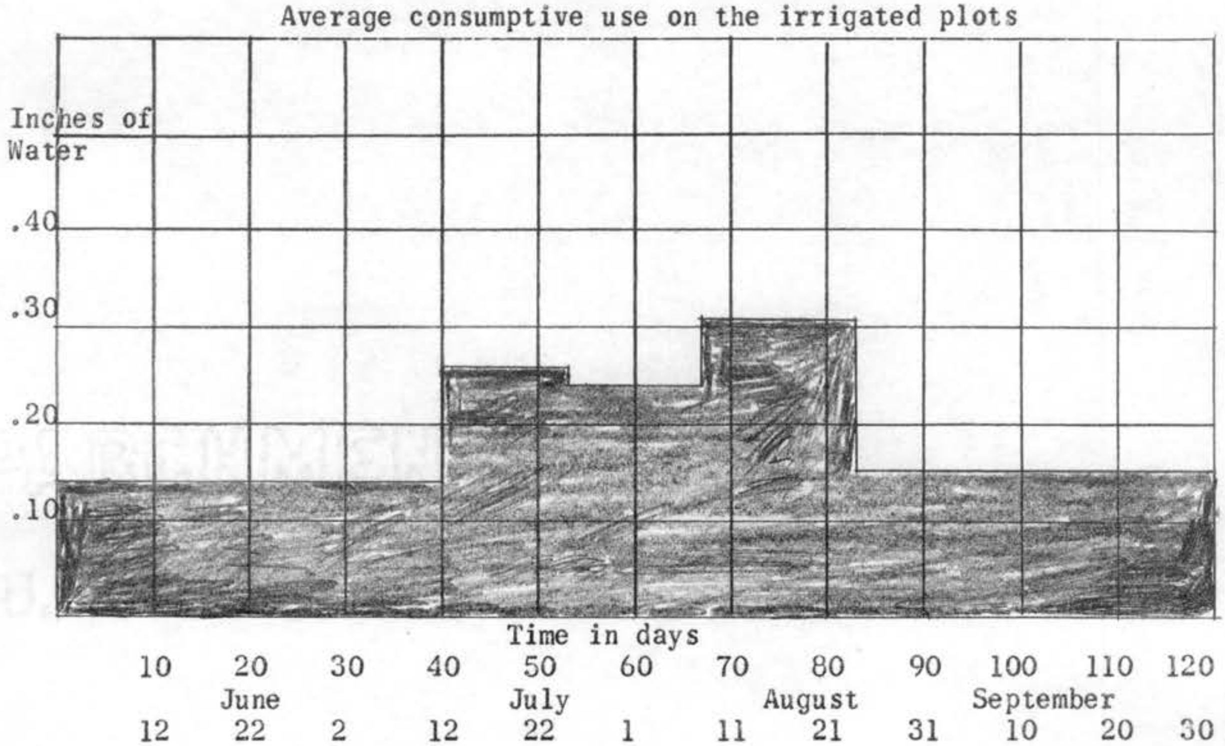


Figure 3. Average consumptive use on the dryland and irrigated plots

Both graphs in Figure 3 indicate a peak use between the 40th and 53rd day. Although the irrigated plots were irrigated July 12, the 40th day, the sorghum in both the irrigated and dryland plots still used the same amount of moisture. The plants on dryland were apparently able to remove enough moisture from the soil to continue normal growth. After July 25, there was a very significant decrease in the amount of water used on the dryland plots. The moisture sampling data indicate that on the 25th of July, all of the available moisture had been removed from the first and second feet.

On the irrigated plots, there were two peak use periods, one between the 40th and 53rd day of growth and one between the 67th and 83rd day of growth. The peak between the 40th and the 53rd day was during the boot stage and the peak between the 67th and the 83rd day was during the heading stage. From this information it appears that the boot stage, and the heading stage are critical periods of water supply for sorghums.

Table 5. Consumptive Use for Various Periods and Average Use Per Day in Irrigated Sorghum. (expressed in inches)

		Rep. I		Rep. II		Rep. III		Rep. IV		Average	
Period	Days	Water use	Use per day	Water use	Use per day	Water use	Use per day	Water use	Use per day	Water use	Use per day
6/2-7/12	40	5.66"	.13"	5.41"	.13"	7.13"	.18"	4.08"	.10"	5.50"	.14"
7/12-7/25	13	3.16	.24	2.93	.22	3.90	.30	3.43	.26	3.34	.26
7/25-8/8	14	3.47	.25	3.62	.25	3.47	.25	3.12	.22	3.42	.24
8/8-8/24	16	4.39	.27	6.07	.38	5.48	.34	3.96	.25	4.97	.31
8/24-9/30	37	4.55	.12	3.53	.10	6.64	.18	6.84	.18	5.43	.15
Total	120	21.23	.18	21.55	.18	26.62	.22	21.43	.18	22.66	.19

Table 6. Consumptive Use for Various Periods and Average Use Per Day in Dryland Sorghum. (expressed in inches)

		Rep. I		Rep. II		Rep. III		Rep. IV		Average	
Period	Days	Water use	Use per day	Water use	Use per day	Water use	Use per day	Water use	Use per day	Water use	Use per day
6/2-7/12	40	4.60"	.12"	5.69"	.14"	4.94"	.12"	5.47"	.13"	5.17"	.13"
7/12-7/25	13	4.14	.32	2.78	.21	3.42	.26	2.69	.21	3.26	.25
7/25-8/8	14	2.41	.22	1.24	.11	.96	.09	1.41	.13	1.50	.15
8/8-8/24	16	2.21	.09	2.08	.08	2.09	.08	1.50	.06	1.97	.08
8/24-9/30	37	1.28	.04	1.34	.04	1.48	.05	1.99	.06	1.52	.05
Total	120	14.64	.12	13.13	.11	12.89	.11	13.06	.11	13.42	.11

THE SUITABILITY OF AN ALLUVIAL SOIL FOR FIELD EXPERIMENTS

Criteria used in evaluating the uniformity of the experimental site are grain yield, protein content of grain, phosphorus content of grain, and chemical and physical analyses of the soil.

Yield Data:

Yields from individual plots are presented in Table 7. The yield data was analyzed statistically to determine whether or not irrigation affected yields and to assess the variability of the area. The analysis is presented in Table 8. Irrigation brought about a significant increase in yield of 42.7 bushels, from 48.2 to 90.9 bushels per acre.

The coefficient of variation in yield was calculated by the formula:

$$CV = \frac{\sqrt{EMS}}{M}$$

CV = Coefficient of variation

M = Mean

EMS = Error mean square

The coefficient of variation was 22.80%. The coefficient of variation times mean yield equals the yield differences due to variability and experimental error. In an experiment where treatments on the individual plots of this site are varied, differences due to treatments would have to exceed 15.90 bushels per acre to be significant. Differences of this magnitude could hardly be expected from treatments used in conventional fertilizer experiments.

Table 7. Yields of Grain, Uniformity and Consumptive Use Experiment, Lake Carl Blackwell Area, 1955. (bu. per acre.)

	Dryland					Irrigated				
Plot	I	II	III	IV	Avg.	I	II	III	IV	Avg.
1	66.1	18.4	64.8	45.6	48.7	94.9	77.9	123.3	106.3	100.6
2	42.6	56.6	62.3	83.9	61.4	103.9	81.7	88.8	85.2	89.4
3	19.9	41.5	50.9	42.2	38.6	110.0	70.1	91.4	78.7	87.6
4	49.3	34.8	51.3	65.9	50.3	89.9	101.8	103.1	91.6	96.6
5	53.3	54.6	40.0	29.6	44.4	89.2	92.8	91.9	93.4	91.1
6	19.5	37.3	50.6	75.2	45.7	103.1	91.1	66.1	56.1	79.2
Avg.	41.8	40.5	53.3	57.1	48.2	98.5	85.9	94.1	84.9	90.9

Table 8. Analysis of Variance, Yield Data.

Variant	df	SS	MS	F
Total	47	33,460.21		
Reps.	3	724.13	241.38	---
Water	1	21,854.35	21,864.35	16.13**
Error	43	10,871.73	252.83	

**Significant at the .01 level.

A coefficient of variation was calculated considering only replications I and II where there was less bird damage and it was felt that yields were more accurate. The coefficient of variation for this area is 20.59%. With a mean yield of 66.68 bushels per acre, differences due to treatments would have to exceed 13.73 bushels per acre to show significance.

A coefficient of variation was calculated only on the irrigated plots to determine whether there is more or less variation under irrigation than under dryland conditions. The coefficient of variation for the irrigated area was 15.76%. With a mean yield of 90.90 bushels per acre, the difference due to treatments would have to exceed 14.33 bushels per acre to be significant.

A coefficient of variation, considering only replications I and II of the irrigated plots, was calculated. It was 10.92%. With a mean yield of 92.20 bushels per acre, the difference due to treatment would have to exceed 10.07 bushels per acre to be significant.

The yield data and their analysis show that they are too hetergenous to be a desirable site for conducting a fertility experiment.

Protein Content:

Protein content was determined for all plots. The results of the protein determinations are presented in Table 9. The analysis of variance of the protein data is presented in Table 10. Irrigation brought about a significant reduction in protein content of the grain. This was not surprising since the yields were increased by irrigation and when yields are increased without additional applied nitrogen, one would expect the protein content to vary inversely with yield.

The coefficient of variation in protein content was calculated

Table 9. Protein Content of Grain, Uniformity and Consumptive Use Experiment, Lake Carl Blackwell, 1955. (in percent).

Plot	I	II	III	IV	Avg.	I	II	III	IV	Avg.
1	9.60	11.11	9.77	11.58	10.52	8.49	9.52	9.75	8.92	9.17
2	11.90	11.46	9.43	10.71	10.88	8.64	9.03	9.57	9.50	9.19
3	12.84	11.42	10.26	11.15	11.42	8.39	9.92	9.80	9.42	9.38
4.	9.97	10.18	12.39	12.22	11.19	8.70	9.00	9.41	9.06	9.04
5	10.05	10.52	11.33	9.49	10.33	9.85	9.32	9.51	9.08	9.43
6	12.00	11.01	12.38	9.33	11.18	9.30	9.32	9.16	9.40	9.29
Avg.	11.06	10.95	10.93	10.75	10.92	8.89	9.35	9.53	9.23	9.25

Table 10. Analysis of Variance, Protein Data.

Variant	df	SS	MS	F
Total	47	63.1933		
Reps	3	0.5594	0.1865	---
Water	1	33.4334	33.4334	16.71**
Error	43	29.2005	0.6791	

**Significant at the .01 level.

by the same formula used in the yield data. The coefficient of variation is 8.17%. Difference in protein caused by treatments would have to be in excess of 0.82% to be significant. Such differences might well be obtained from treatments ordinarily used in fertilizer experiments. Protein data were much more uniform in the irrigated area than on the dryland plots.

Phosphorus Content:

The phosphorus content of the grain and the analysis of variance are found in Tables 11 and 12 respectively.

The calculated coefficient of variation was 12.88%. Replications III and IV were significantly higher in phosphorus than replications I and II. Grain from the irrigated plots was significantly higher in phosphorus than that from the dryland plots. This probably was due to the fact that there was more phosphorus in solution when the moisture content was high. Precipitated inorganic phosphate compounds in the soil have a certain solubility product constant (which varies with different compounds and different soils). This means that a certain quantity of the compounds is dissolved in a given amount of water. By increasing the total water in the soil, the total amount of phosphorus in solution is increased.

Differences in phosphorus content of the grain would have to be about .048% to be significant in a fertility experiment on this site.

Chemical Analysis of the Soil:

Nitrogen, available phosphorus, exchangeable potassium, calcium, and sodium, and pH were determined on samples of the soil. The soil samples were taken from 15 random locations over the experimental area.

Table 11. Phosphorus Content of Grain, Uniformity and Consumptive Use Experiment, Lake Carl Blackwell Area, 1955.

	Dryland					Irrigated				
Plot	I	II	III	IV	Avg.	I	II	III	IV	Avg.
1	.256	.236	.369	.429	.348	.315	.381	.381	.423	.375
2	.285	.266	.326	.347	.306	.358	.336	.442	.404	.385
3	.369	.256	.237	.393	.314	.369	.369	.454	.347	.385
4	.369	.305	.482	.393	.387	.315	.404	.482	.417	.405
5	.294	.305	.417	.369	.346	.358	.358	.429	.417	.391
6	.399	.381	.442	.381	.401	.404	.442	.429	.404	.420
Avg.	.329	.308	.379	.385	.350	.353	.382	.436	.402	.393

Table 12. Analysis of Variance, Phosphorus Content.

Variant	df	SS	MS	F
Total	47	.162177		
Reps	3	.041150	.013717	5.967*
Water	1	.022188	.022188	9.651**
Error	43	.098830	.002299	

* Significant at the .05 level
**Significant at the .01 level

The sampling locations are designated on the plot map in Figure 4. The results of the chemical determinations are in Table 13.

Replication I: The dryland and irrigated plots were both low in nitrogen. They were medium in the amount of available phosphorus and were high in exchangeable potassium, calcium, and sodium. The pH ranged from 5.7 to 6.0 in the top 6 inches.

Replication II: The nitrogen content was low for all plots. Both dryland and irrigated plots were high in available phosphorus, exchangeable potassium, calcium, and sodium. The pH ranged from 5.8 to 6.0 in the top 6 inches.

Replication III: The nitrogen content in the third replication was slightly higher than that in replications I and II. The amounts of phosphorus, potassium, calcium and sodium were very high. The pH in the top 6 inches ranged from 5.5 to 6.1.

Replication IV: The nitrogen content was low. The dryland plots contained slightly more nitrogen than the irrigated plots. The available phosphorus was very high on both dryland and irrigated plots. The potassium content was considerably higher in the dryland plots than in the irrigated plots. The calcium and sodium content remained about the same in both areas.

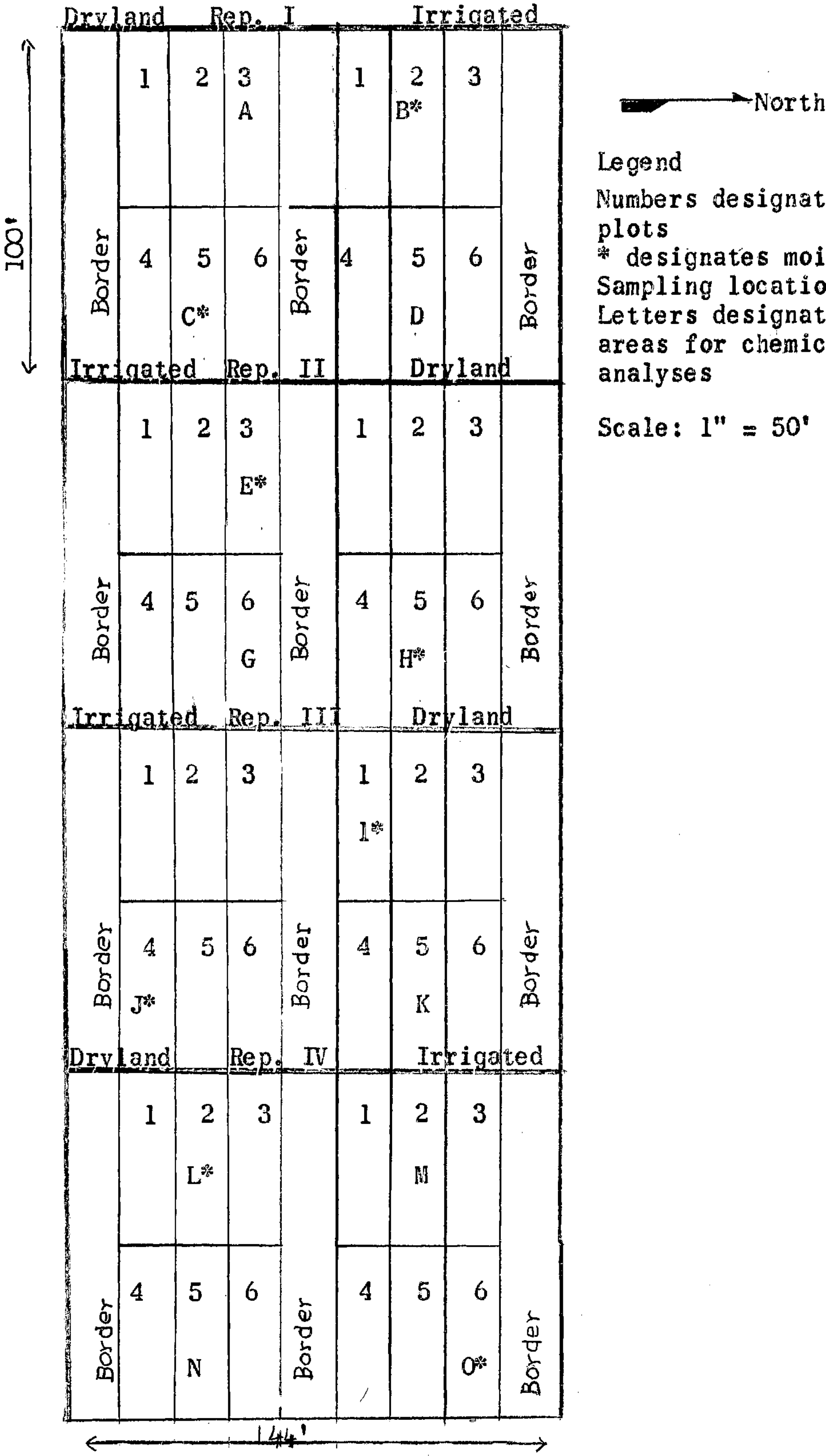
The nitrogen content was slightly higher in replications III and IV than in replications I and II. The phosphorus and potassium was considerably higher in replications III and IV than in replications I and II. The calcium and sodium content remained fairly uniform throughout the area.

The soil reaction tends to go from very acid to neutral. This trend was from west to east. The chemical analyses show that the area

Table 13. Chemical Analysis of the Soil from the Grain Sorghum Experimental Area

Sample No. *	Percent N		Available P_2O_5 #/A.		Exch. K #/A.		Exch. Ca #/A.		Exch. Na. #/A.		pH	
	0-6"	6-12"	0- "	6-12"	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"
A	.033	.054	155.5	78.0	500.0	360.0	960.0	360.0	510.0	500.0	5.8	5.8
B	.040	.031	105.5	71.0	534.0	628.0	600.0	480.0	420.0	360.0	5.8	5.9
C	.041	.040	190.0	190.0	534.0	564.0	720.0	1320.0	460.0	550.0	6.0	6.2
D	.048	.037	96.0	71.0	509.0	620.0	480.0	1200.0	370.0	580.0	5.7	6.4
E	.041	.037	114.5	87.0	564.0	518.0	960.0	1080.0	530.0	350.0	5.8	6.2
F	.045	.045	199.0	96.0	534.0	526.0	360.0	1200.0	370.0	580.0	6.0	6.3
G	.048	.048	76.5	87.0	591.0	500.0	960.0	960.0	530.0	470.0	5.8	6.2
H	.046	.018	155.0	64.0	554.0	509.0	720.0	600.0	480.0	420.0	6.0	6.0
I	.058	.078	348.0	300.0	754.0	500.0	960.0	960.0	550.0	440.0	5.5	5.4
J	.041	.078	615.0	300.0	983.0	808.0	600.0	1320.0	380.0	570.0	6.1	6.1
K	.052	.038	348.0	277.0	833.0	646.0	960.0	600.0	510.0	390.0	6.1	6.2
L	.061	.031	430.0	313.5	1000.0	1000.0	1440.0	600.0	400.0	530.0	6.3	6.4
M	.048	.027	348.0	252.0	763.0	673.0	1200.0	1320.0	500.0	400.0	6.1	6.4
N	.089	.041	497.0	300.0	833.0	736.0	960.0	1440.0	400.0	440.0	6.1	6.1
O	.051	.042	265.5	361.5	664.0	526.0	600.0	720.0	250.0	380.0	6.7	6.7

*Sampling locations are located on the plot map on page 42.



Legend
Numbers designate plots
* designates moisture Sampling locations
Letters designate areas for chemical analyses

Scale: 1" = 50'

Figure 4. Field plot design of sorghum experiment, Lake Carl Blackwell area

was fairly uniform except for the phosphorus and the pH.

Soil Physical Characteristics:

To determine the relation between soil-moisture content and soil-moisture retention, moisture retention curves were prepared. The moisture equivalent was used for the 1/3 atmosphere point on the curves. The retention at 1, 3, 5, 8, and 15 atmospheres pressure was determined by using the method described by Richards (20).

In connection with the moisture retention curves prepared for both the dryland and irrigated plots, tables giving the available moisture holding capacity and percentage of sand, silt, and clay were prepared for each moisture sampling depth.

Replication I: The moisture retention curves for replication I are shown in Figures 5 and 6. The available moisture holding capacity and texture are given in Table 14 and 15.

The irrigated plots were slightly sandier than the dryland plots, and they held slightly less water. There was a marked increase in the water holding capacity between the 3rd and 4th feet in the dryland plots, this marked increase in available moisture was found between the 4th and 5th feet in the irrigated plots. If one foot of soil was taken from the surface of the irrigated plots, this area, according to the moisture retention curves, would have practically the same profile as the dryland area.

Replication II: The moisture retention curves for the dryland and irrigated plots are shown in Figures 7 and 8 respectively. Tables 16 and 17 give the available water holding capacity of the dryland and irrigated areas.

Available moisture was slightly higher in the dryland than in the

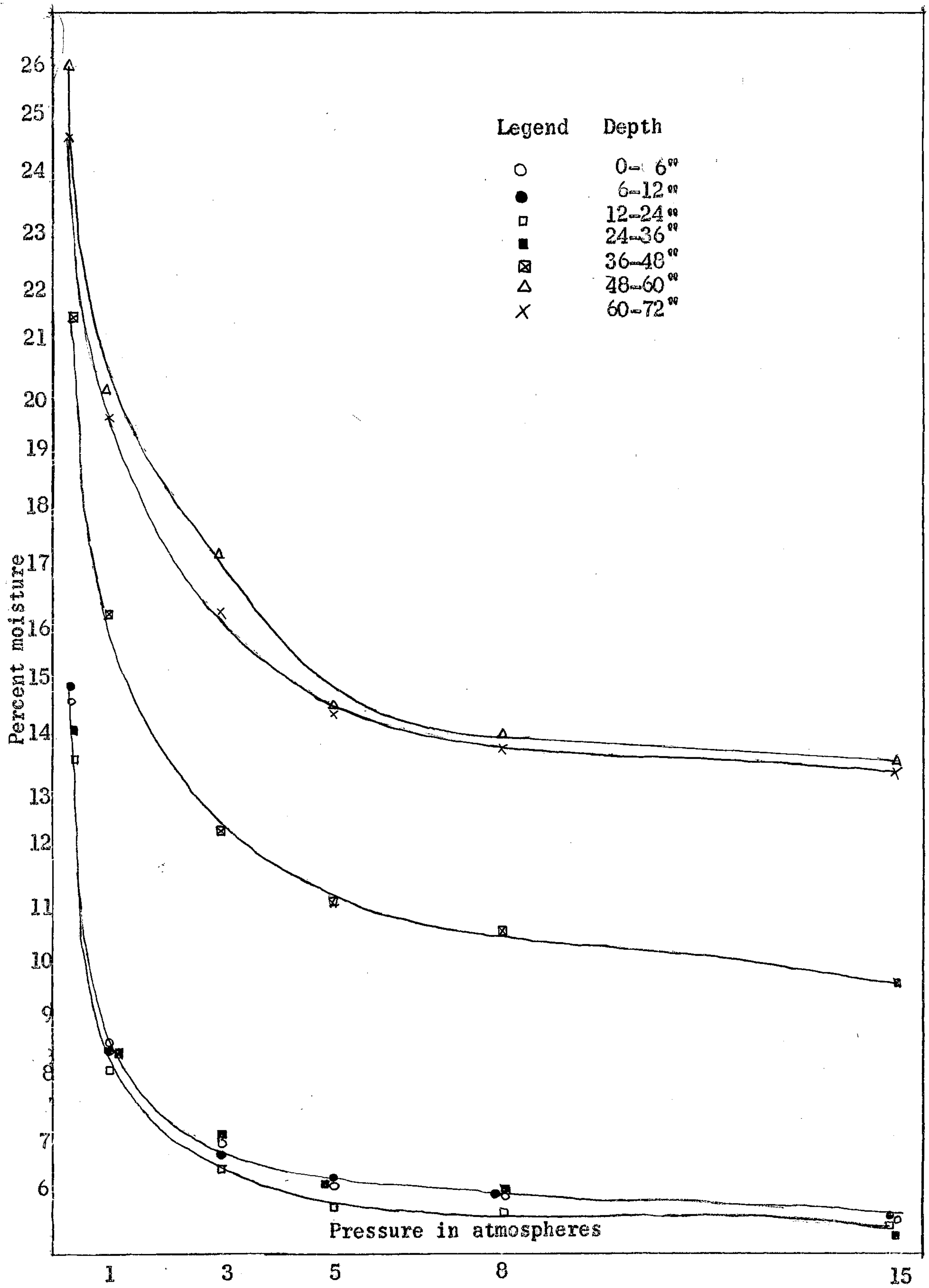


Figure 5. Moisture retention curves, replication I, dryland

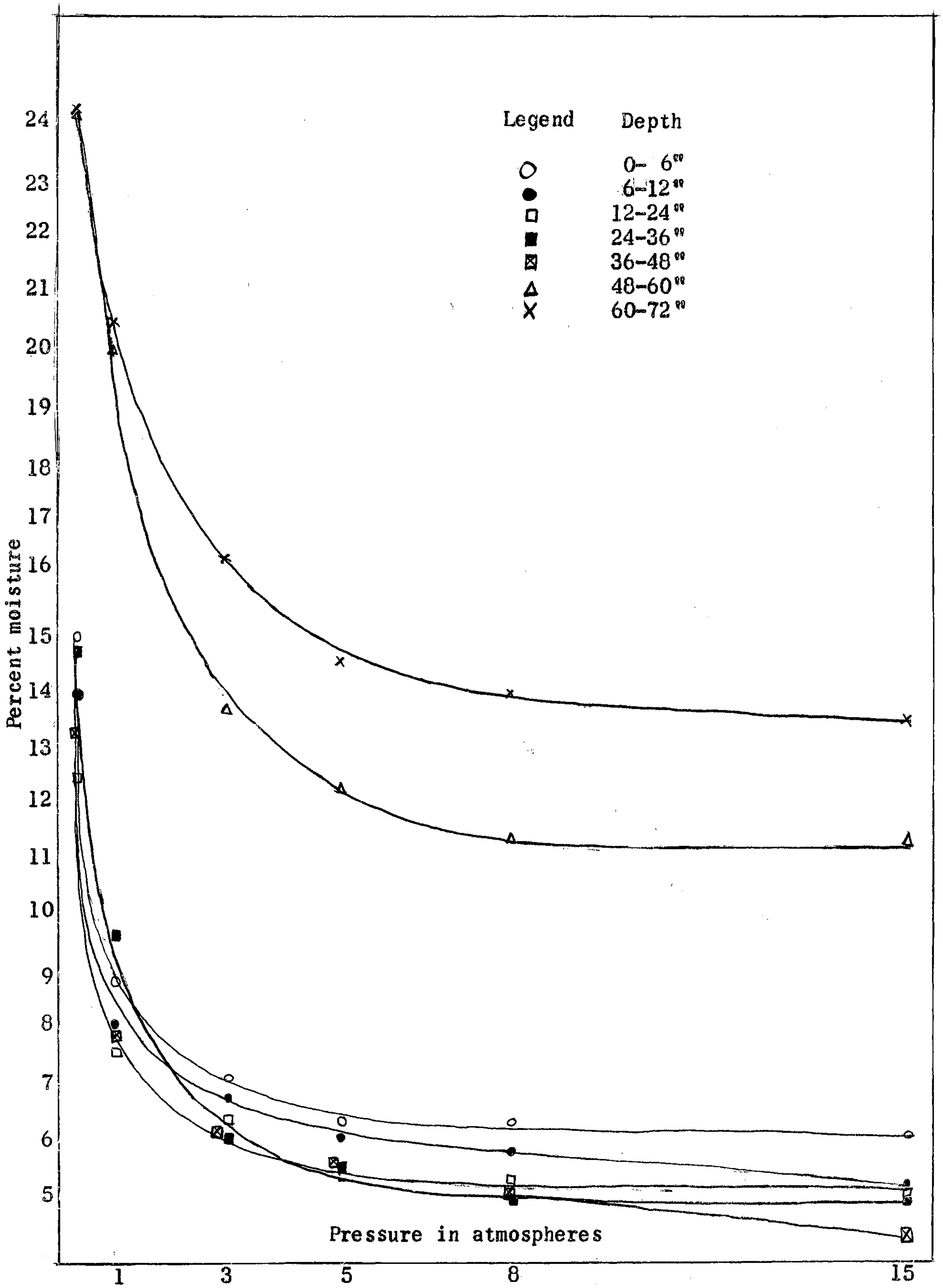


Figure 6. Moisture retention curves, replication I, irrigated

Table 14. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. I in the Irrigated Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.81	Sandy loam	72.25	14.50	13.25
6-12	.81	" "	58.25	26.25	15.50
12-24	1.57	" "	62.25	21.25	15.50
24-36	1.90	" "	60.25	26.50	13.25
36-48	1.74	Silt loam	34.25	53.25	12.50
48-60	2.41	Sandy clay loam	68.25	9.50	23.25
60-72	2.01	Loam	32.25	38.75	29.00
Total	11.25				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

Table 15. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. I in the Dryland Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.85	Loam	50.75	39.00	10.25
6-12	.86	Sandy loam	58.00	30.00	12.00
12-24	1.52	Loam	52.75	33.25	14.00
24-36	1.78	Sandy loam	56.75	32.00	11.25
36-48	2.24	Loam	38.75	39.25	22.00
48-60	2.33	Sandy clay loam	59.79	14.25	26.00
60-72	2.11	Loam	32.75	44.75	23.00
Total	11.69				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

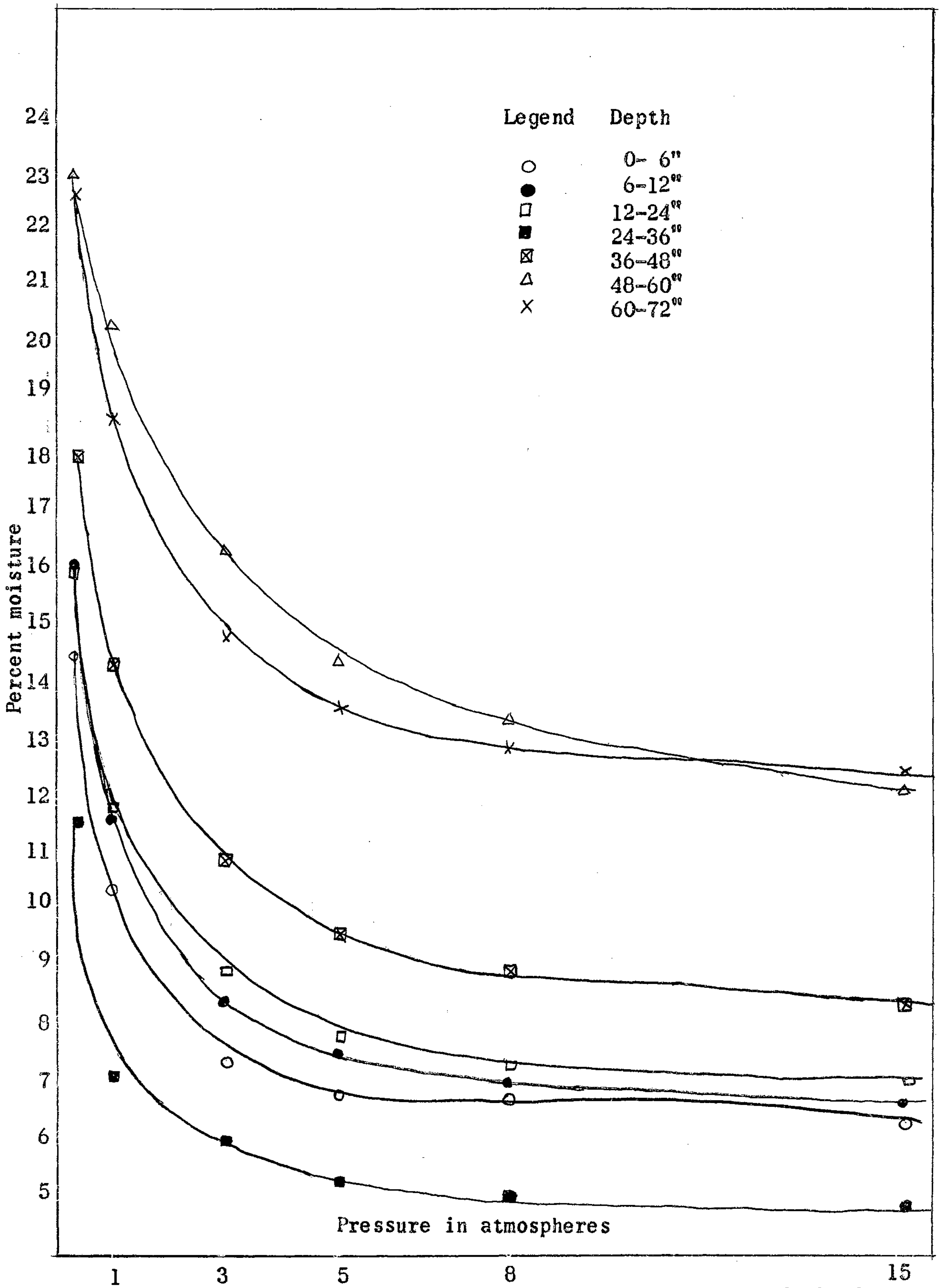


Figure 7. Moisture retention curves, replication II, dryland

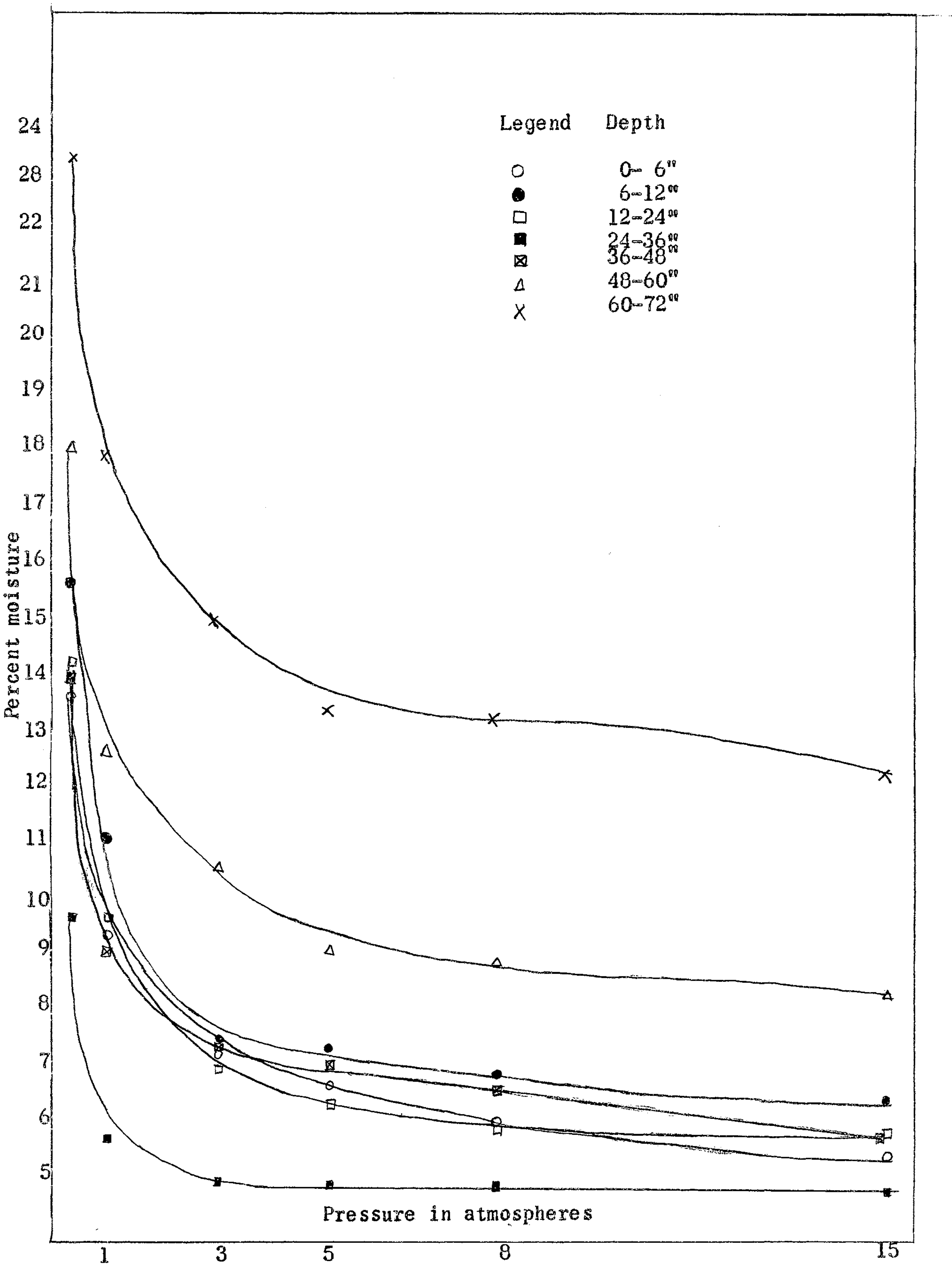


Figure 8. Moisture retention curves, replication II, irrigated

Table 16. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. II in the Irrigated Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.81	Loam	51.75	38.25	10.00
6-12	.87	Sandy loam	55.50	34.50	10.00
12-24	1.47	" "	55.50	35.50	9.00
24-36	.94	" "	73.50	19.50	7.00
36-48	1.60	" "	67.75	21.50	10.75
48-60	1.66	Loam	49.75	33.50	16.75
60-72	1.98	"	32.75	43.25	24.00
Total	9.33				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

Table 17. Available Moisture and percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. II in the Dryland Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.81	Sandy loam	55.25	38.25	26.50
6-12	.79	Loam	43.50	42.75	13.75
12-24	1.59	"	43.50	40.50	16.00
24-36	1.27	Sandy loam	63.50	27.25	9.25
36-48	1.84	Loam	38.75	40.50	20.75
48-60	1.83	Clay loam	31.75	37.50	30.75
60-72	1.77	Loam	31.75	46.50	21.75
Total	9.90				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

irrigated plots due to the very low amount of available moisture in the 24-36 inch depth. This is shown in the 24-36 inch curve in Figure 7. The moisture content is practically at the wilting point at the 5 atmosphere level.

Like replication I, according to the soil stratification, the irrigated plots of replication II seemed to have a profile similar to the dryland plots if the first foot of the irrigated plots was disregarded.

Replication III: The moisture retention curves for the dryland and irrigated plots of replication III are shown in Figures 9 and 10 respectively. The available moisture holding capacity and textural percentages are given in Tables 18 and 19.

The available moisture holding capacity in the irrigated soil was 1.32 inches greater than that in the dryland profile. Like the previous curves, there was a considerable amount of variability within the profiles.

Replication IV: The moisture retention curves for the dryland and irrigated plots of replication IV are presented in Figures 11 and 12 respectively. The available moisture holding capacity and textural percentages are given in Tables 20 and 21.

Moisture retention curves show that the soil stratification in both areas was similar. The area shows a profile of sandy soil to a depth of 3 feet underlain by finer textured soil.

The irrigated area contains layers of finer texture, therefore the available water holding capacity is slightly higher.

The soil in the area as a whole is a sandy soil underlain by a finer textured soil. The thickness of the sandy layer varies from 3 to 4 feet. In all of the soil horizons, with few exceptions, very little water was available for plant use below the 5 atmosphere level. In some of the sandier horizons very little available moisture remained below the 1

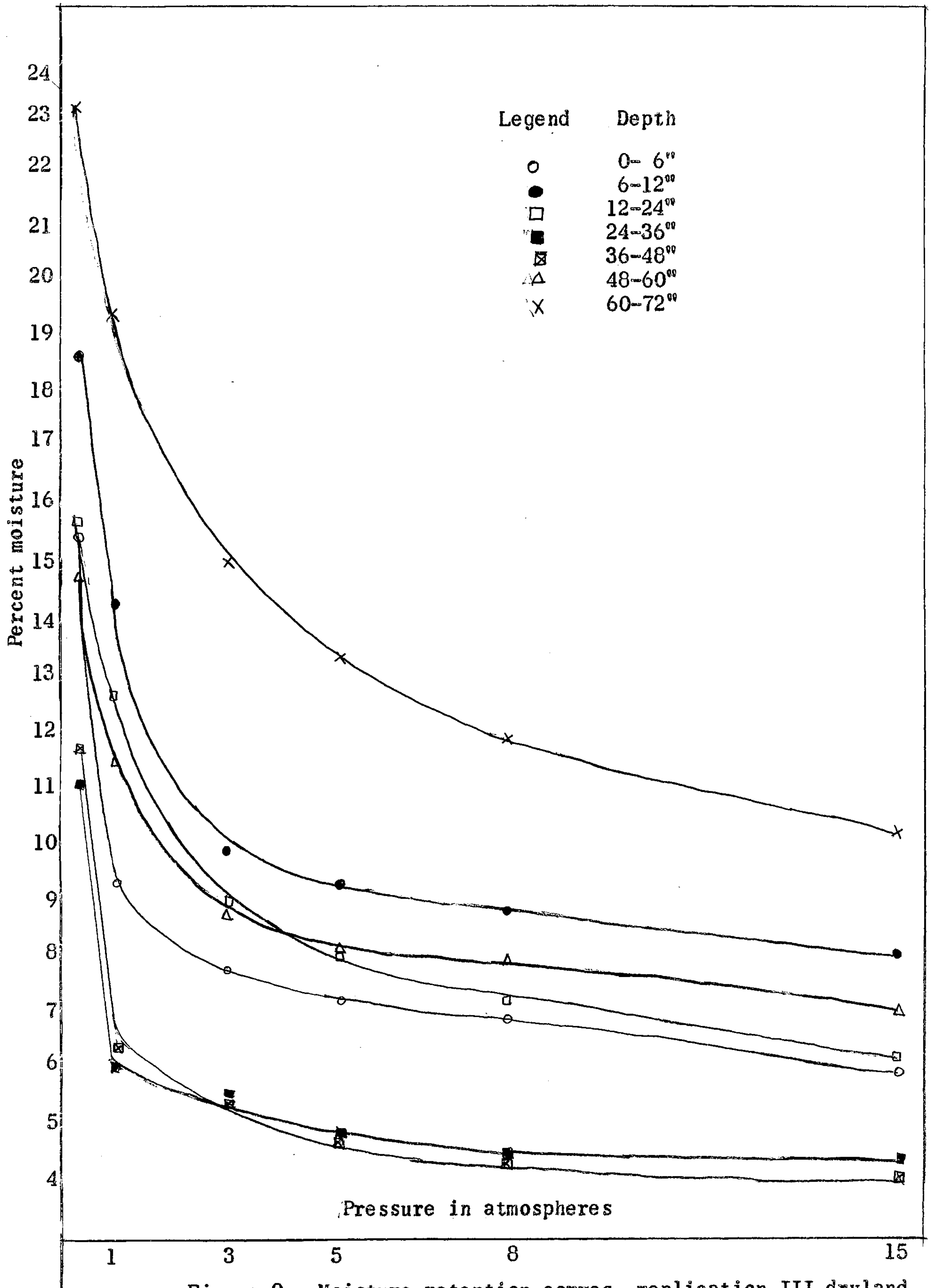


Figure 9. Moisture retention corves, replication III, dryland

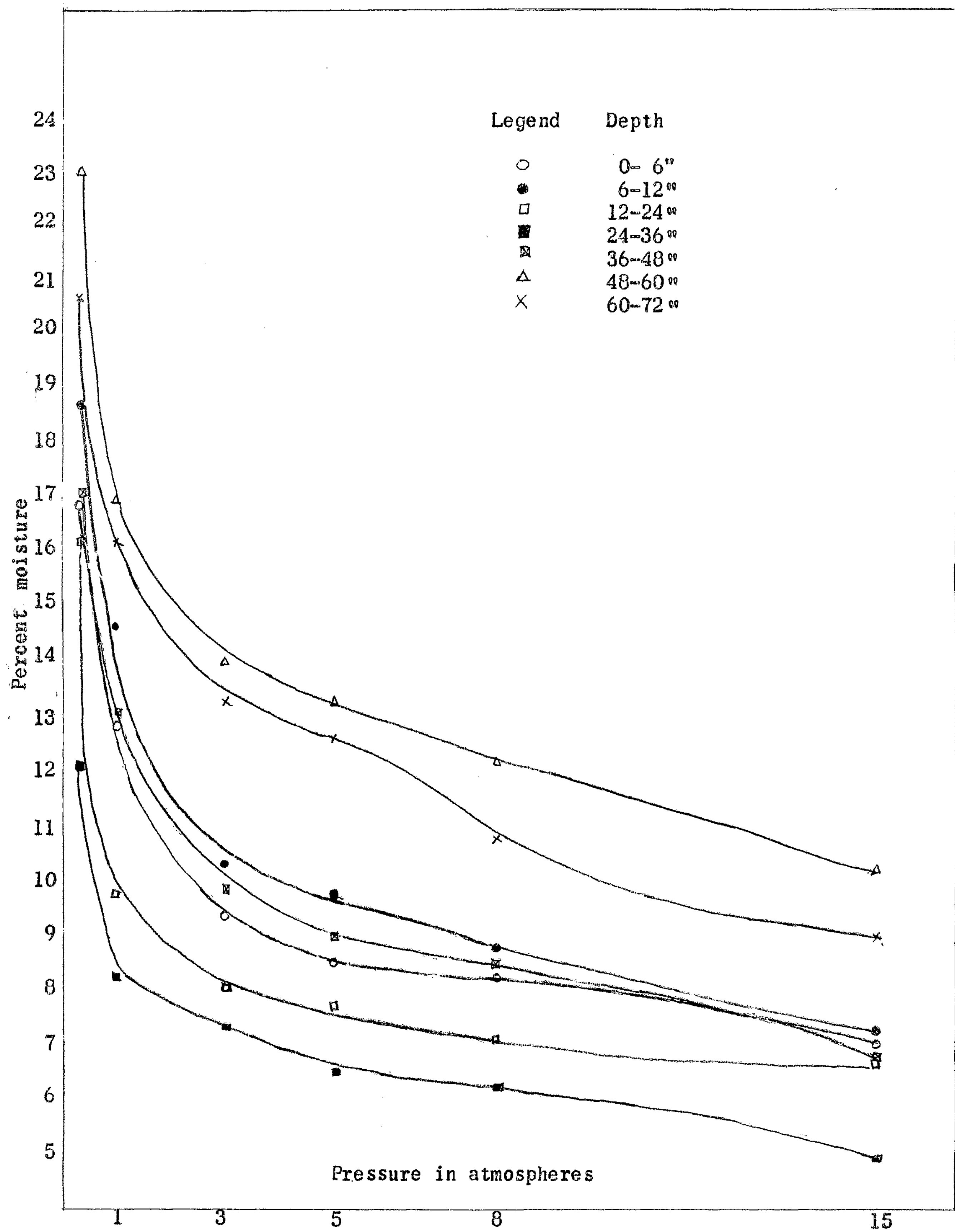


Figure 10. Moisture retention curves, replication III, irrigated

Table 18. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. III in the Irrigated Plots.

Depth	A.M.H.C.*	Texture	Percent Sand	Percent Silt	Percent Clay
0--6"	.88	Loam	45.00	39.25	15.75
6-12	1.07	"	36.00	45.25	18.75
12-24	1.72	"	38.75	40.50	19.75
24-36	1.37	Sandy loam	58.75	25.25	16.00
36-48	1.97	Loam	46.75	31.25	22.00
48-60	2.42	Clay loam	27.75	44.75	28.00
60-72	2.17	Clay	30.75	24.00	45.25
Total	11.60				

*A.M.H.C. = Available moisture holding capacity, expressed as inches

Table 19. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. III in the Dryland Plots.

Depth	A.M.H.C.*	Texture	Percent Sand	Percent Silt	Percent Clay
0--6"	.86	Silt Loam	24.75	62.75	13.00
6-12	.99	Loam	36.75	41.25	22.00
12-24	1.72	"	41.75	38.25	20.00
24-36	1.40	Sandy loam	66.75	22.25	11.00
36-48	1.34	" "	66.75	22.25	11.00
48-60	1.58	" "	56.75	24.25	19.00
60-72	2.39	Clay loam	28.50	44.00	27.25
Total	10.28				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

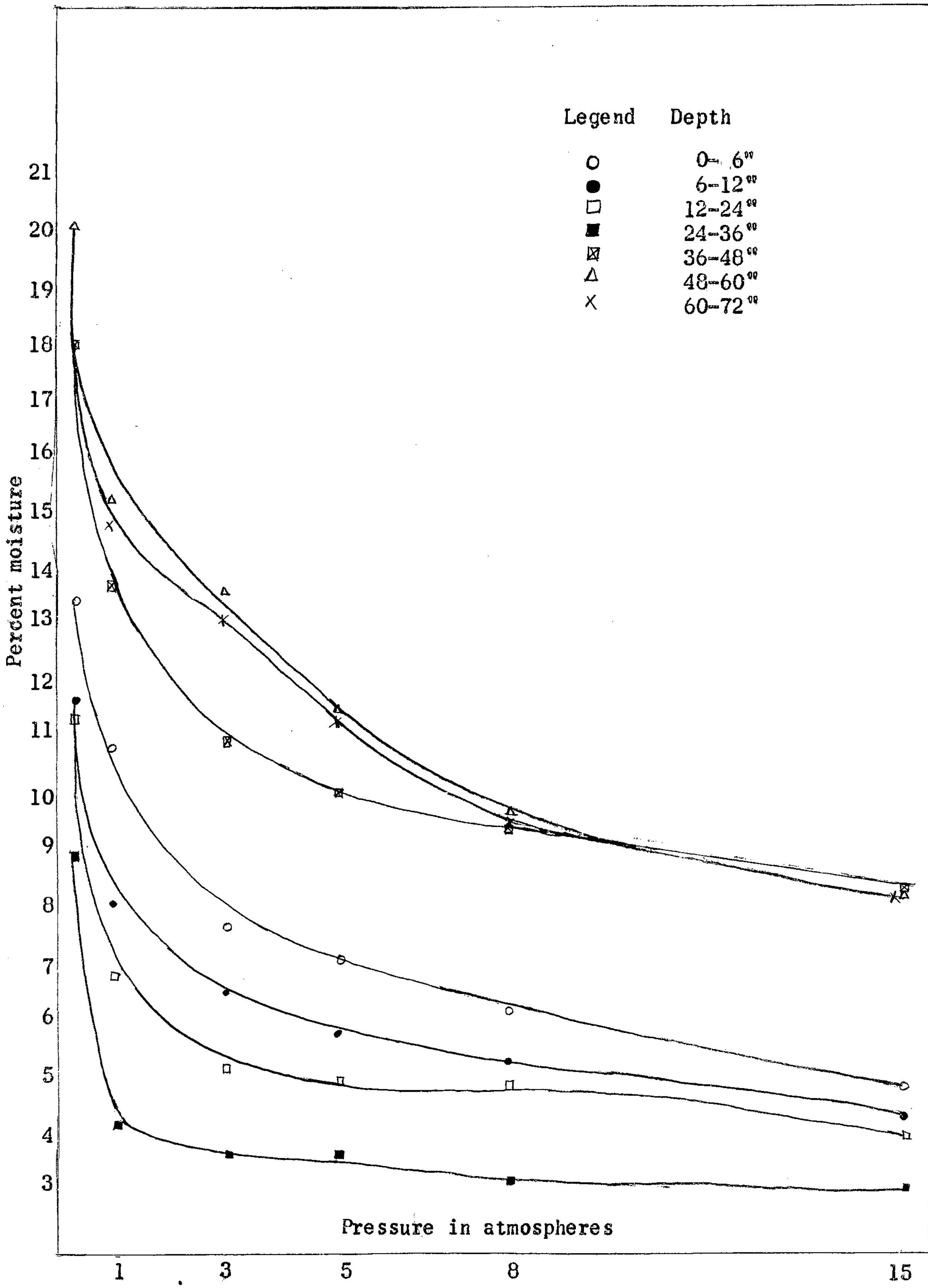


Figure 11. Moisture retention curves, replication IV, dryland

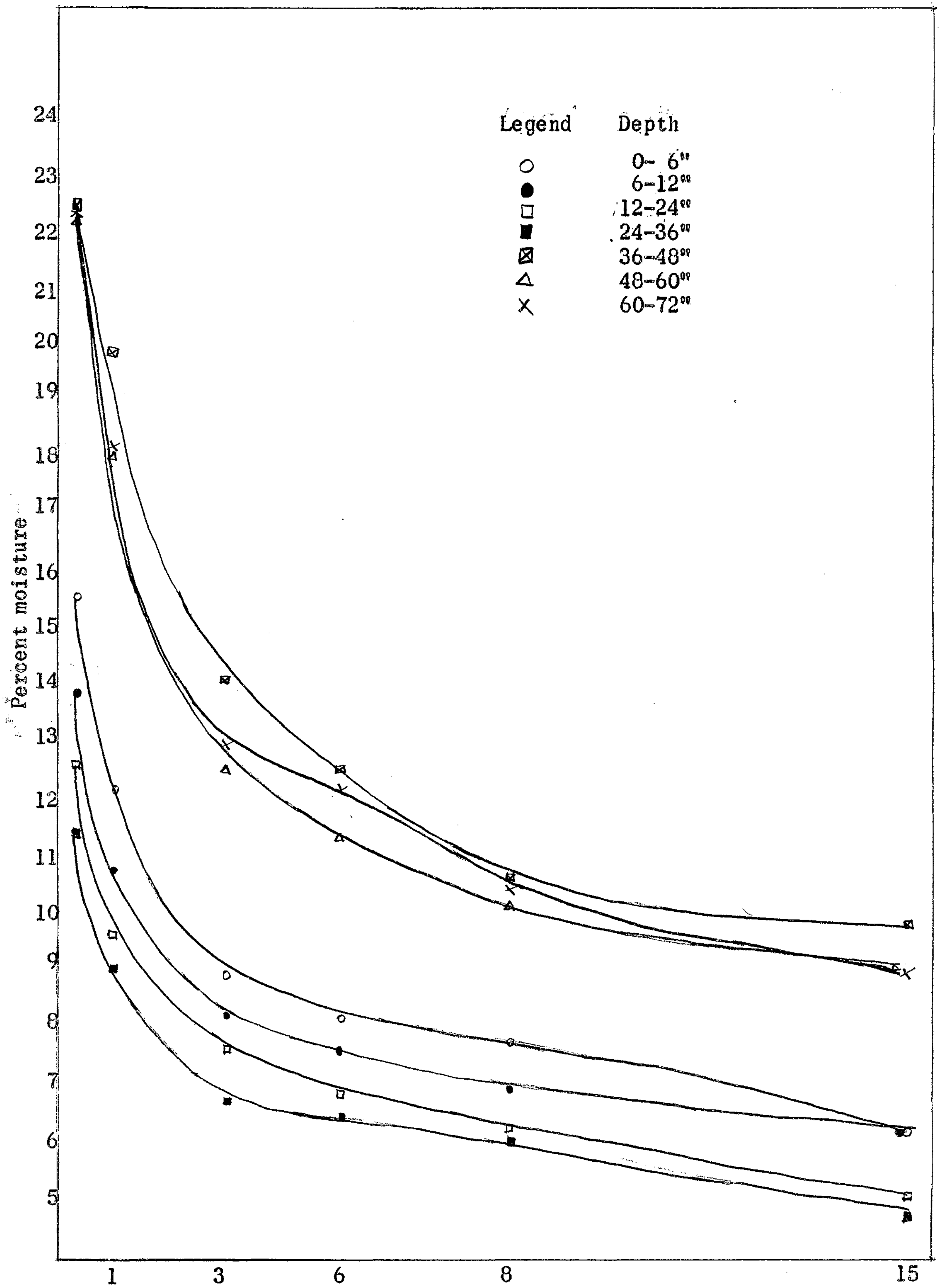


Figure 12. Moisture retention curves, replication IV, irrigated

Table 20. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. IV in the Irrigated Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.98	Loam	47.25	38.00	14.75
6-12	.73	Sandy loam	59.25	26.00	14.75
12-24	1.14	Sandy loam	64.75	20.50	14.75
24-36	1.29	Sandy loam	61.00	27.50	11.50
36-48	2.47	Loam	34.75	41.00	24.25
48-60	2.41	Silt loam	25.00	54.50	20.50
60-72	1.94	Loam	37.00	38.50	24.50
Total	10.88				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

Table 21. Available Moisture and Percent of Sand, Silt, and Clay in the Moisture Sampling Location of Rep. IV in the Dryland Plots.

			Percent		
Depth	A.M.H.C.*	Texture	Sand	Silt	Clay
0--6"	.79	Sandy loam	53.00	32.50	14.50
6-12	.70	Sandy loam	59.25	27.25	13.50
12-24	1.38	Sandy loam	62.25	25.25	12.50
24-36	1.12	Sandy loam	69.00	24.25	6.75
36-48	1.86	Sandy loam	60.00	21.25	18.75
48-60	2.20	Loam	28.00	48.25	23.75
60-72	1.95	Loam	35.25	43.00	21.75
Total	10.00				

*A.M.H.C. = Available moisture holding capacity, expressed as inches.

atmosphere level.

The following formula was used in determining the available moisture holding capacity of each individual moisture sampling depth.

$$D = \frac{(FC-WP)\ Vd}{100}$$

FC = The percent moisture at field capacity.
WP = The percent moisture at the wilting point.
V = The apparent specific gravity or volume weight.
d = The depth of soil in inches.
D = The equivalent depth of water in inches.

Volume Weights:

Volume weight data, by depths, for the four replication are presented in Table 22. The volume weight of the soil was determined by using the following formula:

$$\text{Volume weight} = \frac{\text{Weight of soil (dry)}}{\text{Volume of soil (calculated from the dimensions of the soil sampler)}}.$$

In calculating the available water holding capacity of the soil, the average volume weights of the dryland and irrigated plots of each replication were used. The volume weights of each moisture sampling depth vary with like layers of the other profiles, thus the overall profiles are comparable.

Table 22. Volume Weights, Grain Sorghum Experiment, Lake Carl Blackwell, 1955.

Depth	Rep. I	Rep. II	Rep. III	Rep. IV
0- 6"	1.54	1.63	1.49	
6-12	1.52	1.58	1.54	1.58
12-24	1.54	1.47	1.50	1.56
24-36	1.59	1.57	1.59	1.58
36-48	1.57	1.58	1.58	1.62
48-60	1.57	1.42	1.56	1.55
60-72	1.57	1.46	1.55	1.50

The yield data indicate that the experimental site lacks sufficient uniformity to be acceptable as a site for a conventional soil fertility experiment. Differences due to treatment would have to be quite wide before they could be segregated from the effects of soil heterogeneity and experimental error.

Grain protein and phosphorus data are variable but probably not any more variable than to be expected with the wide fluctuations in yield.

Although the chemical analysis data (soil) indicate heterogeneity in phosphorus and pH with replications, it alone does not indicate sufficient variability to make the site undesirable.

The physical data show no more variability than would be expected in a block of alluvial soil deposited by a small stream.

The uniformity data show that chemical test and physical examination of the soil are not sufficient criteria for assessing the homogenity of a soil area. Productivity data must be available before one can be sure of the uniformity of a soil area.

SUMMARY AND CONCLUSIONS

An experiment was conducted with Redlan grain sorghum, in the Lake Carl Blackwell Area, to determine the consumptive use of grain sorghum in Central Oklahoma and to determine whether or not the experimental site is sufficiently uniform for use as a site for a fertility experiment.

Consumptive Use of Moisture by Grain Sorghum:

Grain sorghum under irrigation consumed very little water from below a depth of 4 feet while sorghum under dryland conditions obtained a relatively large amount of water from the 5th and 6th feet of soil.

Grain sorghum under both dryland and irrigated conditions used practically the same amount of water for the first 53 days of the growing period, thereafter, due to drought conditions, there was a rapid decline in water use on the dryland plots.

The highest use of water under irrigation, which occurred during the heading stage, was .31 inches per day for a 16 day period. It was from the 68th to the 83rd day after planting and fell between August 8 and August 24.

The highest water use under dryland conditions was .25 inches per day for a 13 day period between July 12 and July 23.

The total consumptive use for the irrigated plots was 22.65 inches. The average daily use for the growing season on the irrigated plots was .19 inches.

The total consumptive use for the dryland plots was 13.42 inches. The average daily consumptive use for the growing season on the dryland plots was .11 inches.

The irrigation requirement for the grain sorghum was 9.20 inches.

The Suitability of an Alluvial Soil for Field Experiments:

The yields on both the dryland and irrigated plots were quite erratic. The average grain yield on the dryland plots was 48.2 bushels per acre. The average grain yield on the irrigated plots was 90.9 bushels per acre. The coefficient of variability on the yield data was 22.86 percent.

Grain protein and phosphorus data were variable but did not show as much variation as the yield data. Coefficients of variability for these were 8.17 and 12.88 percent respectively. The protein content of the grain was decreased by irrigation while the phosphorus content was increased.

Chemical and physical analyses of the soil and chemical analyses of the grain showed some heterogeneity but did not give conclusive evidence that the site was undesirable for a fertilizer experiment. The grain yield data showed that the site is undesirable for use as a location for a fertilizer experiment.

LITERATURE CITED

1. Barrett, W. C. and C. H. Milligan, 1953. Consumptive water use and requirements in the Colorado River area of Utah. Utah Agri. Exp. Sta. Spec. Report No. 8.

2. Blaney, H. F., 1952. Consumptive use. Trans. Amer. Soc. Civ. Engr. 117: 949-976.

3. _______, and W. D. Criddle, 1949. Determining water requirements in irrigated areas from climatological and irrigation data. Division of Irrigation and Water Conservation. S. C. S., U. S. D. A., TP-96.

4. Bloodgood, D. W. and A. S. Curry, 1925. Net requirements for irrigation water in the Mesilla Valley. New Mexico Agri. Exp. Sta. Bul. 149.

5. Bouyoucos, G. J., 1936. Directions for making mechanical analysis of soil by the hydrometer method. Soil Sci. 42: 225-229.

6. Feustel, I. C. and H. G. Byers, 1936. The comparative moisture-absorbing and moisture-retaining capacities of peat and soil mixtures. U. S. D. A. Tech. Bul. 248.

7. Fortier, S., 1928. Irrigation requirements of the arid and semi-arid lands of the Missouri and Arkansas River Basins. U. S. D. A. Tech. Bul. 36.

8. _______, and S. H. Beckett, 1942. Evaporation from irrigated soils. U. S. D. A. Exp. Sta. Bul. 248.

9. _______, and A. A. Young, 1933. Irrigation requierments of the arid and semiarid lands of the Pacific Slope Basins. U. S. D. A. Tech. Bul. 379.

10. _______, and _________, 1933. Irrigation requirements of the arid and semiarid land of the Southwest. U. S. D. A. Tech. Bul. 185.

11. Hansen, V. E., 1955. Infiltration and soil water movement during irrigation. Soil Sci. 79: 93-105.

12. Harris, K. and R. S. Hawkins, 1942. Irrigation requirements of cotton on clay loam soils in the Salt River Valley, Arizona. Ariz. Agri. Exp. Sta. Bul. 181.

13. Marr, J. C., 1927. The use and duty of water in the Salt River Valley. Ariz. Agri. Exp. Sta. Bul. 120.

14. McDowell, C. H., 1937. Irrigation requirements of cotton and grain sorghum in the Wichita Valley of Texas. Texas Agri. Exp. Sta. Bul. 543.

15. Miller, E. C., 1916. Comparative study of the root systems and leaf areas of corn and the sorghums. Jour. Agri. Res. 6: 311-333.

16. Musick, F., 1954. Consumptive use of corn, grain and forage sorghums in Oklahoma. Masters Thesis, Oklahoma A. and M. College.

17. Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S. D. A. Cir. 939.

18. Peech, M., L. A. Dean, L. T. Alexander, and J. F. Reed, 1947. Determination of exchangeable potassium, sodium, and calcium. U. S. D. A. Cir. 757.

19. Peele, T. C., O. W. Beal, and F. F. Lesene, 1948. Irrgation requirements of South Carolina Soils. Agri. Engr. Jour. 29: 157-158.

20. Richards, L. A., 1941. A pressure membrane extraction apparatus for soil solution. Soil Sci. 51: 377-386.

21. Russell, J. C., 1939. The effect of surface cover on soil moisture lost by evaporation. Proc. Soil Sci. Amer. 4: 65-70.

22. Shelton, W. R., and H. J. Harper, 1941. A rapid method for the determination of total phosphorus in soil and plant material. Iowa State College Jour. Sci. 15: 403-413.

23. Shockley, D. R., 1955. Capacity of soil to hold moisture. Agri. Engr. Jour. Vol. 36: 109-112.

24. Thorne, D. W. and H. P. Peterson, 1949. Irrigated soils, their fertility and management. The Blakiston Co., Philadelphia.

25. Veihmeyer, F. J. and A. H. Hendrickson, 1949. Methods of measuring field capacity and permanent wilting percentage of soils. Soil Sci. 68: 75-94.

26. Whitt, D. R., 1955. Irrigation consumptive use. Assoc. South. Agri. Workers. Proc. 52: 26-27.

27. Young, A. A., 1945. Irrigation requirements of California crops. Div. of Water Res. Calif. Dept. Pub. Works Bul. 51.

APPENDIX

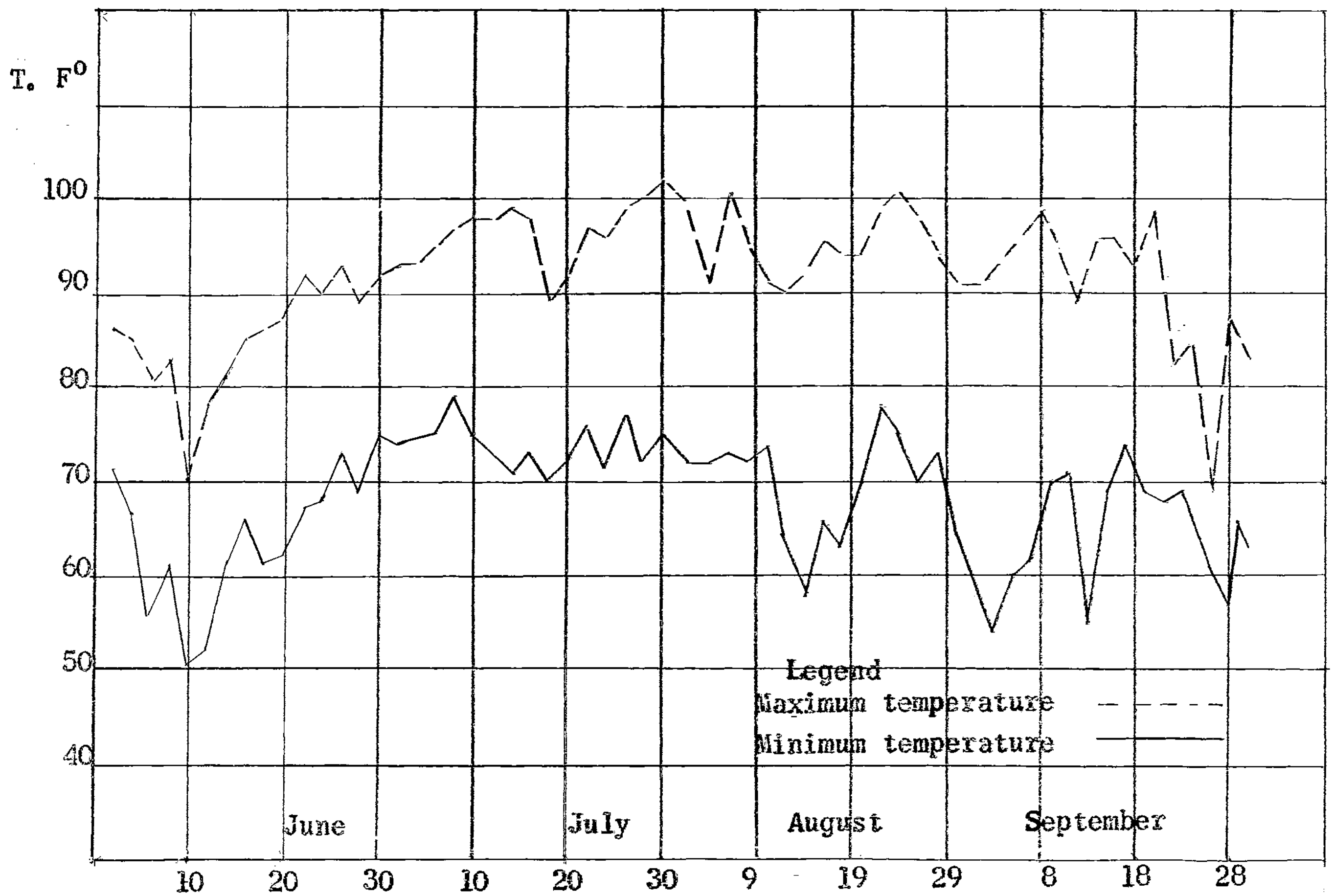


Figure 13. Maximum and minimum temperatures at Stillwater, Oklahoma (based on even days)

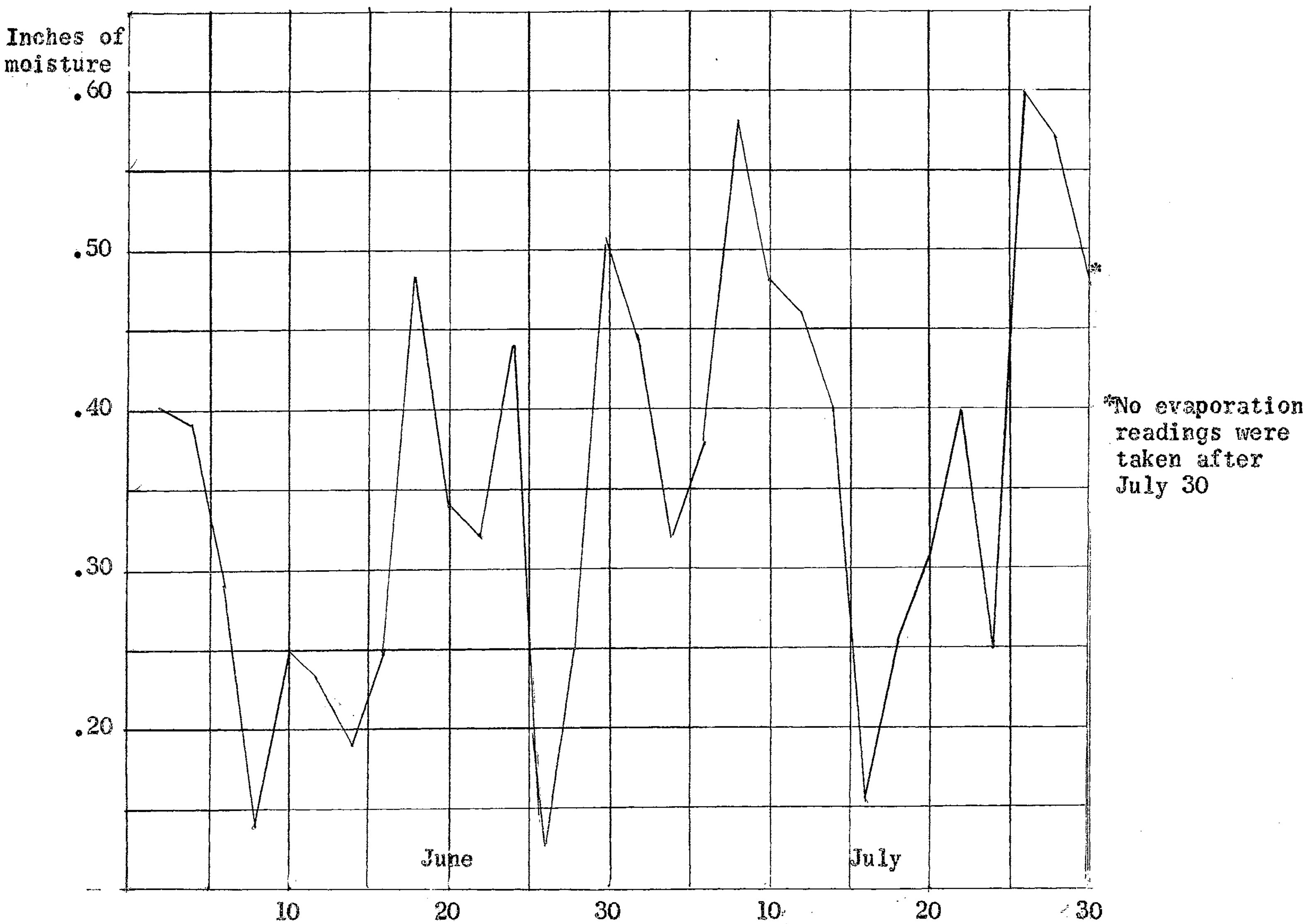


Figure 14. Evaporation from an open pan at Stillwater, Oklahoma
(based on even days)

VITA

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Candidate for the Degree of

Master of Science

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