Bulletin 838 September 1956

A PART OF THE TEXAS A&M COLLEGE SYSTEM

Guides in COTTON IRRIGATION *on the High Plains*

LIBRARY
NOV 13
New Mexico College of Agriculture and Mechanic Arts

in cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

TEXAS AGRICULTURAL EXPERIMENT STATION
R. D. LEWIS, DIRECTOR, COLLEGE STATION, TEXAS

Summary and Recommendations

This bulletin gives the results of studies conducted for several years at Lubbock and Tulia on the use of irrigation water by cotton.

Cotton yields in pounds of lint per inch of water were about the same for all moisture levels studied.

In general, the high moisture levels are the most profitable.

If the supply of water is short, no significant loss will occur in yield per acre-inch of water by following any one of the treatments studied.

Cotton uses varying amounts of water efficiently, which makes it an easier crop to irrigate than grain sorghum.

The preplanting irrigation is the most important one.

Definition of Terms

Transpiration: The water absorbed by the crop and evaporated from plant surfaces. It does not include soil evaporation. It is expressed as acre-feet or acre-inches per acre, or as a depth in feet or inches.

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, snow or intercepted precipitation on the area in any specified time, divided by the given area. If the unit of time is small, the consumptive use is expressed in acre-inches per acre or depth in inches; but if the unit of time is large, such as a crop-growing season or a 12-month period, the consumptive use is expressed as acre-feet per acre or depth in feet or inches.

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 usually is expressed in depth (volume per unit area) for a given time.

Irrigation Requirement: The quantity of water, exclusive of precipitation, required for crop production. It includes surface evaporation and other economically unavoidable wastes. It usually is expressed as depth in inches or feet for a given time.

Irrigation Efficiency: The percentage of irrigation water delivered to the farm or field that is available in the soil for consumptive use by the crops. When measured at the field or plot, it is called field-irrigation efficiency.

Moisture Percentage: The percentage of moisture in the soil, based on the weight of the ovendry material.

Field Capacity: The moisture percentage, on a dry-weight basis, of a soil after rapid drainage has taken place following an application of water, provided there is no water within capillary reach of the root zone. This moisture percentage usually is reached in 2 to 4 days after an ordinary irrigation, the time interval depending on the soil type.

Permanent Wilting Percentage: The percentage of water in the soil when plants wilt permanently.

Guides in COTTON IRRIGATION *on the High Plains*

E. L. THAXTON, JR. and N. P. SWANSON*

GEOLOGISTS MAKING STUDIES OF THE UNDERground water of the High Plains estimate there are approximately 150 million acre-feet of water stored in the sands which underlie this region.

The efficient use of water from this water-bearing sand, in a supplemental form, has made it possible to increase production as much as 300 percent over normal dryland crop production during the past few years. More than 40,000 irrigation wells are being pumped to supply water to more than 3 million acres. This represents an investment of more than 100 million dollars in irrigation plants and equipment alone.

The High Plains produces about one-tenth of the total United States cotton crop and one-third of the total Texas crop. The terrain is level and, therefore, is suited to large-scale, high-speed, mechanized operation. The soils have a high degree of inherent fertility and produce good yields of cotton and other crops with minimum expense.

Climate

The High Plains are in the northwestern corner of Texas and are well over 3,000 feet in elevation. Records from the Lubbock station show that the annual rainfall has averaged slightly over 18 inches for a 44-year period (Table 1). Approximately 82 percent of this rainfall occurs from April through October. Distribution is more important than the total amount of rainfall received. The two rainfall peaks of the year are in May and September. In 4 years out of the 10 the September rainfall is more than 3 inches.

Efficient use of irrigation water to supplement the annual rainfall helps insure a good yield of high-quality cotton. The Lubbock vicinity has a normal frost-free season of 211 days. The average dates of killing frosts are April 6 in the spring and November 4 in the fall. The short growing season is a constant threat to the cotton producer. Because other climatic conditions, such as cool nights, wind, high-intensity rains and hail, make it impractical to plant cotton before early May, 40 to 50 of the 211 frost-free days are lost. Only 160 to 170 days are left for maturing the crop to a point where there is a minimum damage from frost. Any practice that tends to delay maturity should be avoided.

High Plains Cotton Soils

Pullman clay loam, Amarillo fine sandy loam and Amarillo loam make up the largest part of the area farmed to cotton on the High Plains of Texas. Three million acres may be planted in irrigated cotton on the three soil types.

Most of the Pullman clay loam soil is on the northern edge of the cotton belt in the Texas Panhandle. The Amarillo loam is the transition soil between the Pullman clay loam and the Amarillo fine sandy loam.

Pullman clay loam is a deep, fine-textured, slowly permeable soil, often 5 to 6 feet in depth and capable of holding a large amount of water. The greatest problem encountered in irrigating these soils is getting adequate water into the soil. Infiltration rates may be as low as one-tenth inch of water per hour.

Amarillo fine sandy loam is a freely permeable, medium-textured soil. It is about 3 to 4 feet deep and is underlain by a rock-like accumulation of highly calcareous material. The infiltration rate is often 2 inches per hour. Cotton is grown on about a million and a half acres of this soil type.

Amarillo loam is an intermediate or transition type. It is fine to medium-textured, permeable and averages 4 to 5 feet in depth. Infiltration rates average 1 to 1½ inches per hour. Cotton is grown on about 300,000 acres of this soil type.

Contents

*Respectively, assistant irrigation engineer, Substation No. 8, Lubbock, Texas; and irrigation engineer, Soil and Water Conservation Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Lincoln, Nebraska, and formerly of the Amarillo Experiment Station, Bushland, Texas.

Figure 1. Water applications were measured carefully onto level borders in the water management study near Tulia in 1954.

Previous Work at Lubbock

Pump irrigation studies at the Lubbock station by D. L. Jones and Frank Gaines (Progress Report 667) pointed out the need of a preplanting irrigation on the fine sandy loam soils of the area (Table 2).

Two preplanting irrigations gave good results in these early tests, primarily because of the additional water stored in the root zone. Summer irrigation was profitable, but the preplanting irrigation was the most valuable from the yield of lint per acre-inch of water.

Similar irrigation tests were continued through 1951-54, but the dates of irrigation were revised to conform with certain stages of plant development. Table 3 indicates that a preplanting irrigation again gave the greatest yield of increase, but that two summer irrigations were profitable. Summer irrigations were applied at the time of the first flowering and again at the peak fruiting stage. No attempt was made to keep the plants out of stress between irrigations although normal summer rainfall usually corrected this deficit.

TABLE 1. A 44-YEAR SUMMARY OF NORMAL PRECIPITATION BY MONTHS, LUBBOCK STATION, 1911-54

Month	Mean rainfall	Years below average, percent	Years within one-fourth of average, percent	Years of 3 inches or more, percent
January	.53	61	11	2
February	.65	70	11	5
March	.78	59	20	5
April	1.37	59	10	14
May	2.72	64	27	30
June	2.25	59	20	27
July	2.03	59	18	23
August	1.96	52	34	16
September	2.60	59	14	36
October	2.18	64	5	30
November	.55	57	14	0
December	.69	64	16	0
Yearly average	18.37			

Tests Near Tulia

An irrigation test on cotton was set up in 1953 to determine seasonal and average daily consumptive use of water on Pullman clay loam soil near Tulia.

Irrigations were measured carefully onto level borders so that accurate moisture figures could be obtained (Figure 1). There were no losses of rainfall or irrigation water by runoff. A rain gage was located on the site to measure precipitation.

Soil moisture samples were taken several times during the season to depths of 6 feet. Readings were taken three times a week during the irrigation season from Bouyoucos blocks. Every plot had blocks in each foot of soil to a depth of 5 feet, with an additional location in each plot for measuring moisture in the 0 to 2-foot depth. A calibration curve made on Pullman clay loam at the Amarillo Experiment Station was used at the Tulia location following early comparisons of moisture values obtained by gravimetric and electrical resistance methods. Some modifications in calibration were made for the lower depths of soil at Tulia following further comparisons during the 1953 season.

Consumptive use data obtained for the various moisture levels used in these tests are shown in Tables 4 and 5. Moisture use approached 0.25 inch per day on the cotton plots during the peak use period in both 1953 and 1954. Figures 2 and 3 show moisture depletion during the season. Increased water use started near the first-bloom stage and continued as long as there was readily available water in the profile.

The general pattern of moisture extraction consisted of removal first near the surface, with subsequent withdrawals at deeper depths until all available moisture in the 5 to 6-foot zone was utilized.

There was essentially no difference in water utilization efficiency regardless of irrigation treatment. The pounds of lint per acre-inch of

TABLE 2. SUMMARY OF COTTON IRRIGATION TESTS AT THE LUBBOCK STATION, 1937-41[1]

Treatment	Total annual irrigation	Lint yield per acre	Lint per inch of water	Increase or decrease compared with 6-inch preplanting
	Inches	Pounds	Pounds	Pounds of lint per acre
No irrigation	0	309	15.7	
2 preplantings	6	457	18.8	
1 preplanting	3	387	17.6	−70
1 preplanting and 1 postplanting	6	442	18.0	−15
1 preplanting and 2 postplantings	9	464	16.9	+17

[1]Rainfall ranged from 11.71 to 40.55 inches.

water ranged from 17.4 to 21.5 in 1953 and from 19.6 to 21.9 in 1954. This indicates that cotton used water effectively over a wide range of availability, thus providing some latitude for the time of its application to cotton on the High Plains.

The data on consumptive use during 1953-54 cover 2 years of very low rainfall. In a normal year, cotton probably would use water at about the same rate during peak-use periods, but the rainfall during the growing season would make summer irrigations less frequent. Even though expected rainfall occurred, it still would be necessary to apply 3 to 4 inches of water to the cotton during the growing season, in addition to the preplanting irrigation, to be assured of better than average production. In years of more than average rainfall and higher relative humidity, lower transpiration rates would be expected, thereby reducing the consumptive use. In this case, rainfall distribution will be as important as the total amount.

Infrequent, heavy rains would not be as beneficial to the plants as moderate weekly or semiweekly rains, even though the total amount of rainfall was the same. This is because of possible losses by deep percolation and runoff. Rainfall in excess of the moisture deficit in the root zone will not be useful to the crop. On the other hand, light rains falling on the air-dry surface of a clay loam soil often fail to bring the moisture content of the surface above wilting point. The moisture replenishes, or partially replenishes, the deficit caused by evaporation, but little or no moisture becomes available to the plants.

Water Management

When Pullman clay loam soils are wet to a depth of 6 feet, moisture storage provides almost 12 inches of available water. Water-use studies on this soil show that enough water is withdrawn at 6 feet to justify storing water for crop use at that depth. It is possible for the farmer to store a large part of the water required for maximum crop production in the soil prior to planting by a preplanting irrigation.

About 9 inches of available water can be stored in Amarillo fine sandy loam when the soil profile is wet to field capacity to a depth of 6 feet. In many places, it is feasible to wet the soil profile to depths of 4, 5 or even 6 feet with one summer irrigation.

Pullman clay loam, which takes water slowly, cannot be irrigated effectively more than 3 or 4 feet deep with a summer irrigation. Refilling the entire profile of the Pullman clay loam with a summer irrigation might temporarily wet the soil to a point where the cotton roots would suffer from lack of oxygen. Water stored 4 to 6 feet

TABLE 3. SUMMARY OF COTTON IRRIGATION TESTS AT THE LUBBOCK STATION, 1950-54[1]

Treatment	Total annual irrigation	Total water[2]	Lint yield per acre	Lint per inch of water	Compared with preplanting
	Inches	Inches	Pounds	Pounds	Pounds of lint per acre
None		13.2	165	12.5	255
April only	8.2	21.4	420	19.6	
April, June	12.2	25.4	451	17.8	+ 31
April, July	12.0	25.2	470	18.7	+ 50
April, Aug.	12.5	25.7	517	20.1	+ 97
April, June, July	12.9	26.1	468	17.9	+ 48
April, June, Aug.	16.2	29.4	588	20.0	+168
April, July, Aug.	15.5	28.7	590	20.6	+170
April, June, July, Aug.	19.5	32.7	518	15.8	+ 98

[1]Irrigations were made near these dates each year: April 20, June 25, July 15 and August 5.
[2]Including rainfall.

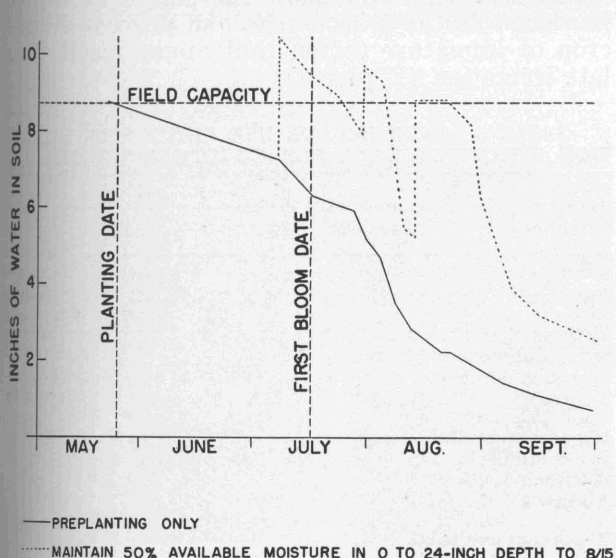

Figure 2. Available moisture in soil storage in 0 to 60-inch depth of soil, cotton, Tulia, 1953.

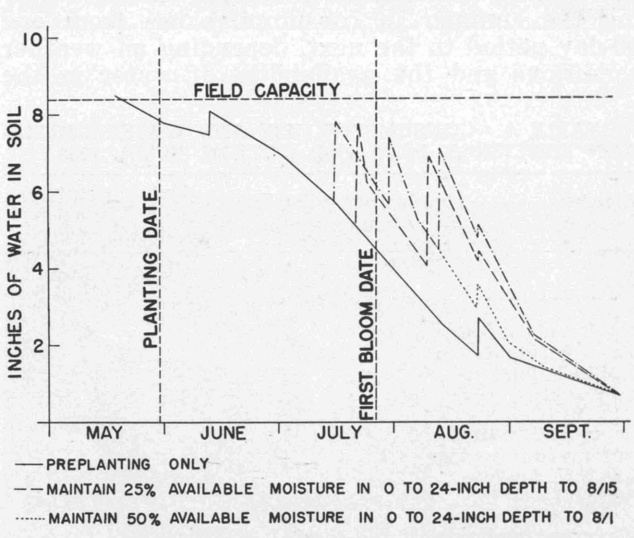

Figure 3. Available moisture in soil storage in 0 to 60-inch depth of soil, cotton, Tulia, 1954.

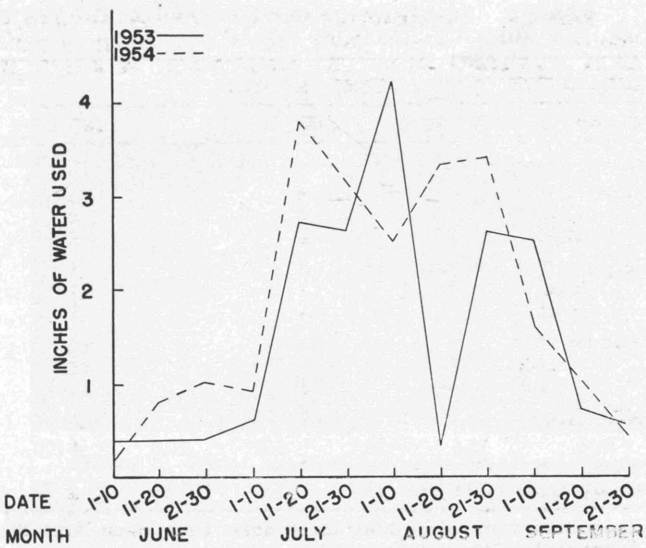

Figure 4. Consumptive use of cotton by 10-day periods on Pullman clay loam soil, Tulia. Daily water use for July 31 and August 31 has been included in the last 10-day periods.

deep in Pullman clay loam soil usually is adequate to meet the seasonal withdrawal by the cotton crop from those depths without replenishment after planting.

In general, the preplanting irrigation on the three important cotton-producing soil types of the High Plains should be adequate to bring the soil profile to field capacity to a depth of 6 feet on deep soils and 4 feet on soils of medium depth. Each summer irrigation should be sufficient to store about 4 inches of water in Pullman clay loam and 4 to 5 inches in Amarillo fine sandy loam. In dry years, when little or no rainfall occurs, irrigation will be needed every 14 to 18 days. Allowing for losses in application, as much as a 6-inch application may be required, depending on the efficiency of the irrigation system.

Table 6 shows there is a great variation during the summer in consumptive use from one 10-day period to the next, depending on weather conditions and the availability of water in the soil. Consumptive use by cotton was measured as high as 0.42 inch per day during extremely hot, dry periods. Normal use should be about one-fourth inch per day during August. Moisture use increases as the plant grows until the maximum fruiting period is reached (Figure 4). This period normally starts during late July and may continue into September. Cotton uses less water with a decreasing availability of soil moisture, particularly on clay soils. Cotton can survive for many days with very low water use, but normally growth and production are not achieved (Figures 5 and 6).

Average rainfall for July and August is about 2 inches per month. Consumptive use measurements show that cotton is capable of using 8 inches of water during July and over 9 inches during August (Table 7). These amounts, less expected rainfall, leave a deficit of 6 inches of water to be supplied by irrigation and from depletion of soil-moisture storage during July, and 7 inches to be supplied similarly during August, if the crop has all the water required to make good growth. A total moisture deficit of 15 inches may be expected for July and August (Figure 7). Soil-moisture storage is inadequate to supply this amount and the storage possibly will have been depleted by deficits in May and June.

The lower consumptive use in midseason, as indicated in Figure 4, was caused by rains in the latter half of July 1953 and by a few days of relatively cool weather in early August 1954.

The consumptive use for September was somewhat lower, less than 6 inches. The expected September rainfall is 2.6 inches, therefore, the required withdrawal from soil moisture storage would be about 3.4 inches. Sound irrigation planning insures that this amount of readily available water will be stored in the soil profile at the beginning of September, eliminating late-season irrigations. This will allow the plants to become hardened as the season ends and prevent a large crop of immature cotton that might result from late irrigation (Figure 8).

TABLE 4. CONSUMPTIVE USE AND WATER UTILIZATION EFFICIENCY DATA FOR COTTON, TULIA, 1953

Moisture treatment	Number of irrigations	Total water	Lint yield per acre	Lint per acre-inch of water
		Inches	Pounds	Pounds
Preplanting only	2	12.7	273	21.5
25 percent available water maintained in 0-24-inch depth to August 15	4	20.0	361	18.1
50 percent available water maintained in 0-24-inch depth to August 1	4	19.6	341	17.4
50 percent available water maintained in 0-24-inch depth to August 15	5	23.2	476	20.5

TABLE 5. CONSUMPTIVE USE AND WATER UTILIZATION EFFICIENCY DATA FOR COTTON, TULIA, 1954

Moisture treatment	Number of irrigations	Total water	Lint yield per acre	Lint per acre-inch of water
		Inches	Pounds	Pounds
Preplanting only	1	14.5	302	20.8
25 percent available water maintained in 0-24-inch depth to August 15	3	22.5	442	19.6
50 percent available water maintained in 0-24-inch depth to August 1	4	22.0	481	21.9
50 percent available water maintained in 0-24-inch depth to August 15	4	26.0	521	20.1

There were no runoff losses from the irrigation and rainfall measured in these studies. The irrigations were adequate, with uniform moisture distribution and penetration, and there were no deep percolation losses. Losses by evaporation were as low as could be expected under the conditions experienced. Since most farm-irrigation systems are not as efficient as the one used for these studies, greater applications of water will have to be made to compensate for the higher losses on less efficient systems.

Summer irrigations should begin about the time of first bloom and terminate by the end of August. The size of the area selected for summer irrigation should not be too large for irrigation on an 18-day schedule with the water available. Timely rainfall in some seasons will permit extending the irrigated acreage.

The depth of water to be applied at an irrigation depends on the moisture content and storage capacity of the soil. Enough water should be applied to replenish the moisture deficit in the root zone or to obtain field capacity to a desired depth.

Experience and the use of a sharpshooter (pointed shovel), soil tube and a soil auger or probe to determine depths of water penetration and to estimate moisture content are invaluable. Over-irrigation wastes valuable water and time and is detrimental to the crop. Under-irrigation requires more frequent applications with higher evaporation losses and labor costs.

See your local Extension Service or Soil Conservation Service personnel for assistance in estimating moisture conditions in the soils on your farm.

Cultural Practices

Cotton should be planted between May 10 and 20 to obtain a good stand and yield. Studies at the Lubbock station show that little gain in maturity is obtained by earlier planting. Early-planted cotton often has to be replanted, or a poor stand is obtained with some decrease in yield as a result of cold ground, disease and weather conditions.

The planting rate should be 20 to 30 pounds of seed per acre. Normally cotton is planted in 40-inch rows to facilitate the use of the cotton

TABLE 6. CONSUMPTIVE USE OF COTTON BY 10-DAY PERIODS ON PULLMAN CLAY LOAM SOIL WITH 50 PERCENT AVAILABLE MOISTURE MAINTAINED IN 0-24-INCH SOIL DEPTH UNTIL AUGUST 15, TULIA

Period	1953	1954
	Inches of water	
June 1-10	.4	.2
11-20	.4	.8
21-30	.4	1.0
July 1-10	.6	.9
11-20	2.7	3.8
21-30[1]	2.6	3.2
August 1-10	4.2	3.3
11-20	.3	3.4
21-30[1]	2.6	3.4
September 1-10	2.5	1.6
11-20[2]	.7	.8
21-30[2]	.5	.4
Water used by plants	17.9	19.4

[1]Daily water use for July 31 and August 31 has been included in the last 10-day periods.
[2]Low availability of moisture in 0-24-inch depths.

TABLE 7. MONTHLY CONSUMPTIVE USE BY COTTON WHEN NOT LESS THAN 50 PERCENT AVAILABLE MOISTURE WAS MAINTAINED IN THE 0-24-INCH SOIL DEPTH UNTIL AUGUST 15, TULIA

Month	Year 1953	Year 1954	Average
	Inches		
June	1.0	2.0	1.5
July	5.9	7.9	6.9
August	7.1	9.2	8.1
September	3.7	2.8	3.3
Total	17.7	21.9	19.8

Figure 5. Yields were considerably lower on the borders receiving only a preplanting irrigation in the test near Tulia, 1954.

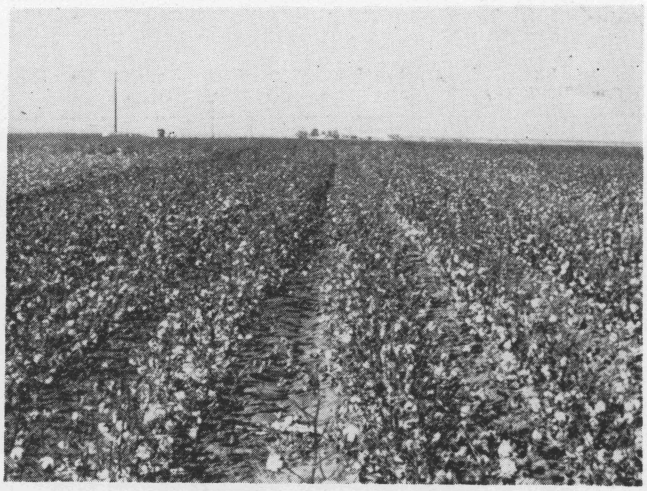

Figure 6. Yields were high on borders kept at not less than 50 percent available moisture to August 15 in the test near Tulia, 1954.

Figure 7. Plants receiving only a preplanting irrigation had exhausted most of the water in the soil profile before September 29 on the irrigation tests near Tulia, 1953.

stripper. The cotton should be planted in shallow furrows and covered 1½ to 2 inches deep.

Cultivation should be made only when needed for weed control. Cultivations to maintain a dust mulch do not conserve moisture. High residue crops and minimum tillage operations, however, help maintain adequate intake rates. Even though hand harvest is still used by many farmers, economic studies conducted on the High Plains show that the stripper harvester is more economical and nets the farmer the most money.

Figure 8. Sound irrigation practices allow plants to become hardened as the season ends and prevent a crop of "bolly" cotton. These stormproof bolls were well matured by frost, 1954.

Methods of Irrigation

The furrow method of water application is most commonly used on the High Plains. A system of graded furrows has been most popular, although little consideration has been given to an efficient design. A few farmers using level furrows find that more uniform crops and higher yields with less water are possible, but more labor may be required than with the graded furrow. Some cotton is being produced on the bench-leveled slopes with level borders, graded borders, level furrows or graded furrows. These benches, usually 8 to 12 rows wide, are farmed with conventional equipment. Small streams of water available on most of the farms in the area make the border method of irrigation impractical.

Sprinkler irrigation has become popular and is more efficient than the furrow method of application on the very sandy and rolling land found in part of the cotton-producing areas. A well-designed sprinkler system is recommended where the soils take water rapidly or the terrain is not suitable for furrow irrigation.

Most growers find that the furrow method of distributing water is the most satisfactory and cheapest on the finer textured soils. The use of underground tile and portable aluminum pipe, or portable aluminum pipe only, has been satisfactory, especially where the farm has steep slopes.

Fiber Quality

The quality of cotton may be affected greatly by summer irrigations. Fiber tests made on cotton from the irrigation tests at Lubbock show that the highest quality cotton was produced with only a preplanting irrigation. Largest yields were made with two summer irrigations but the quality of the cotton produced was low. Three summer irrigations reduced both the yield and quality. A good compromise between quality and yield came from a late July irrigation which produced less lint per acre but better fiber quality. Late irrigations, after August 30, are likely to cause poor quality fiber and also may reduce yields.

The fiber qualities most adversely affected by late irrigations are micronaire fineness and maturity. If these two tests are not made, the poor quality will be reflected by the cotton classer's grade. Other factors of quality which may be affected are strength, uniformity and color.

Acknowledgment

These studies were conducted cooperatively by the Texas Agricultural Experiment Station and Soil and Water Conservation Research Branch, Agricultural Research Service, U. S. Department of Agriculture.