CONSUMPTIVE USE OF WATER BY COTTON AT ALTUS, OKLAHOMA, 1956

By

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PREFACE

The experimental work for this thesis research project was performed under the Agricultural Engineering Department as part of Oklahoma Agricultural Experiment Station Project No. 622. The main objectives were to determine daily, peak daily, and seasonal consumptive use of water by cotton. The location for the experimental field plots was the Irrigation Research Station, Altus, Oklahoma.

The results presented in this study should help in the selection of a more economical and efficient irrigation schedule. Efficient irrigation is required for profitable irrigation, and this can only be made possible through intensive irrigation research.

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CHAPTER I

INTRODUCTION

Irrigation is the artificial application of water to soil to assist in the production of crops.

Scientific irrigation involves a knowledge of the available water supply, its conservation and application to the land, the characteristics and needs of the different soils, and the requirements of the various crops to be produced.

In general, irrigation is most extensively practiced in arid regions where agriculture without it is hazardous or impracticable. Irrigation is also applied to land in the semi-arid regions and to special crops in the humid regions to increase yields. In fact, there are comparatively few regions so free from occasional drouth that irrigation would not be profitable if it could be provided cheaply.

An irrigation region has certain advantages over a humid region in the production of crops. Being able to supply the quantity of water needed at the correct time is an advantage. The soil of arid regions is apt to be better supplied with mineral plant foods that have not been leached out by excessive rain and sunlight and which are important factors in plant life. Growth is more intense and constant in arid regions than in humid regions. If sufficient care and skill are applied to secure the full benefit of these important advantages, the acreage yields under irrigation may be far larger than under natural precipitation.

The proper use of irrigation water is perhaps the most fundamental problem in crop production in regions where crops are grown under irrigation. Studies on irrigation in various parts of the world have shown that an irrigation practice is influenced by many factors, among which are kind of crop grown, nature of soil, amount and distribution of rainfall, temperature, and evaporation. Conditions vary widely in different regions and make it difficult to develop a suitable and rational irrigation practice.

It is not possible to determine to what extent insufficient rainfall fails to supply the needs of plants for water without first knowing their water requirements. Therefore, the determination of rates and amounts of evaporation and transpiration from land areas under different types of cover in various parts of the country are major research problems.

A determination of the consumptive use of water by crops is necessary to produce optimum yields and to be a guide in the design and operation of an economical irrigation system. A basic problem, common to all participants in the field of irrigation, is when to irrigate and how much to irrigate. Again, this problem of determining the consumptive use pattern for the growing season of the crop, in particular, is required. The consumptive use pattern of a crop is known to vary according to the type of crop, stage of maturity, and climatic factors during the growing season.

A thorough knowledge of the consumptive use pattern is necessary for determining an irrigation schedule which will avoid the common problem of waiting too long to irrigate and, also, the problem of excessive irrigation. Both of these common mistakes in scheduling irrigations are known to result in decreased yields. The lack of sufficient moisture in this experiment was evident in both appearance and decreased yields. Excessive irrigation is an uneconomical practice, and it can also reduce yields due to keeping the soil moisture level too high. With a knowledge of the variation of consumptive use, an irrigation schedule can be set up that will irrigate the optimum acreage for the greatest net return.

CHAPTER II

OBJECTIVES

The objectives of this research project were as follows:

1. Determine the consumptive use of water by cotton for optimum yields in southwestern Oklahoma, 1956, by the soil moisture depletion method and the field plot method.
    a. Determine the seasonal transpiration pattern.
    b. Determine the peak average daily transpiration between irrigations.
    c. Determine the peak monthly transpiration.
    d. Determine the seasonal transpiration.
    e. Determine the total seasonal moisture use.
2. Determine the effect of varying the amounts of fertilizer on the yield of the cotton of the different water treatments.
3. Study the reliability of the electrical resistance method for determining when to irrigate.

CHAPTER III

REVIEW OF LITERATURE

Definition of Terms

The writer believes it necessary for the reader to fully and correctly understand the following terms, as defined by Young (26), before reading this thesis.

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

Consumptive Use (evapo-transpiration): The sum of the volumes of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil or intercepted precipitation on the area in any specified time, divided by the given area. 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 is transpired and used directly in the building of plant tissue in a specified time. It does not include soil evaporation. 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 rapid 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 based 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 percentage of the dry weight of the soil or 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.

Real Specific Gravity: The ratio of the weight of a single soil particle to the weight of a volume of water equal in volume to the particle of soil.

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.

Factors Affecting Consumptive Use

There are several independent and related variables that will affect the consumptive use of water by plants. These factors are not necessarily constant and are known to differ with locality and fluctuate from year to year. Most of these factors are related to the natural influences, such as climate, water supply, type of vegetation grown, soil, and topography.

Consumptive use is probably affected more by temperature than by any other factor. Abnormal low temperatures may retard plant growth, and unusually high temperatures may produce dormancy. Consumptive use is known to vary even in years of equal accumulated temperatures because of the deviations from the normal seasonal temperature. Transpiration is not only influenced by temperature, but also by the area of the leaf surface and physiological needs of the plant, both of which are related to the state of maturity.

Evaporation and transpiration are both accelerated by days of low humidity and slowed during periods of high humidity. If the average relative humidity percentage is low during the growing season, a greater use of water by vegetation can be expected.

Wind or moving air will cause the rate of evaporation to increase from that of a still, calm day. Hot, dry winds and other unusual wind conditions during the growing period will greatly affect the amount of water utilized by the plant.

Latitude is also known to have considerable influence on the rate of consumptive use of water by various plants. Due to the rotation of the earth and axial inclination, the hours of daylight during the summer are much greater in the northern latitudes than at the equator. The longer days 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.

The preceding factors discussed have been concerned with natural factors. The physical factors should not be omitted as they have a definite effect on consumptive use. The physical factors include the method of delivery to the farm, layout of farm as to proper irrigation system design, preparation of land for irrigation, and the method of applying the water to the land. Noxious weeds can increase consumptive use by adding undesirable and unnecessary vegetation. Plant diseases and harmful insects can inhibit plant growth and thereby reduce consumptive use.

Methods of Determining Consumptive Use

The six most common methods of determining consumptive use according to Israelsen (16) are as follows: tank and lysimeter experiments, field experiment plots, soil moisture studies, analysis of climatological data, integration method, and inflow-outflow for large areas. The encountering of problems are common regardless of the method used.

For the tank and lysimeter experiment method to be reliable for determining consumptive use, natural conditions need to be reproduced as closely as possible. The tank needs to be located in an area in which the natural growth will be the same inside the tank as outside. The tanks are usually two or three feet in diameter and six-feet deep. The lack of being able to reproduce the natural conditions can be attributed to limitations of the soil, size of tank, regulation of water supply, and sometimes environment.

The field plot experiment method of determining consumptive use is found to be more reliable than the tank and lysimeter method. The procedure for determining consumptive use by this method is to measure the volume of water applied to the plot and prevent or measure any surface runoff that might occur. The water should be applied in small depths, not to exceed five inches, to prevent percolation of water below the root zone. It is better for the water table to be low so that no water will be supplied to the plants in the plots by capillary soil moisture.

Consumptive use determination by the soil moisture study method is widely used and considered one of the more dependable methods. The soil needs to be fairly uniform and the water table low enough that ground water fluctuations will not reach the root zone. Soil moisture samples are taken at various depths in the root zone before and after each irrigation and also between irrigations. The soil moisture samples are dried, and the percent of moisture is figured on the oven-dry weight basis. From the moisture percentage, the water in acre-inches can be computed.

The analysis of climatological data has been an aid to irrigation engineers for determining consumptive use formulas that will give fairly reasonable and accurate results. Several individuals have attempted to develop these formulas, but Blaney's (3) formula is probably more widely accepted than any other. His formula is based on mean monthly temperature and monthly percentage of daytime hours of the year. Expressed mathematically, $U = KF = \Sigma kf$, in which U is the consumptive use of water in inches by the crop for any period; F is the sum of the monthly consumptive use factors for the period (sum of the products of mean monthly temperatures, and monthly percentage of daytime hours of the year); and K is the empirical consumptive use coefficient.

The integration method requires a knowledge of unit consumptive use of water and acreages of crop, natural vegetation, bare land, and water surfaces. The consumptive use is then the summation of the products of unit consumptive use for each crop times its area, plus the unit consumptive use of natural vegetation times its area, plus evaporation from bare land times its area, plus water surface evaporation times water surface area.

The inflow-outflow method is more applicable to large areas. The consumptive use for the area is determined from the amount of water that flows into the area during the one-year period, plus the yearly precipitation in the area, plus the ground water storage at the beginning of the year, minus the water in ground storage at the end of the year, minus the yearly outflow from the area.

Consumptive Use of Water by Cotton

In the Wichita Valley of Texas, McDowell (20) reported the amounts of irrigation water ranged from 2 to 34 acre-inches in addition to the rainfall during the season. The largest yields in cotton were obtained where 28 to 32.4 acre-inches of water, including the rainfall, was used during the growing season; the average was 16 inches of irrigation water. For the five years, the highest average yield was obtained on plots receiving a total of 30 inches of water. The total amount of water received by a plot included the water applied in preirrigation three weeks before planting and that applied by irrigation up to harvest, plus whatever rainfall which occurred during that period. The yield decreased as the amount of water was increased, or decreased from 30 inches.

In actual irrigation practice, Marr and Smith (19) reported that on 13 different farms located on Maricopa sandy loam soil in the Salt River Valley of Arizona, the yield of lint cotton increased as the amount of irrigation water was increased. The average yield of cotton increased from 175 pounds per acre where 1.22 acre-feet of water was applied, to 650 pounds per acre where 3.5 acre-feet was applied.

Marr and Hemphill (18) studied the amount of water needed by the cotton crop in the southwestern United States. In the Salt River Valley of Arizona, the quantity of water used for cotton varied from 2 to more than 4 acre-feet. At the United States Field Station, Sacaton, Arizona, in 1923, Pima cotton yielded 1,391 pounds of seed cotton per acre, while Acala yielded 2,269 pounds with an application of 2 acre-feet of water per acre. In the Imperial Valley of California, the quantity of water used ranged from 2.5 to 6 acre-feet. The larger quantity of water was needed on very sandy soils, and the smaller amount on fertile, sandy loam soils with a larger water-holding capacity. In the upper Rio Grande and Pecos Valleys in New Mexico and Texas, from 8 to 20 acre-inches of water was required. In the lower Rio Grande Valley of Texas, 3 to 21 acre-inches of water was required, depending on the amount and distribution of rainfall. In the latter region, one to four irrigations were given to the cotton crop.

Beckett and Dunshee (2) found that the yield of cotton increased in general as the amount of irrigation water was increased on sandy loam soil in southern San Joaquin Valley of California. During the five years 1926-30, cotton that received 22.6 acre-inches of water in three irrigations produced an average yield of 603 pounds of lint per acre, while cotton that received 28.6 acre-inches in seven irrigations produced 1,034 pounds of lint per acre.

In New Mexico, Curry (8) conducted experiments from 1925-30 to determine the irrigation requirements of Acala cotton in the Mesilla Valley. He reported that cotton has a wide adaptation with respect to amounts of irrigation water applied. He found that 18.9 to 21.5 acre-inches of water applied in four to five irrigations produced almost as large yields of cotton as 41 acre-inches applied in ten irrigations.

Fortier and Young (11) conducted experiments to determine the amount of water required to produce cotton in the Pacific Slope Basin. They reported that the average maximum production of 2.06 bales per acre was obtained from 3.46 acre-feet of water applied in seven irrigations during the years 1926-30. This amount included a six-inch preirrigation and rainfall.

At the New Mexico Station, Bloodgood and Curry (4) applied 20 acre-inches of water to cotton in three irrigations and obtained a yield of 819 pounds of lint per acre. They stated that the general practice of irrigating cotton in the Mesilla Valley is to apply about 18 inches in three or four irrigations.

McDowell (20) reported on growing cotton under irrigation in the Wichita Valley of Texas for the years 1932-33. He stated that the largest yield of cotton, 450 pounds of lint per acre, was obtained from 28.54 acre-inches of water. When the water was increased to 31 acre-inches, the yield was reduced to 427 pounds of lint per acre.

Fortier and Young (10) observed that in growing cotton at the New Mexico Station, on adobe soil overlying coarse sand, a total of 1,775 pounds of seed cotton per acre was obtained when 33 acre-inches of irrigation water was applied in five to six irrigations. When the water was increased to 37 inches, the yield was reduced as much as 200 pounds of seed cotton per acre. With cotton grown on worn-out, fine sandy soil at the Medina Project, Medina, Texas, a maximum production of 260 pounds of lint per acre was obtained with 22 acre-inches applied in one to six irrigations.

Cook and Martin (9), Camp (7), Marr and Hemphill (18), and Hudson (15) discussed in detail irrigation methods best suited to cotton. They stated that the general appearance of the cotton plant is a good index as to the time to apply water. The apparent quantity of water previously applied could not be accepted generally as a safe basis upon which to determine the time for subsequent irrigations. According to information at that time, the appearance of the crop offered the only dependable guide.

The foundation for maximum production of cotton was laid only if sufficient water was given the plants during the early stage of development to keep them in a healthy, growing condition. Wilting of some of the plants in the middle of the day during early growth was not harmful and was not conclusive evidence that a general irrigation was needed.

When the cotton plants began fruiting and flowering, they needed and used a maximum quantity of water, with subsequent irrigations frequent and heavy enough to prevent any serious wilting during the middle of the day. When the plants indicated a need for irrigation, neglect for only a few days was likely to result in serious loss from shedding of young squares and bolls. Careful observations showed that the color of the cotton foliage in the dry areas of the field appeared somewhat darker with a slightly bluish tinge; therefore, the cotton in need of water was recognizable from a distance. The color change was noted even before the plants began to show signs of wilting and was a definite warning that water was needed. Another sign upon which growers of upland cotton relied was the color of the terminal growth. When in a thriving condition, the plants would ordinarily show three to four inches of tender, light-green stem between the terminal bud and the reddish coloring of the stalk. A rapid extension of the reddish coloring towards the terminal bud showed a checking of growth and indicated a need for irrigation. When the flowers could be seen extending above the terminal buds of the plants and a decided yellow color was noted over the field, it was evident that irrigation had been postponed too long. An excess of water was usually indicated by a waxy sheen on the foliage, by large coarse leaves, and by excessive terminal growth.

In California in 1954-55, studies on the irrigation of cotton were conducted by Stockton and Doneen (22). Research was conducted as to the relationship of soil moisture to growth, physiological development, and yield of the plants. As the plants developed in size and the days became warmer, moisture use rates increased to approximately 0.15 inches per day for June, 0.20 inches per day for the first part of July, and 0.30 inches per day or more in latter July and throughout August, with a rapid decline in September.

The high yielding cotton plot of 2.92 bales per acre was one that received ten irrigations through the season for a total of 30 inches of water applied. The treatment that received 26 inches of water yielded 2.90 bales per acre, and the treatment that received 52.5 inches of water yielded 2.81 bales per acre.

Adams, Veihmeyer, and Brown (1) in their investigation of cotton irrigation in the San Joaquin Valley of California were concerned mainly with plant responses to irrigation. A number of irrigation level treatments were used, but the main terms used were "wet", "medium", and "dry". The objective for the "wet" treatment was to maintain soil moisture above the permanent wilting percentage. The "dry" treatment was unirrigated. The "medium" treatment soil moisture was not maintained as high as the "wet" treatment.

It was evident that if the soil moisture were allowed to remain at the permanent wilting percentage for extended periods, there would be a definite reduction in plant heights and yields. Between the principal "wet" and "medium" treatments, the yields of neither group were consistently higher nor lower than those of the other group.

An irrigation differential planting date experiment on cotton was conducted by Bloodworth, Burleson, and Cowley (5) at the Lower Rio Grande Valley Experiment Station during the 1955 season. They found that the timing of irrigation water applications to coincide with critical stages of cotton plant growth was very important. Yield of lint cotton, boll size, staple length, and oil content of the seed were not significantly affected by either irrigation differentials or planting dates. Irrigation water applied during the fruiting and boll maturity stages gave the greatest yield.

Thaxton (24) reported that from experiments on the High Plains of Texas, the quality of cotton may be affected by summer irrigation. Fiber studies made on cotton from irrigation tests at the Lubbock Station showed that the highest quality of cotton was produced with only a preplanting irrigation. The largest yield was made with two summer irrigations, but this produced the lowest quality cotton. Three summer irrigations reduced both yield and quality. A good compromise came from a late July irrigation which averaged about 100 pounds less lint but produced a much better fiber.

A study by Brown, Benedict, and Bryan (6) on the need of irrigation in the humid regions was conducted for the years 1950-54 in Arkansas. They reported there was a statistically significant increase in seed cotton yields as a result of irrigation. The average yield from all irrigated plots was 2,589 pounds per acre of seed cotton; for nonirrigated plots, it was 1,394 pounds per acre. This gave an increase of 1,195 pounds per acre, or an 86 percent increase due to irrigation. The daily consumptive use of water by plants from the irrigated soil was greatest during the peak fruiting stage of growth, after which it decreased considerably. The average daily consumptive use during the month of June was 0.13 inches; during July, it was 0.26 inches; and during August, it was 0.15 inches. The timing of each irrigation was based on the percentage of available moisture remaining in the soil at depths which varied with the method used to indicate soil moisture content. During the last two years of the experiment, irrigation was begun when available soil moisture was 50 percent.

Spooner and Caviness (21) reported in their study, which was to determine the critical stages for irrigating cotton, that irrigation increased the yield of seed cotton significantly for all irrigation treatments when compared with non-irrigation. The greatest increase in yield amounted to nearly a bale per acre and was obtained by irrigating throughout the growing season. The data indicated that the cotton plants may be allowed to wilt during their early growing period without greatly reducing the yield, but an adequate moisture supply must be available during the entire fruiting period if the highest yield were to be expected. The increase in yield due to irrigation was obtained by prolonging the effective fruiting period, rather than by increasing the fruiting at any given time.

A report by Harris, Hawkins, Cords, and Aepli (14) covered four years of work with differential irrigation schedules. The irrigation schedules were designed to determine the extent to which soil moisture supplies should be limited during the fruiting period and to ascertain the best time to change from abundant to limited soil moisture. The soil used had a water-holding capacity of 18 percent and a wilting point of 8 percent. There were no significant differences between the yields of plants irrigated at 8-percent soil moisture after midsummer and those irrigated at 10 percent during that same period. The report also stated that any condition retarding early growth tends to throw the plants into a vegetative condition during the fruiting season which was a detriment to the yield.

A six-year report on differential irrigation schedules with cotton was made by Harris and Hawkins (13). The irrigation schedules were designed to determine the best type of plant growth from planting to the fruiting period to obtain maximum yield. Results showed that plants which grew most rapidly from time of planting to July 31 and continued growth at a moderate to low rate from July 31 to September 10 were the highest in production. The plants which grew slowly from time of planting to July 31 and continued with slow growth from July 31 to September 10 were the lowest in production. Plants making intermediate growth prior to July 31 and comparatively rapid growth from July 31 to September 10 were intermediate in production. The data indicated that cotton plants should be allowed to reduce available soil moisture more completely between irrigations during the fruiting period than prior to this period, unless they were stressed too severely prior to fruiting.

Because of the need to know how many times to irrigate and when irrigation should stop, Stockton and Doneen (23) have been conducting experiments at Shafter, California. Irrigation frequency appeared to have little effect on yield and quality of cotton fiber until it was reduced to the point where cotton plants were allowed to wilt. Too many irrigations, even on well drained soil, appeared highly undesirable from both yield and quality standpoints. Twelve applications with a total of 34 inches showed the highest yield for 2.97 bales per acre. The yields decreased as the amount of water and number of applications were increased or decreased.

From a review of literature by Krantz, Swanson, Stockinger, and Carreker (17), they concluded that for maximum production of cotton, the plants should never wilt. Irrigation should be according to the needs of the plants, and not by the calendar. They reported that irrigation should start when the plants begin showing a need for water, and irrigation should continue until all the bolls which are expected to mature are set. Later irrigations were likely to cause undesirable vegetative plant growth.

Careful tests on cotton plants in the San Joaquin Valley, as reported by Whitney (25), showed that practically all the water that cotton required was about 29 inches per season, not counting evaporation or percolation losses. August was the month of greatest moisture use. Tests indicated the best yields of cotton were grown on land irrigated so frequently that the wilting point was never reached.

Irrigation experiments began in the Texas Brazos River Field Laboratory in 1952 as reported by Garrett (12) to determine the effect of irrigation in a humid region. The four water treatments used in the experiment were as follows:

1. The high moisture level was 50-percent available moisture or above.
2. The medium level treatment was maintained above 25-percent available moisture until the cotton began to bloom and then was raised to 50-percent available moisture.
3. The low moisture level was maintained at or above 25-percent available moisture throughout the growing season.
4. A nonirrigated plot was maintained.

The first year's results from the high moisture level treatment which received only 3 inches of irrigation were roughly 1,000 pounds of lint cotton per acre as compared with 632 pounds from the nonirrigated plot.

For the second year of the experiment, the high moisture level treatment produced 1,012 pounds of lint per acre with 9 inches of irrigation; the medium moisture level produced 786 pounds per acre with 7-1/2 inches of irrigation; the low moisture level produced 665 pounds of lint per acre with 4-1/2 inches of irrigation; and the nonirrigated produced 399 pounds of lint cotton per acre.

For the 1955 season, 14 inches of irrigation on the high moisture level plots produced 1,755 pounds of lint cotton per acre as compared with 500 pounds per acre for the nonirrigated plot.

CHAPTER IV

PROCEDURE

Location of Experimental Area

The Agricultural Engineering Irrigation Research Station near Altus, Oklahoma, was selected for the location of the experimental plots. The plots were located on Foard clay loam soil and were underlaid by a clay subsoil to a known depth of 60 inches. The soil was considered uniform over the entire experimental area.

Equipment Used

The irrigation water used on the experimental plots was delivered by the W. C. Austin Irrigation District. The water was delivered in open, unlined canals to the research station. The turnout structure and the water measuring device was a double submerged orifice type as illustrated in Figure 1. Open, unlined ditches were used to transport the water from the turnout to the experimental plots. The water was then transferred from the small head ditch to the plots by 3-inch siphons four-feet long.

A standard 8-inch nonrecording rain gage was used to measure the rainfall. A hygrothermograph was installed the first of August, but before that time no temperature or relative humidity percentages were recorded on the research station.

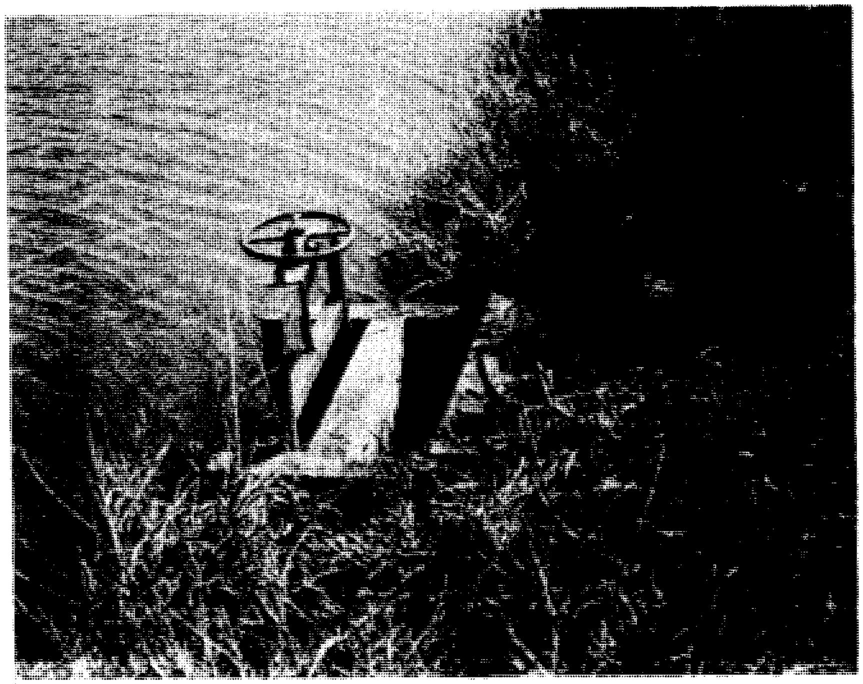

Figure 1. Double submerged orifice type water measuring device and turnout structure.

The soil moisture samples were taken with a standard soil sampling tube and were collected in 16-ounce soil sampling cans. The samples were dried in an infrared oven for one hour, and then the moisture percentage was figured on a dry weight basis. The moisture percentages that were calculated using the infrared oven were corrected to the standard oven. An electrical resistance soil moisture measuring device, Irrigage, was used on a separate water application treatment which was irrigated the same as the high moisture level treatment.

Plot Layout and Treatment Used

The statistical design for the plots was a completely randomized split plot. The design of the layout permitted a statistical analysis of the yields. There were five water treatments used and four replications of each treatment. Within each replication of each water treatment, there were four fertilizer treatments. Each replication of each water treatment consisted of eight rows approximately 150-feet long. The two outside rows of each plot were guard rows, thereby permitting 100 feet of the four center rows to be harvested for the test. Since there were four fertilizer treatments within each replication of each water treatment, the plots were split into quarters. The plot layout is best described by Figure 2. The variability in stand was accredited to lack of soil moisture.

Irrigation Procedure

The irrigation water was applied to the plots from the head ditch through 3-inch aluminum siphon tubes. The large siphons were selected to permit flooding of the plots so as to obtain a uniform distribution of water. Borders and berms encircled each plot to prevent any runoff of the irrigation water. The irrigation of a plot using the 3-inch siphons is illustrated in Figure 3.

Since the irrigation water supply was dependent on the W. C. Austin Irrigation District, no water was available for irrigation purposes until June 30. At this time, all water

150'	150'	150'	150'	
C A W_3 D B	D A W_3 B C	B D W_1 C A	A C W_3 B D	8 rows
A C W_1 D B	D A W_4 B C	A D W_1 B C	B D W_2 C A	8 rows
D C W_5 B A	B D W_2 A C	B C W_5 A D	C A W_4 B D	8 rows
B C W_1 D A	B A W_2 C D	A C W_5 B D	D C W_4 B A	8 rows
D A W_5 B C	B D W_3 C A	D A W_4 B C	A C W_2 B D	8 rows

Water Treatments

W_1 – No irrigation

W_2 – Irrigate after plants wilt one week

W_3 – Irrigate after plants wilt 24 hours

W_4 – Maintain soil moisture above 17 percent

W_5 – Irrigate same as W_4 and compare soil moisture percentages with Irrigage

Fertilizer Treatments

A – No fertilizer

B – 267 pounds of 15-15-0

C – 533 pounds of 15-15-0

D – 800 pounds of 15-15-0

Figure 2. Layout of cotton plots

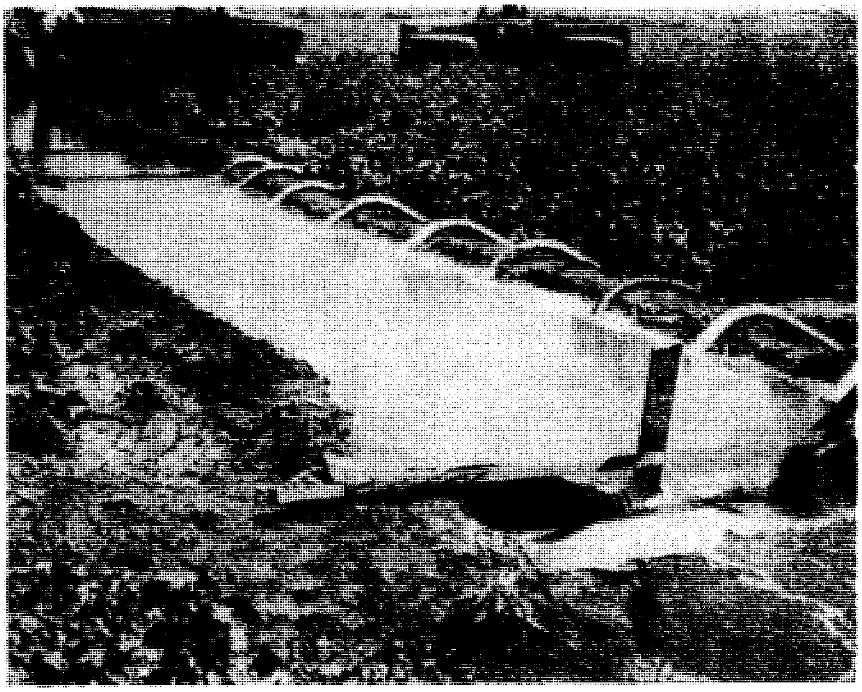

Figure 3. Flooding experimental plots with 3-inch aluminum siphon tubes.

treatments with the exception of W_1 (no water) received a 3-inch application. Thereafter, each water treatment received a 4-inch application as required to maintain its desired moisture level. The irrigations continued until after the first week in September. At this time, the water allocation for the research station had been exhausted.

After the first irrigation, the time to irrigate was determined by the following methods. The W_2 and W_3 water treatments were irrigated according to when they showed signs of wilting. The W_2 water treatment was irrigated one week after the first sign of permanent wilting. The W_3 water treatment was irrigated 24 hours after permanent wilting was observed. The W_4 was irrigated when the moisture percentage in the 6- to 12-inch depth dropped to approximately 17 percent. This moisture level was selected because in prior experiments there was no indication of cotton plant stress if a soil moisture percentage of about 17 percent was maintained in the first foot of the root zone. The W_5 was irrigated the same as the W_4 water treatment, and Irrigage readings were compared with the soil moisture percentages.

Crop Management Procedure

The variety of cotton selected for this experiment was Western Stormproof. The plots were planted May 9, 1956, with a two-row planter. The first emergence observed was May 14, 1956. After the rains in late May, there was considerable crusting of the soil. This hindered the emergence and required the use of rotary hoes to break the crust. An effort was made to eliminate the larger skips in the cotton rows by replanting them with a one-row planter, with the final stand of the cotton being approximately 21,950 stalks per acre.

The plots were cultivated June 12, and on the same day they were sprayed for cotton fleahoppers. The chemical used for this spraying was one pint of Dieldrin per acre. The plots were first hoed June 18, and the following day they were again sprayed for cotton fleahoppers using the same amount and type of chemical as before. The first fertilizer, 15-15-0, was applied June 25 in the liquid form as a side dressing. To get the various amounts of fertilizer on the subplots, the applications were repeated until the desired amount was obtained.

All the plots with the exception of the W_1 (no water) received a 3-inch irrigation June 30. The second cultivation on July 9 was to break the soil crust and eliminate weeds. The plots were again sprayed for fleahoopers July 11 with the chemical decreased to 3/4 pint per acre. Water treatments W_4 and W_5 each received a 4-inch irrigation on July 12. The second hoeing was on July 20 to eliminate the larger weeds that had been missed by the cultivator. Due to the infestation of the plants by cotton leafworms, the plots were sprayed July 21 with 1-1/4 pounds of DDT and 83/100 pound of Chloradane per acre.

Water treatment W_3 was given a 4-inch irrigation July 26 after the plants wilted 24 hours. After a week of wilting, water treatment W_2 was given a 4-inch irrigation. Spraying to eliminate leafworms was again required on July 28, but this time 1 pound of DDT was used and 2/3 pound of chloradane. Water treatments W_4 and W_5 were again irrigated July 30. The plots were sprayed again on August 4 for leafworms. Water treatments W_3, W_4, and W_5 were given a 4-inch application of water on August 10. Sprayings were again repeated August 19 and August 27 because of infestation by cabbage loopers. On August 24, W_4 and W_5 were again irrigated. The final irrigation for W_2 and W_3 was August 29 and for W_4 and W_5 was September 5.

Soil Sampling Procedure

Soil moisture samples were taken the day the cotton was planted with periodic samplings continued on the plots until the first irrigation. At this time, a prescribed sampling procedure went into effect. Samples were taken on the plots the day before they were to be irrigated, and then two days and four days after each irrigation. Biweekly sampling was then practiced until the next irrigation.

Composite samples were taken from the four replications of each water treatment at 6-inch intervals to a depth of 30 inches. Since the plots were flooded, the water distribution was fairly uniform. The samples were taken in a row midway betweem two plants of uniform stand so as to obtain a more reliable indication of the depleted soil moisture.

The standard method for determining soil moisture on the dry weight basis was used except an infrared oven was used to dry the samples instead of a standard oven. The infrared oven was calibrated to the standard oven with all soil moisture percentages corrected to the standard oven.

Undisturbed core samples for determining apparent specific gravity were taken with a Pomona soil sampler. Samples were taken at three different locations near the center of each foot depth of soil. The real specific gravity was determined by the use of a 150 ml. pycnometer bottle. A summary of real and apparent specific gravities, along with estimated and laboratory determined values for field capacity and wilting point, is given in Table VII of the appendix.

Use of Electrical Resistance Unit as an Irrigation Scheduling Guide

In each of the replications of the W_5 water treatment, an Irrigage stake soil unit was placed in the ground. This unit was located in one of the two center rows of the plot, approximately 20 feet from the head ditch. The unit was placed midway between two plants of uniform stand. On each of the stakes, there were four gypsum rings containing stainless steel electrodes. The gypsum rings were spaced on the stakes at 6 inches, 12 inches, 18 inches, and 24 inches from ground level. The Irrigage stake soil units were placed in the soil two weeks before the irrigation season began and were not removed until after the crop was harvested. Daily readings, as time permitted, were taken on each of the four stakes. The 6- and 12-inch readings were averaged to provide more reliability in determining when to irrigate.

Crop Yield Sampling Procedure

Since the plots were laid out in a split-plot design, four separate crop yield samples were taken from each plot. Each sample consisted of the yield from two rows, 50-feet long. The harvest rows were the inside four of the eight rows planted. The two outside rows on each side of the plots were used as guard rows. Midway in each plot was a 10-foot guard zone to allow for a change in fertilizer level. The 50-foot harvest rows were measured from the edge of the guard zone. A sketch of the harvest section is shown in Figure 4.

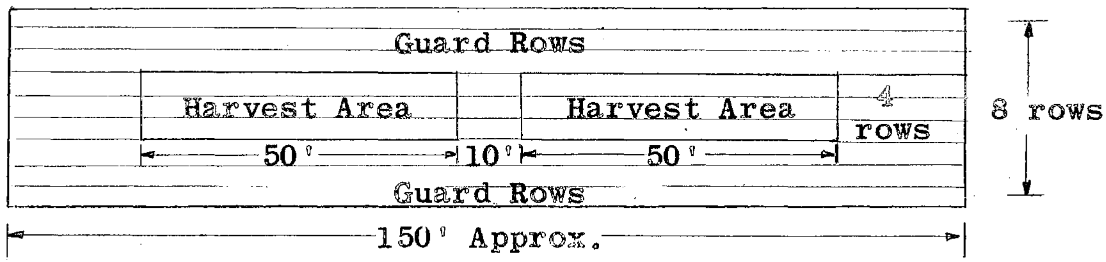

Figure 4. Sketch of harvest area within plot

The plots were first harvested on the fourth of September as there was a considerable amount of cotton open at that time. This harvesting was ginned and graded separately from the final harvesting which was November 23. The crop yield samples were bagged and labeled and taken to the gin at the Chickasha Experiment Station where they were ginned and graded. The samples were weighed to the nearest 1/100 of a pound.

Procedure for Calculations

The basic formula used for calculating transpiration is as follows:

$$d = \frac{P\ A_s\ D}{100}$$

where d = depth of soil moisture depletion in inches,

P = difference in percent of soil moisture between two determinations,

A_s = apparent specific gravity of the soil, and

D = depth of soil sampled in inches.

An attempt was made to determine the average daily transpiration rates between irrigations, but due to the erratic soil moisture levels encountered, this produced unreliable information. The consumptive use rates for the irrigation intervals were determined as follows:

$$\text{Total Consumptive Use (inches/day)} = \frac{\text{Irrigation (inches)} + \text{Rainfall During Irrigation Interval (inches)}}{\text{Number of Days in Irrigation Interval}}$$

In using this method, the soil moisture level was assumed to be the same before each irrigation.

The yields were statistically analyzed in order to determine if the water and fertilizer treatment means were significantly different. The new multiple range test was run on the water treatment means at the 1-percent and 5-percent levels to determine if there were significant differences in the mean yields.

CHAPTER V

RESULTS

Yield and Consumptive Use for Cotton

The cotton yields in pounds of lint per acre for the water and fertilizer treatments are summarized in Table I. The yields were statistically analyzed to determine if there were significant differences in the water treatments, fertilizer treatments, and their interaction. The analysis of variance, as listed in Table III, for the water treatments was highly significant. Neither the fertilizer treatments, nor the interaction between the water and fertilizer treatments was significant. The new multiple range test for significant difference between water treatment means at the 1-percent and 5-percent levels is presented in Table IV. Since W_4 and W_5 received the same water applications, there was no reason for a significant difference between these two means.

The relation between water treatment and yield in pounds of lint cotton per acre for each fertilizer treatment is illustrated in Figure 5. A difference can be noted in the water treatments, but there is very little difference in the yields due to the fertilizer treatments. It is apparent from the results of this experiment that a higher level of water

TABLE I

LINT COTTON YIELDS IN POUNDS PER ACRE

Fertilizer Treatments	Water Treatments				
	W_1	W_2	W_3	W_4	Means
F_A	173.48	335.51	480.24	1102.62	522.96
F_B	158.77	305.14	556.37	923.90	486.04
F_C	158.45	280.31	578.91	990.88	502.13
F_D	151.92	318.86	610.60	1017.02	524.60
Means	160.55	309.95	556.63	1008.60	
Number of Irrigations	0	3	4	6	
Inches of Water Applied	0	11	15	23	
Yield Increase in #/Acre Per Inch of Water		13.58	26.40	36.87	

TABLE II

AVERAGE NUMBER OF BOLLS PER STALK AND AVERAGE HIGHEST AND LOWEST BOLL PER STALK

Water Treatments	Average Number of Bolls Per Stalk	Average Height of High Boll (inches)	Average Height of Low Boll (inches)
W_1	5.6	11.5	4.2
W_2	7.5	14.8	5.5
W_3	10.3	18.3	5.3
W_4	18.2	24.4	3.9

TABLE III

ANALYSIS OF VARIANCE OF COTTON YIELDS

Source	d.f.	M.S.	F
Water Treatment	4	138.1744	82.0952**
Main Plot Error	15	1.6831	
Fertilizer Treatment	3	0.3146	
Fertilizer x Water	12	0.6146	
Subplot Error	45	0.7288	

TABLE IV

NEW MULTIPLE RANGE TEST FOR SIGNIFICANT DIFFERENCE

Water Treatments	W_1	W_2	W_3	W_5	W_4
Means for 1 Percent Level	1.23	2.37	4.25	7.49	7.72
Means for 5 Percent Level	1.23	2.37	4.25	7.49	7.72

Note: Any two means not underscored by the same line are significantly different.

Any two means underscored by the same line are not significantly different.

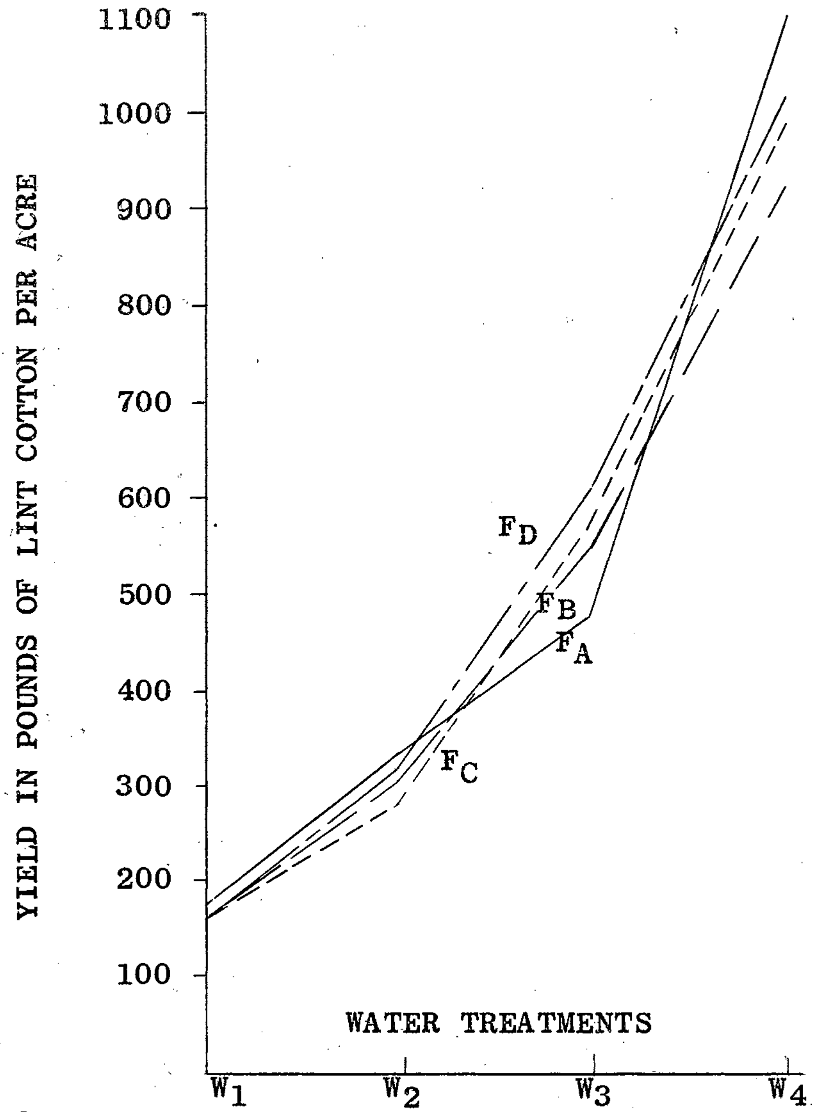

Figure 5. Relation between crop yield and water treatments for each fertilizer treatment.

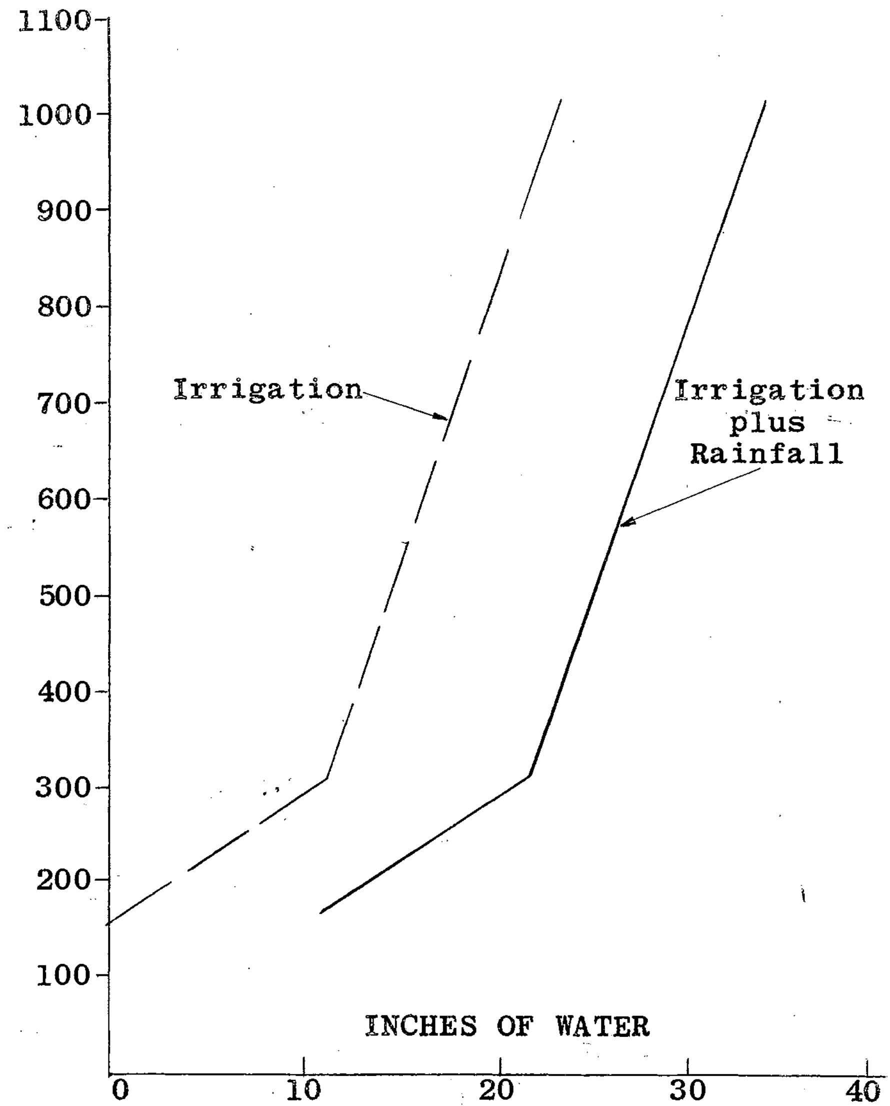

Figure 6. Relation between crop yield and inches of water applied.

application is needed in order to determine optimum crop yield.

At various times during the growing season, the heights of the cotton plants in each water treatment were measured and recorded. The results are illustrated in Figure 7. Two weeks after the first and second irrigations, the plants in the different water treatments began to show a difference in size and color. The fertilizer treatments did not seem to have any effect on the rate of growth, size, number of bolls per stalk, or color. Table II summarizes the effect of various water application levels on the average number of bolls per stalk, and the average height of the highest and lowest boll. The four water treatments of the cotton plots near maturity are illustrated in Figure 8.

Due to the type of soil on which the experiment was located, the soil moisture determinations were too erratic to be considered reliable in determining transpiration rates. In Table VIII, of the appendix, comparing the soil moisture levels of the W_4 and the W_5 water treatments which received the same amount of water at the same time, it is evident that there were inconsistent variations in the results. It was decided that these results were questionable and should not be used as conclusive evidence in determining daily transpiration.

A summary of consumptive use rates are listed in Table V for the W_2, W_3, and W_4 water treatments. The peak daily consumptive use for W_4, which appeared between

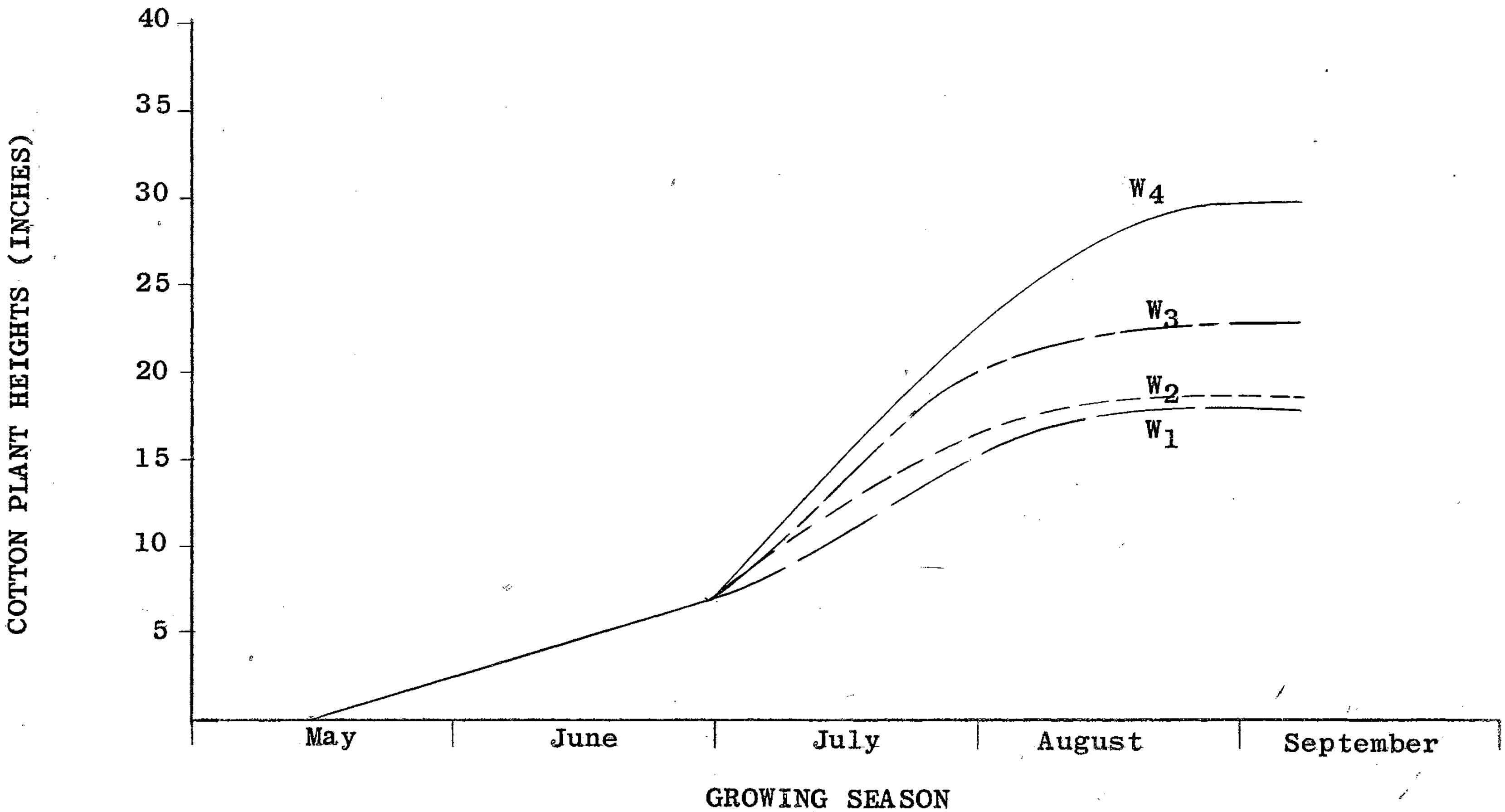

Figure 7. Relation between water treatments and plant heights

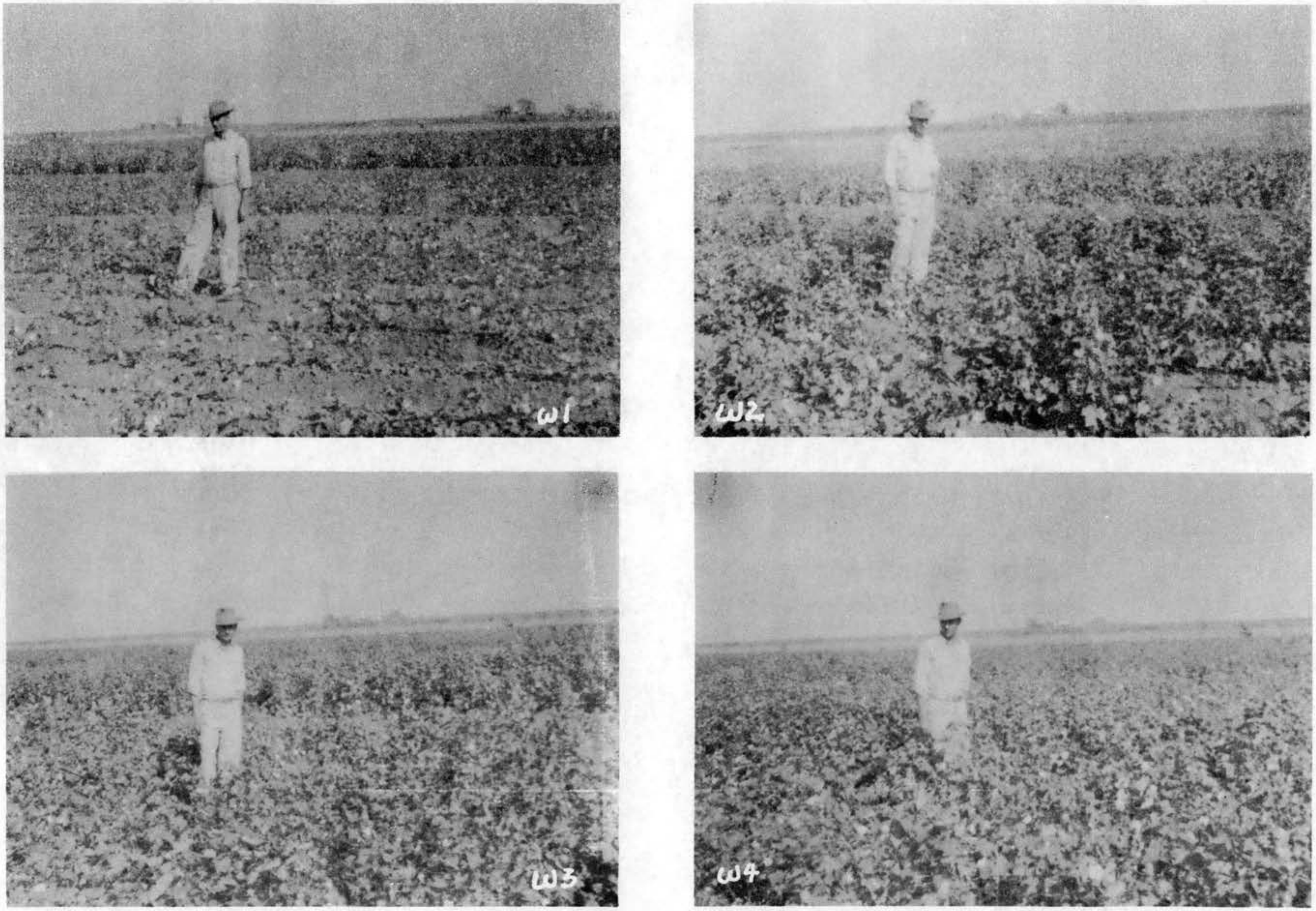

Figure 7. **Cotton Plots Near Maturity**

TABLE V

SUMMARY OF CONSUMPTIVE USE OF WATER BY COTTON
ALTUS, OKLAHOMA, 1956

Crop and Treatment		Peak Daily Use* (inches)	Date for Peak Use	Avg. Daily Use for Irrigation Season (inches)	Peak Monthly Use (inches)	Total Seasonal Consumptive Use (inches)
Cotton	W_2	0.174	August 8 - August 28	0.145	5.38	21.72
	W_3	0.293	July 25 - August 8	0.212	8.83	25.72
	W_4	0.374	August 10 - August 23	0.314	10.69	33.72

*Peak daily use is the peak average use between irrigations.

August 10 and August 23, was 0.374 inches per day. The peak daily use occurred at a time when the maximum temperatures were the highest. The peak monthly consumptive use of 10.69 inches was during August with a decline beginning about the last of August. The total seasonal consumptive use of the W_4 water treatment was 33.72 inches. The seasonal use patterns are illustrated in Figures 9, 10, and 11 for water treatments W_2, W_3, and W_4 respectively. These illustrations indicate that consumptive use rates are related to the degree of available soil moisture.

Economic Analysis for Water and Fertilizer Treatments

In order to determine the greatest net return, considering both water and fertilizer, an economic analysis was made. Since the other costs would remain constant, only water, fertilizer, irrigation labor, and harvesting were included in this analysis. With the exception of the W_3 water treatment, the fertilizer failed to show an increase in returns. All water treatments showed a definite increase in net returns as the amount of water was increased. A W_4 water treatment with no fertilizer was the high net return plot of $220.46 per acre, which was $32.50 per acre over the next highest yielding fertilizer treatment.

From Table VI in which the net returns are summarized for the different water and fertilizer treatments, it is evident in comparing the W_3 and W_4 water treatments that

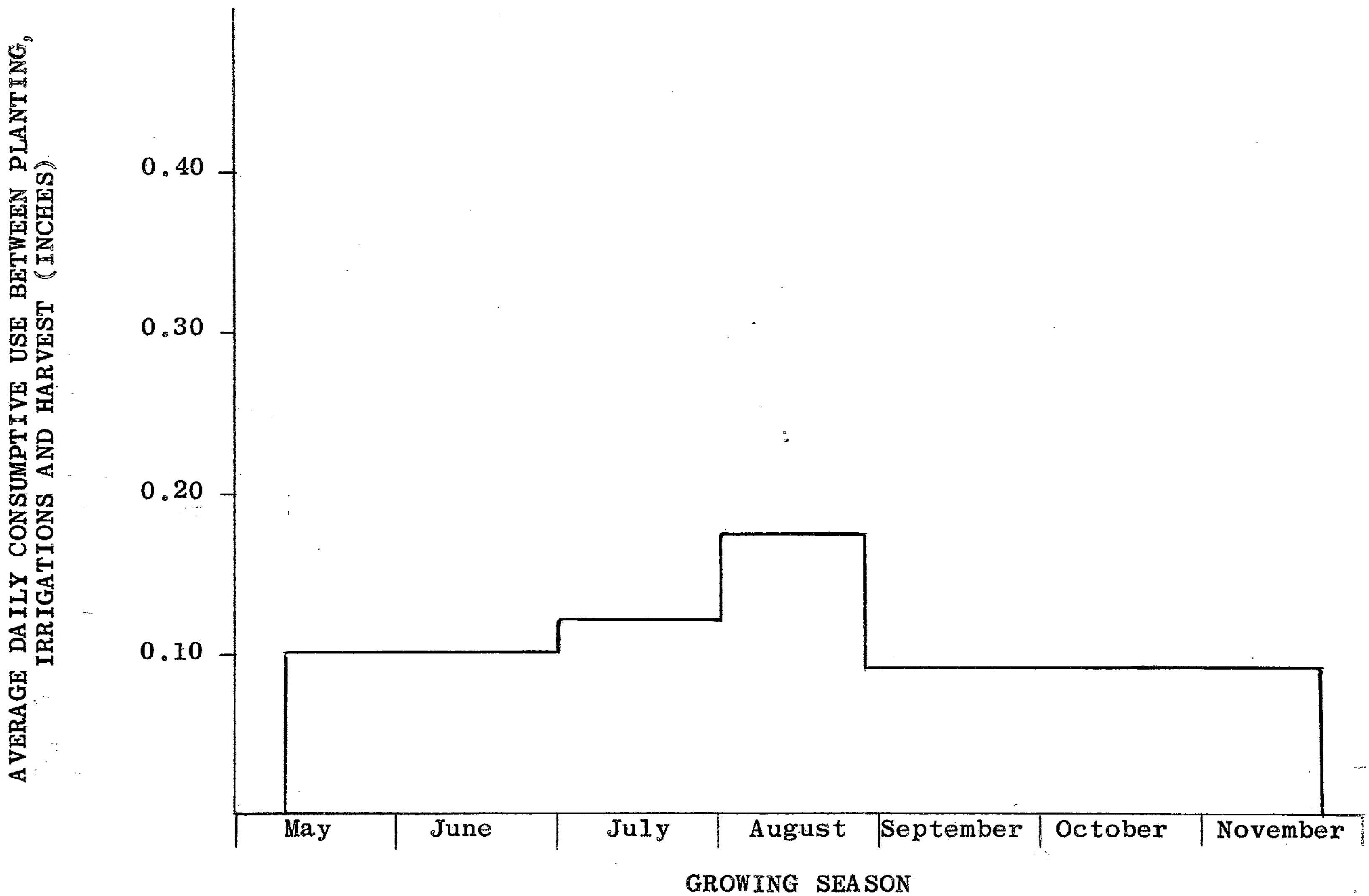

Figure 9. Average daily consumptive use for W_2 water treatment

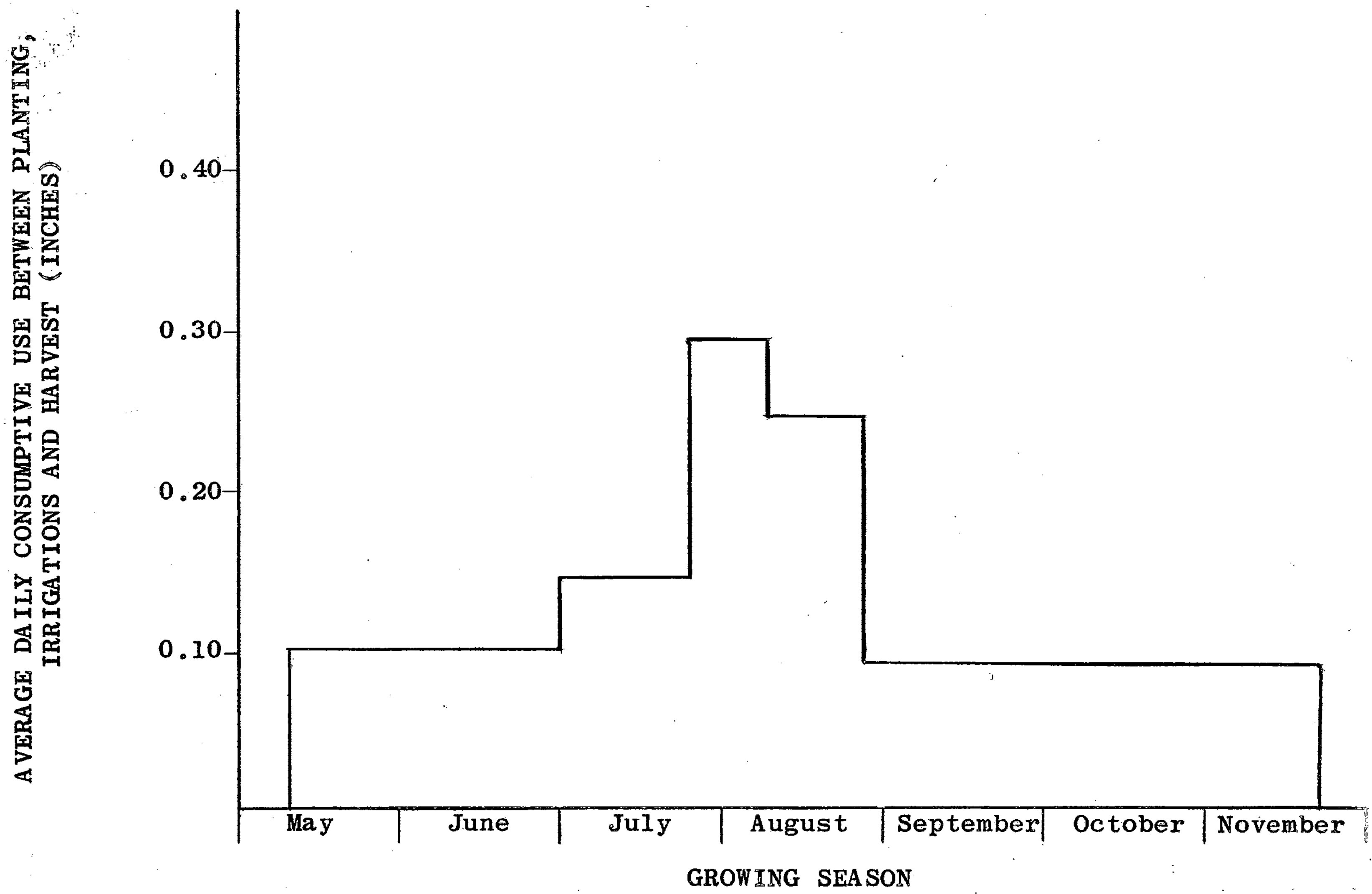

Figure 10. Average daily consumptive use for W_3 water treatment

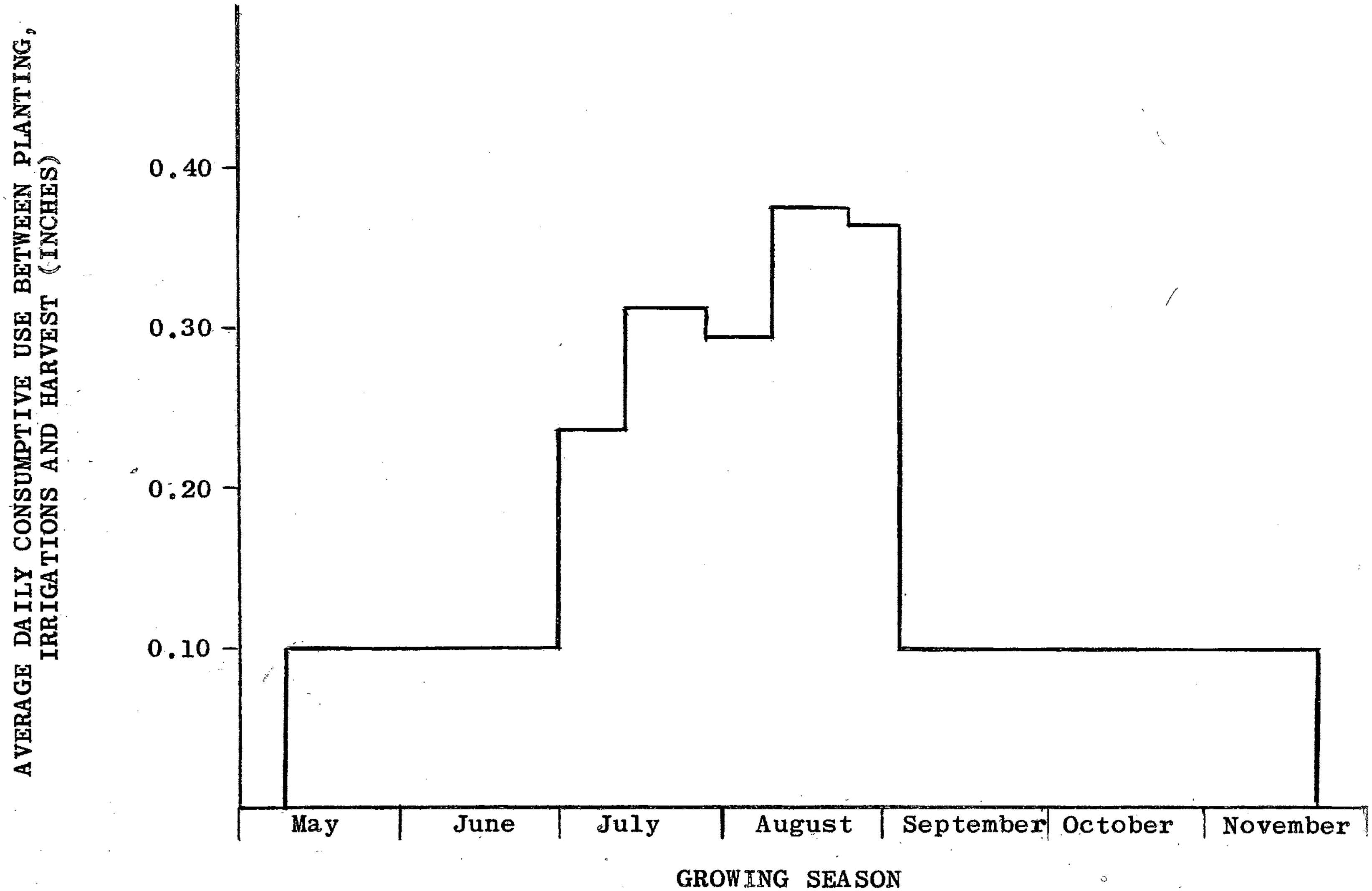

Figure 11. Average daily consumptive use for W_4 water treatment

TABLE VI

ECONOMIC ANALYSIS FOR IRRIGATED COTTON TREATMENTS
ALTUS, OKLAHOMA, 1956

Treatments		Returns 1st Pulling ($/Acre)	Returns 2nd Pulling ($/Acre)	Total Returns ($/Acre)	*Cost of Water, Fert. and Irrigation Labor ($/Acre)	Harvest Cost ($/Acre)	Net Returns from Lint Cotton ($/Acre)
W_1	F_A	29.39	15.42	44.81	00.00	9.64	35.17
	F_B	27.15	15.82	42.97	11.86	8.85	22.26
	F_C	21.75	17.36	39.11	23.69	8.99	6.43
	F_D	26.50	14.69	41.19	35.56	8.61	-2.53
W_2	F_A	33.70	52.47	86.17	10.08	20.77	55.32
	F_B	27.37	54.36	81.73	21.94	18.46	41.33
	F_C	27.96	47.51	75.47	33.77	16.67	25.03
	F_D	32.79	53.19	85.98	45.64	18.93	21.41
W_3	F_A	42.23	83.07	125.30	13.75	26.52	85.03
	F_B	57.92	93.52	151.44	25.61	31.25	94.58
	F_C	42.66	111.14	153.80	37.44	32.25	84.11
	F_D	62.13	106.30	168.43	49.31	34.60	84.52
W_4	F_A	36.34	267.34	303.68	21.08	62.14	220.46
	F_B	24.38	236.63	261.01	32.94	49.14	178.93
	F_C	23.24	248.36	271.60	44.77	58.94	167.89
	F_D	17.46	285.83	303.29	56.64	58.69	187.96

*Cost of water $5 per acre-foot, labor $1 per hour, and fertilizer 46¢ per gallon.

for an additional cost of $7.33 per acre for water and labor the net return could be increased $101.75 per acre. The water treatment W_3 is a common irrigating procedure for many farmers who wait until the cotton plants show a sign of wilt before they irrigate.

Climatological Data

Precipitation and temperatures are the principal climatic factors involved in the consumption of water by crops. Other weather phenomena, such as wind, relative humidity, and evaporation, are known to affect the soil moisture conditions and available moisture supplies, but none are as important as precipitation and temperature. The peak daily use of moisture for the W_4 water treatment was during a period of $100^{\circ}+$ temperatures. Climatological data for the 1956 growing season are presented in the following tables in the appendix.

Table X	Precipitation Data for Irrigation Research Station, Altus, Oklahoma, 1956.
Table XI	Maximum and Minimum Daily Temperatures, Altus, Oklahoma, May through September, 1956.
Table XII	Daily Evaporation and Wind Velocity for Altus Dam, Altus, Oklahoma, May through September, 1956.

Study Made with Electrical Resistance Method for Determining When to Irrigate

The standard method of determining soil moisture by sampling, drying, and weighing was used as a comparison to the electrical resistance method. The particular electrical resistance unit used in this study is manufactured under the trade name, "Irrigage". The readings taken from the Irrigage were very erratic and little reliability could be expected from the Irrigage as a guide for determining when to irrigate. One of the possible sources of error in using the Irrigage stake is that the clay soil will shrink away from the stake soil unit and thereby break the soil moisture movement between the soil and the electrodes embedded in the gypsum rings. A single stake soil unit therefore cannot be depended on as a means of determining when to irrigate in this type of soil. Table XIII of the appendix gives some of the data collected from the Irrigage and corresponding moisture percentages as determined by the standard soil moisture sampling technique. Figure 12 illustrates the relation between the dial readings at 6- and 12-inch depths as compared with the actual soil moisture percent.

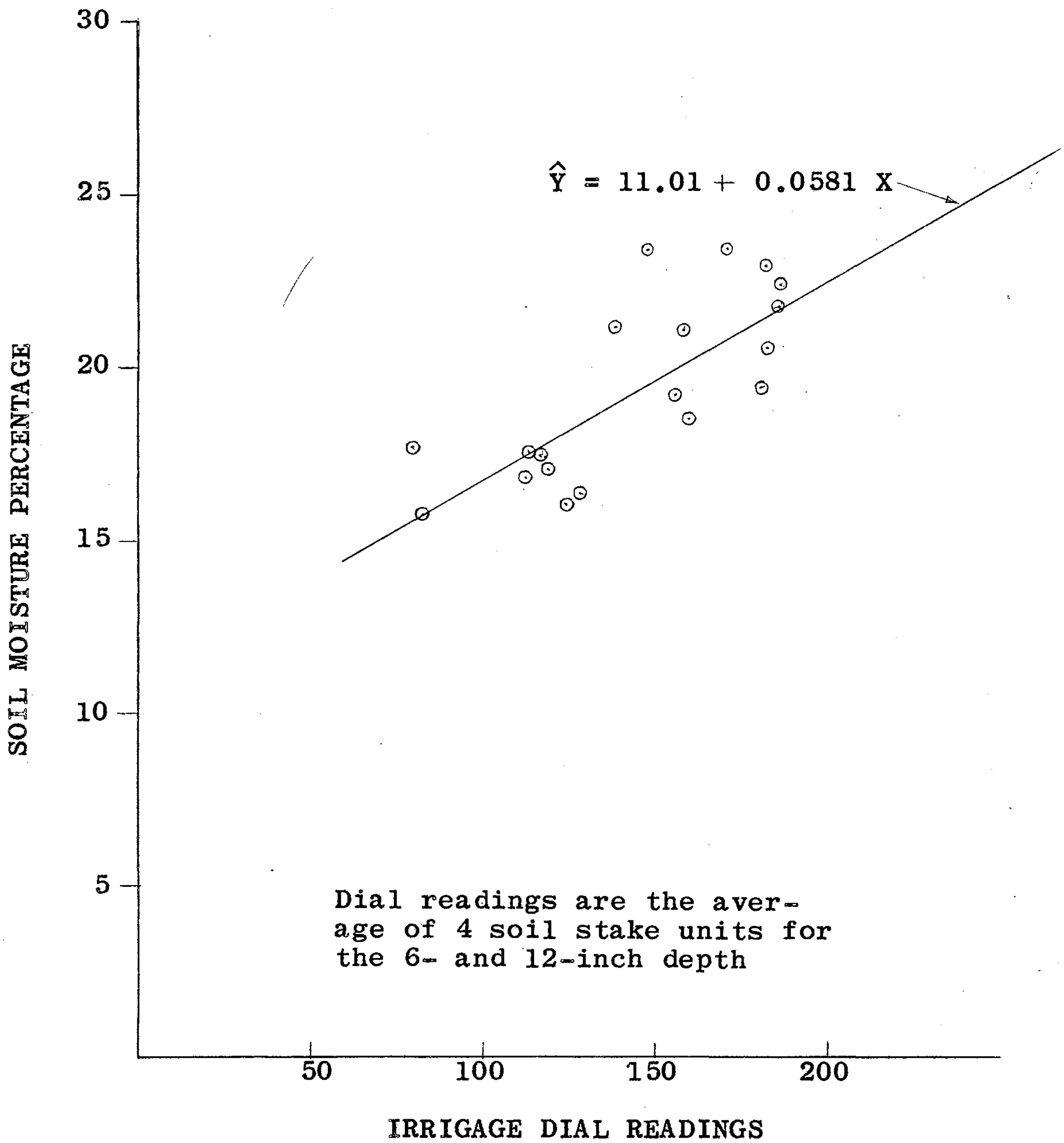

Figure 12. Comparison of soil moisture percentages and Irrigage dial readings taken on corresponding days.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A study was made on the consumptive use of water by cotton at the Irrigation Research Station, Altus, Oklahoma. The experimental field plot with a completely randomized design was used, and the consumptive use rates were determined by the field plot experiment method. The effects on the yields by varying the amounts of water and fertilizer are recorded in tables contained in this thesis. A statistical analysis was made of the mean yields to determine the significant differences between the various treatments.

The following conclusions were made from this study based on the results obtained:

1. The peak daily consumptive use which occurred in the W_4 water treatment between August 10 and August 23 was 0.374 inches per day. For the irrigation season, the average daily use for W_4 was 0.314 inches per day, with the peak monthly use of 10.69 inches. The total seasonal consumptive use for W_4 was 33.72 inches.
2. A decrease in yield occurred when the cotton plants were allowed to wilt before being irrigated.
3. The application of 267 pounds, 533 pounds, or 800 pounds of 15-15-0 fertilizer failed to show any

increase in yield as compared with the fertilizer treatment which received no fertilizer. The statistical analysis showed there was no significant difference in any of the fertilizer treatments.

4. From the economic analysis, it is evident that the greatest net return resulted from the water treatment that was never allowed to permanently wilt. The maximum net return was $220.46 per acre as compared with $35.17 per acre from the plot that received no irrigation. An additional $7.33 per acre for 8 inches of water and necessary labor will increase the net return from $87.06 to $188.81 per acre.

5. The data obtained from the electrical resistance method gave inconsistent results. The readings were not consistent or accurate enough to be considered reliable.

6. It is apparent that the consumptive use is influenced by the variations in the climatic conditions.

7. A continuation of this study is recommended to obtain more conclusive results on the consumptive use pattern of water by cotton. The following changes are recommended:

   (a) Eliminate the W_1 and W_2 water treatments and add a higher water treatment than the existing W_4 in order to obtain maximum yields.

(b) Have certain areas designated in the experimental plots for soil moisture sampling to help eliminate sampling errors.

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APPENDIX

TABLE VII

SOIL CHARACTERISTICS OF PLOT AREA, FOARD CLAY LOAM

	Field Capacity (percent)	Wilting Point (percent)
Calculated*	25.83	11.47
Estimated from Sampling	24.05	13.98

APPARENT SPECIFIC GRAVITY**

Soil Depth (inches)	Unit Dry Weight
6	1.413
18	1.575
30	1.685

REAL SPECIFIC GRAVITY

2.73

*Field capacity was calculated by use of ceramic plates for 1/3 atmosphere tension. Wilting point was calculated by use of pressure membrane apparatus for 15 atmosphere tension. Calculations were made by Walter Knisel, Graduate Fellow, Oklahoma A. and M. College.

**Apparent specific gravity values are average values for six undistrubed core samples taken by the Pomona soil sampler.

TABLE VIII

DAILY CONSUMPTIVE USE OF W_2 AND W_3 WATER TREATMENTS DURING IRRIGATION SEASON

Sampling Dates	Daily Use Between Samplings (inches per day)	
	W_2	W_3
June 29 - July 2	0.72	0.51
July 2 - 4	0.22	0.20
July 4 - 9	0.01	0.28
July 9 - 13	0.10	----*
July 13 - 16	0.06	0.03
July 16 - 18	0.15	0.13
July 18 - 23	0.16	0.18
July 23 - 27	0.18	0.68
July 27 - 31	0.02	0.09
July 31 - August 8	0.28	0.06
August 8 - 21	0.11	0.92
August 21 - 25	0.26	0.26
August 25 - 28	0.05	0.16
August 28 - Sept. 1	0.10	0.35
September 1 - 3	0.79	0.68
September 3 - 7	0.07	0.21

*Moisture sampling which showed more soil moisture in the last sampling than in the first sampling including any rainfall during the sampling interval.

TABLE IX

DAILY CONSUMPTIVE USE OF W_4 AND W_5 WATER TREATMENTS DURING IRRIGATION SEASON

Sampling Dates	Daily Use Between Samplings (inches per day)	
	W_4	W_5
June 29 - July 2	0.687	0.483
July 2 - 4	0.165	0.440
July 4 - 9	0.078	0.170
July 9 - 12	-----*	-----*
July 12 - 14	1.122	0.720
July 14 - 16	0.265	0.795
July 16 - 18	-----*	-----*
July 18 - 23	0.270	0.232
July 23 - 27	0.392	0.310
July 27 - August 1	0.400	0.330
August 1 - 3	0.500	0.030
August 3 - 10	0.096	0.290
August 10 - 12	1.010	1.450
August 12 - 15	0.260	0.006
August 15 - 21	0.183	0.220
August 21 - 23	0.285	0.100
August 23 - 26	0.920	0.850
August 26 - 28	0.310	0.235
August 28 - Sept. 4	0.285	0.236
September 4 - 7	0.245	0.610

*Moisture sampling which showed more soil moisture in the last sampling than in the first sampling including any rainfall during the sampling interval.

TABLE X

PRECIPITATION DATA FOR IRRIGATION RESEARCH STATION
ALTUS, OKLAHOMA, 1956

Month	Day	Rainfall in Inches
April	1	0.88
	30	0.19
Total		1.07
May	2	1.61
	23	0.41
	25	1.84
	26	2.59
	31	0.23
Total		6.68
June	27	0.09
July	10	0.08
	17	0.35
	19	0.34
	30	0.10
Total		0.87
August	18	0.45
	19	0.41
Total		0.86
September	24	0.10
October	15	0.53
	18	1.36
	19	0.73
	20	0.17
	29	0.67
Total		3.46
November	4	0.23
	7	0.04
Total		0.27

Rainfall was measured with a standard 8-inch nonrecording rain gage.

MAXIMUM AND MINIMUM DAILY TEMPERATURES FOR ALTUS, OKLAHOMA
MAY through SEPTEMBER, 1956

Day of Month	May		June		July		August		September	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	83	60	80	62	102	76	100	75	93	55
2	83	53	86	62	102	76	100	71	99	61
3	83	54	95	67	100	72	102	73	98	69
4	84	60	92	68	96	73	102	72	97	68
5	88	61	99	71	103	73	105	67	98	69
6	92	61	95	71	105	73	106	70	93	56
7	87	60	99	66	105	71	103	70	85	58
8	91	63	98	72	103	77	105	78	85	53
9	94	66	92	63	94	72	105	72	88	51
10	92	67	93	64	93	70	106	73	96	52
11	96	63	94	67	99	69	104	70	99	55
12	94	71	97	67	101	76	103	69	97	57
13	99	74	95	69	100	76	105	74	101	66
14	96	57	92	67	102	78	108	70	99	66
15	81	54	95	67	105	82	108	73	103	66
16	90	52	103	74	102	77	107	75	104	65
17	99	57	102	77	102	70	105	74	97	67
18	99	55	100	70	94	69	106	70	100	62
19	98	58	97	69	92	68	98	64	97	66
20	95	61	100	70	90	67	79	59	96	58
21	94	62	100	75	99	66	85	55	100	64
22	95	63	103	80	102	75	95	58	98	67
23	93	67	100	74	95	74	100	63	92	66
24	80	62	100	70	99	68	100	62	90	62
25	90	64	100	76	101	71	98	64	89	58
26	87	62	97	77	102	68	95	63	91	50
27	79	59	101	73	100	71	99	68	94	56
28	86	65	99	68	101	73	102	75	97	63
29	92	71	103	67	104	70	106	70	89	58
30	94	67	103	70	101	73	107	73	90	57
31	92	69			101	70	101	64		
Means	90.5	61.9	97.0	70.1	99.8	72.4	101.5	68.8	95.3	60.8

TABLE XII

DAILY EVAPORATION AND WIND VELOCITY FOR ALTUS DAM, OKLAHOMA
MAY through SEPTEMBER, 1956

Day of Month	May		June		July		August		September	
	Evap.	Wind	Evap.	Wind	Evap.	Wind	Evap.	Wind	Evap.	Wind
1	.15	83	.23	78	.60	106	.39	23	.41	108
2	---	73	.23	30	.53	94	.32	50	.41	60
3	.15	55	.39	107	.30	55	.40	72	.43	90
4	.27	79	.31	52	.54	62	.46	68	.44	82
5	.31	108	.20	66	.45	64	.51	62	.46	72
6	.39	130	.47	112	.40	54	.56	82	.40	93
7	.35	95	.39	86	.48	60	.46	31	.28	88
8	.25	70	.46	61	.45	40	.46	52	.24	39
9	.36	111	.24	59	.50	75	.46	40	.28	46
10	.52	137	.35	31	.34	44	.44	25	.32	35
11	.47	122	.43	41	.13	65	.46	50	.42	102
12	.47	96	.42	45	.40	92	.51	75	.48	64
13	.52	163	.40	65	.48	95	.53	75	.48	111
14	.46	97	.41	57	.54	101	.50	46	.45	102
15	.20	104	.39	24	.56	114	.51	36	.45	107
16	.34	66	.40	102	.58	87	.50	30	.45	99
17	.46	70	.56	118	.40	55	.49	74	.49	47
18	.45	60	.50	87	---	91	.51	78	.45	44
19	.53	103	.42	44	.26	26	.40	76	.42	62
20	.57	88	.48	57	.12	28	.15	104	.41	88
21	.51	99	.43	87	.28	37	.34	84	.43	73
22	.48	102	.53	93	.31	61	.31	20	.50	152
23	.48	112	.58	106	.44	55	.39	84	.47	92
24	.32	80	.42	61	.22	21	.41	59	.39	54
25	.07	45	.40	86	.31	21	.40	48	.34	33
26	.24	68	.53	111	.38	34	.47	64	.33	41
27	---	76	.47	56	.42	60	.43	73	.36	58
28	.14	53	.51	81	.49	83	.48	98	.40	63
29	.30	121	.33	18	.45	64	.45	94	.39	47
30	.35	50	.52	83	.36	33	.40	79	.35	82
31	.34	66			.33	27	.54	81		
Total	11.19	2782	12.4	2109	12.45	1904	13.64	1933	12.18	2234

TABLE XIII

CORRESPONDING SOIL MOISTURE PERCENTAGES AND IRRIGAGE READINGS

Date	% Soil Moisture 6-12" Depth	Avg. of 4 Stakes for 6" Depth	Avg. of 4 Stakes for 12" Depth	Avg. of 6" & 12" Depth
June				
27	17.5	143	85	114
July				
4	19.2	182	129	156
9	17.0	113	125	119
12	17.6	52	109	80
14	22.8	186	180	183
16	20.5	184	182	183
18	21.0	140	177	158
23	18.5	140	180	160
27	16.0	79	169	124
August				
1	21.7	186	188	187
3	22.3	184	189	186
10	16.3	94	162	128
15	19.4	176	186	181
21	17.4	100	134	117
23	16.8	80	146	113
26	23.4	184	158	171
28	21.2	137	139	138
September				
5	15.7	34	133	83
7	23.3	148	148	148

TABLE XIV

IRRIGATION SCHEDULE FOR COTTON WATER TREATMENTS
ALTUS, OKLAHOMA, 1956

Water Treatment	Date of Irrigation	Water Application (in inches)
W_1	None	None
W_2	June 30	3
	August 1	4
	August 29	4
Total		11
W_3	June 30	3
	July 25	4
	August 10	4
	August 29	4
Total		15
W_4	June 30	3
and	July 12	4
W_5	July 30	4
	August 10	4
	August 24	4
	September 5	4
Total		23

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