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Requirements for GRAIN SORGHUM IRRIGATION *on the High Plains*

in cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

TEXAS AGRICULTURAL EXPERIMENT STATION
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Summary and Recommendations

Irrigation research was conducted with grain sorghum on the optimum use of underground water resources at the Amarillo and Lubbock Experiment Stations and on off-station plots during the past several years.

Highest returns in pounds of grain per inch of water are received when grain sorghum is supplied with adequate moisture from planting to the soft dough stage.

High-moisture levels are the most profitable; if the irrigation water supply becomes inadequate, the acreage to which water is applied should be reduced.

A grain sorghum crop can be produced with a preplanting irrigation alone in very dry years when dryland crops are complete failures.

Nitrogen fertilizers can be used to advantage with proper water management and will provide yields of 5,000 pounds or more of grain per acre.

Definition of Terms

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

Water Utilization Efficiency. The crop yield produced per inch of water used consumptively. It is expressed as tons of forage or pounds of grain per inch of water.

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 free water within capillary reach of the root zone. This moisture percentage usually is reached within 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.

Available Soil Moisture. The amount of soil moisture available for plant growth at any time is the difference between the moisture content of the soil and the permanent wilting point. It usually is expressed in inches of water per foot of soil depth or in inches of water for the root zone. The difference between field capacity and the permanent wilting point moisture content of a soil is its maximum available moisture storage capacity.

Requirements for

GRAIN SORGHUM IRRIGATION *on the High Plains*

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SORGHUMS HAVE ALWAYS BEEN an important crop on the High Plains of Texas. The crop was irrigated soon after the first irrigation wells were developed in the 1911-14 period. There were approximately 140 irrigation wells on the South Plains (Southern High Plains) in 1914. The first water-use studies with sorghum grain were conducted near Plainview in Hale county in 1918-19 by William L. Rockwell, a U. S. Department of Agriculture irrigation engineer, in cooperation with the Texas Land and Development Company of Plainview.

Dry weather in 1934-35 and the availability of more efficient pumps and power units stimulated further interest in irrigation. The number of wells on the South Plains increased from 300 in 1934 to 1,500 in 1938. The increase in the number of irrigation wells continued and despite wartime restrictions there were 4,300 irrigation wells in the area by 1945.

Irrigation has doubled or tripled grain sorghum yields obtained under dryland conditions on the High Plains of Texas and is a dominant factor in the production of the crop. Over 4,300,000 acres of land are being irrigated from more than 36,500 wells in the High Plains counties. More than 1,500,000 acres of grain sorghum were reported under irrigation in this area in 1955. The number of wells, acres irrigated and acreage of irrigated grain sorghum reported in 1955 by the Texas Agricultural Extension Service are shown by counties in Figure 1.

Irrigation water on the High Plains is supplied almost entirely from underground water. This underground water resource is being depleted further each season. At present there is no economically feasible method of providing an adequate annual recharge of ground water. Use of this water must be planned over a long period of years rather than 1 or 2 years as would be the case with gravity irrigation from a reservoir and streams with a known immediate supply. Irrigation research with grain sorghum on the optimum use of underground water resources has been conducted at the Amarillo and Lubbock stations and on off-station plots during the past several years.

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Research on the High Plains shows that good seedbed preparation and moisture conditions are required so that early germination, a good stand and a vigorously growing crop are obtained to shade and outgrow weeds. Weeds of the broad-leaved type can be controlled effectively by spraying with 2,4-D. Planting in close drill rows without cultivation is not recommended for fields known to be infested with grassy annuals.

Climate

Temperatures may fall below zero on the Northern High Plains during the winter and reach 106° on the Southern High Plains during the summer. The frost-free season averages 175 to 215 days from north to south. Sorghum breeders have adapted varieties to the length of season in their areas.

Wind velocities often are high and the major wind movement normally occurs during the first 6 months of the year. The prevailing wind is from the southwest, and strong winds sometimes interfere with irrigation activities early in the

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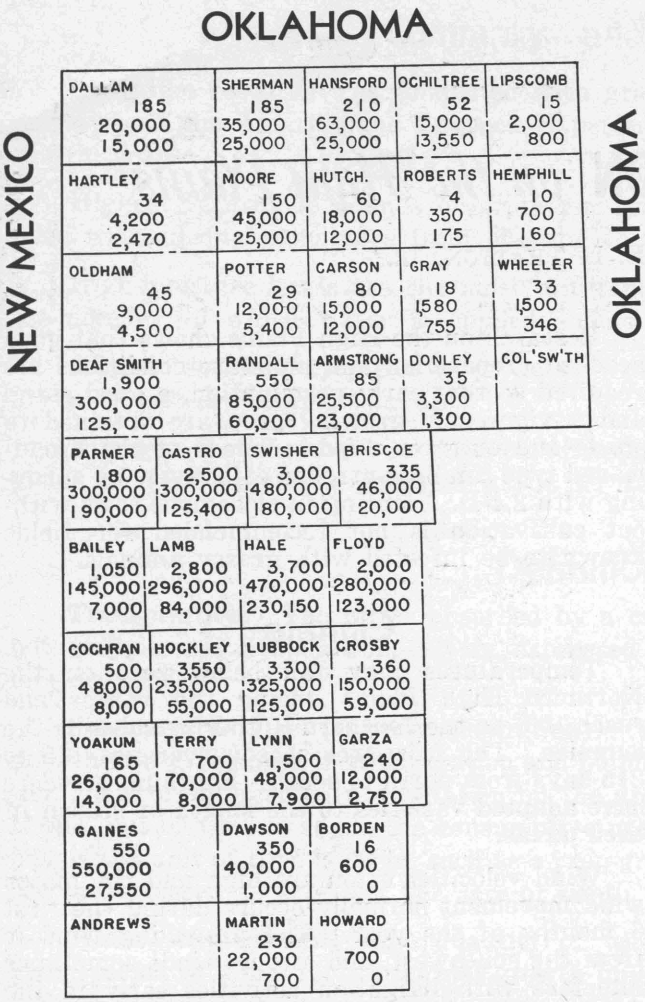

Figure 1. Number of wells (top figure), acres irrigated (middle figure) and acres of grain sorghum irrigated (bottom figure) on the High Plains of Texas as reported by the Extension Service in May 1955.

season. In some years sorghum fields may suffer damage from wind before harvest.

Hail damage occurs in some locality almost every year but widespread damage to sorghum is uncommon.

The variability of rainfall and extended periods of drouth are the greatest problems encountered in producing grain sorghum on the High Plains. Average annual precipitation varies from about 21 inches along the eastern edge of the High Plains to 15 to 18 inches along the Texas-New Mexico state line. Most of the rainfall is received during the April-to-October growing season. The winters usually are dry with little snow, which provides little soil moisture. Evaporation is high and averages from 80 inches annually in the south to 75 inches annually in the north.

Erratic rainfall and poor seasonal distribution of moisture frequently result in poor crop yields during years of above average rainfall. The average monthly distribution of rainfall at Amarillo, Table 1, and at Lubbock, Table 2, shows that few "average" years are anticipated. About 3 years out of 5 have below average monthly rainfall. The other 2 years of average-to-high monthly rainfall provide and maintain the average. The rainfall received during a season may vary widely from one locality to another. During the first 11 months of 1948, Amarillo received more than 24 inches of precipitation, while Lubbock, 120 miles south, received less than 9 inches.

An analysis by Jensen[1] shows that 34 percent of the precipitation received at Amarillo during the 30-year period, 1920-49, was in amounts of 0.50 inch and less, while less than 40 percent of the precipitation was received in amounts exceeding 1.0 inch. One rain in excess of 1.0 inch and three rains ranging from 0.50 to 1.0 inch usually can be expected during July and August.

Soils

The soils of the High Plains are classified in three general groups: the hard or tight lands, the mixed or catclaw lands and the sandy lands. The hard lands comprise about 70 percent of the cultivated land and the mixed land about 25 percent. A generalized soils map of the High Plains is shown in Figure 2.

The hard or tight lands, generally classified as Pullman silty clay loams, consist of 6 to 12 inches of clays or clay loams over heavy clay subsoils, with soft caliche layers at a depth of 3 feet or more. These soils absorb water slowly but have a high water-holding capacity. They usually are capable of storing over 2 inches of available water per foot of soil depth. Intake rates may be as low as 0.10 inch per hour or less, but with proper management practices, intakes of 0.25 to 0.50 inch per hour can be obtained.

The mixed lands generally are Amarillo or Portales fine sandy loams. These soils absorb water more rapidly and have a medium water-holding capacity of 1.5 to 2 inches of available moisture per foot of depth, with intake rates of 1 to 2 inches per hour under normal conditions.

TABLE 1. A 63-YEAR SUMMARY OF NORMAL PRECIPITATION BY MONTHS, AMARILLO STATION, 1892-1954

Month	Average rainfall, inches	Years below average, percent	Years within 1/4 of average, percent	Years of 3 inches or more, percent
January	.64	67	22	0
February	.62	63	21	0
March	1.04	73	13	1
April	1.45	56	14	14
May	3.01	60	22	40
June	3.25	71	21	32
July	2.36	60	25	33
August	2.99	54	25	46
September	2.28	63	24	29
October	1.93	65	14	17
November	.88	62	13	10
December	.67	56	17	1
Yearly average	21.13			

They consist of 6 to 12 inches of clay loams over fine sandy clay subsoils with a caliche layer at a depth of 3 feet or more.

The sandy soils have lower water storage capacities and have not contributed greatly to the acreage of irrigated sorghum.

Shallow soils often are found on the steeper slopes around playa lakes. These soils because of their lack of depth and low moisture storage capacity are not well suited for grain sorghum productions.

Experiments at Lubbock

An irrigation well was completed at the Lubbock station late in the spring of 1936 and irrigation experiments with grain sorghum were initiated the following year. A progress report[2] was published in 1940 summarizing results obtained for 1937-39. On the basis of these studies, recommendations included a preplanting irrigation, planting in late May or early June, irrigating just preceding the booting stage and a third irrigation in 10 days to 2 weeks in very dry years.

A summary of the data obtained from these earlier studies is given in Table 3. Hegari was the variety used. No fertilizer was applied to the fine sandy loam soil which had been dryland cropped for more than 25 years. The four irrigation treatments used were based on fixed dates of irrigation together with the stage of crop growth.

Rainfall in 1937 was well distributed and totaled 22.25 inches. A total of 16.52 inches was received in 1938 with 9.90 inches during June and July; late August and September were dry. Only 11.71 inches of precipitation were received in 1939 and rainfall was deficient throughout the growing season; late August and September were dry and exceptionally hot. This 3-year study showed the value of irrigation in a comparatively favorable season as well as in a dry season. Preplanting irrigations with June or July and August irrigations provided substantial increases in yield every year.

TABLE 2. A 44-YEAR SUMMARY OF NORMAL PRECIPITATION BY MONTHS, LUBBOCK STATION, 1911-54

Month	Average rainfall, inches	Years below average, percent	Years within 1/4 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			

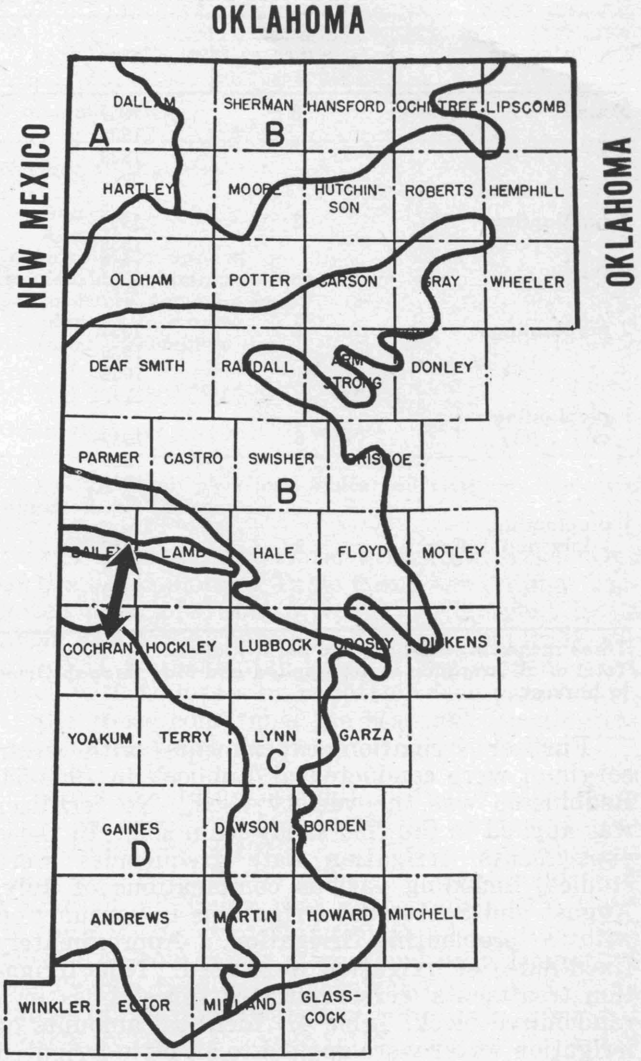

Figure 2. Generalized soil map showing the various soil types and locations on the High Plains of Texas.

A. *Dalhart-Springer Soil Association (mixed land). Predominantly deep, medium and coarse-textured, moderately permeable soils such as Dalhart fine sandy loam and Springer fine sand.*

B. *Pullman Soil Association (hard land or tight land). Predominantly deep, fine-textured, slowly permeable soils such as Pullman silty clay loam.*

C. *Amarillo-Portales Soil Association (mixed land). Predominantly deep, medium-textured, moderately permeable soils such as Amarillo fine sandy loams.*

D. *Brownfield-Tivoli Soil Association (sandy land). Predominantly deep, coarse-textured, moderately permeable soils such as Brownfield fine sand. Occasional areas of dune sand also occur (Tivoli soils).*

TABLE 3. RESULTS OF GRAIN SORGHUM IRRIGATION TESTS AT THE LUBBOCK STATION, 1937-39

Irrigation	Irrigation water, inches[1]	Year	May through Oct. rainfall, inches	Total water irrigation and rainfall, inches[2]	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
None	0	1937	17.6	17.6	1854	106
		1938	13.5	13.5	1333	99
		1939	7.9	7.9	538	68
		Av.	13.0	13.0	1241	96
1 preplanting	3	1937	17.6	20.6	1798	87
		1938	13.5	16.5	1618	98
		1939	7.9	10.9	1523	140
		Av.	13.0	16.0	1646	103
2 preplantings	6	1937	17.6	23.6	1915	81
		1938	13.5	19.5	1820	93
		1939	7.9	13.9	2201	158
		Av.	13.0	19.0	1979	104
1 preplanting and 1 July	6	1937	17.6	23.6	3186	135
		1938	13.5	19.5	3248	167
		1939	7.9	13.9	2710	197
		Av.	13.0	19.0	3048	160
1 preplanting, 1 July and 1 Aug.	9	1937	17.6	26.6	3371	127
		1938	13.5	22.5	3674	163
		1939	7.9	16.9	3293	195
		Av.	13.0	22.0	3446	157

[1]Three inches of water applied per irrigation.
[2]Total of all irrigation water applied and May through October precipitation, not including changes in soil storage from planting to harvest.

Further irrigation experiments with grain sorghum were conducted at Lubbock in 1953-54. Redbine-66 was the variety used. No fertilizer was applied to the fine sandy loam soil. In these experiments, irrigation date frequencies were studied, including various combinations of July, August and September irrigations in conjunction with a preplanting irrigation. Approximately fixed dates of irrigation were used. Nine irrigation treatments were replicated three times in a randomized block, Table 4. Identical amounts of irrigation water were applied to all plots irrigated at any one date of irrigation.

June through September had above normal temperatures and below normal precipitation in 1953 and 1954. Only 3.81 inches of rainfall were received during this period in 1953 and 2.43 inches during 1954. Because of unusually hot, dry seasons, moisture stress was not completely eliminated with any of the treatments used. The treatments that most adequately supplied the water requirements of the crop provided better yields.

Experiments at Amarillo

Irrigation experiments with grain sorghum were initiated at the Amarillo station in 1949. Three treatments were used: a preplanting irrigation with no further irrigation, a preplanting irrigation with one irrigation after planting and a

TABLE 4. RESULTS OF GRAIN SORGHUM IRRIGATION TESTS AT THE LUBBOCK STATION, 1953-54

Irrigation		Irrigation water, inches		Total water, irrigation and growing season rainfall, inches		Grain yield per acre, pounds		Grain yield per acre-inch of water, pounds	
		1953	1954	1953	1954	1953	1954	1953	1954
	None	0	0	6.5	9.8	0	1395	0	142
A	Apr.	13.7	7.5	20.3	17.2	3580	2166	177	126
AB	Apr., July	19.0	10.8	25.6	20.6	4708	2917	184	141
AC	Apr., Aug.	17.3	12.2	23.9	22.0	4268	3312	179	151
AD	Apr., Sept.	19.0	13.0	25.6	22.7	4169	2561	163	113
ABC	Apr., July, Aug.	22.6	15.6	29.2	25.4	4807	3866	165	153
ABD	Apr., July, Sept.	24.3	16.3	30.9	26.1	5640	3593	183	138
ACD	Apr., Aug., Sept.	22.6	17.7	29.2	27.5	4856	3987	166	145
ABCD	Apr., July, Aug., Sept.	27.9	21.1	34.5	30.8	4905	4516	142	146
L.S.D.	.05						366		
	.01						502		

1953 irrigations, inches

A	(3/5 12.2 + 6/17 1.5)	13.7
B	7/10	5.3
C	8/3	3.6
D	9/4	5.3

Growing season rainfall 6.55 inches.
Total year's precipitation 10.69 inches.

1954 irrigations, inches

A	4/26	7.5
B	7/13	3.4
C	8/2	4.7
D	8/30	5.5

Growing season rainfall 9.79 inches.
Total year's precipitation 13.67 inches.

preplanting irrigation with two irrigations after planting. These treatments were similar to the earlier experiments at Lubbock except that fixed dates of irrigation were not used. Soil moisture samples were taken throughout the season and the planned summer irrigations were made when moisture deficiencies of about 4 inches were measured in the root zone. Each treatment was replicated three times in a randomized block. Preplanting irrigations were adequate to bring the Pullman silty clay loam soil to field capacity to a depth of 6 feet. Fertilizer was not used in any of these studies.

Unusually favorable soil moisture conditions in the spring of 1949 made a preplanting irrigation unnecessary. The plots were planted to the Double Dwarf Sooner variety at 7.5 pounds per acre in 38-inch rows. Except for limited irrigation in recent years, the land had a 20-year history of dryland small grain and sorghum cropping. A high-intensity rain on the day of planting caused crusting, and unfavorable stands for an irrigated crop resulted. The yields were not high but good water utilization efficiencies were obtained, Table 5. A favorable distribution of rainfall during the growing season eliminated the need for irrigation during July and only two irrigation treatments were used. The 2.5-inch irrigation applied a week after planting contributed little toward obtaining a better stand and did not provide a high irrigation efficiency. If this irrigation had not been applied it is doubtful that any appreciable difference would have existed in the water utilization efficiency of the two treatments.

TABLE 5. SUMMARY OF CONSUMPTIVE USE DATA, YIELD AND WATER UTILIZATION EFFICIENCIES FOR GRAIN SORGHUM GROWN UNDER IRRIGATION, AMARILLO STATION, 1949

Irrigation	Irrigation water applied after planting, inches	Consumptive use, inches[1]	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
None	0	11.6	2445	210
One 4-inch irrigation, Aug. 16-17[2]	6.5	17.2	2967	173

[1]Preplanting irrigations were not required. Total water includes 8.56 inches of rainfall from planting to harvest and the decrease in soil moisture storage from planting to harvest.
[2]These plots also were given a 2.5-inch irrigation the week after planting to soften the hard surface crust which resulted after a high-intensity rain on the day of planting.

A comparison of sorghum drilled in 10-inch rows with that grown in listed 38-inch rows also was made in 1949. Early Hegari was planted at 14 pounds per acre. Drilled sorghum increased yield approximately 800 pounds per acre above that of row-planted sorghum, and with 3 inches less water for the season, Table 6. The 10-inch drilled plots were not cultivated and weeds were not a problem. Evaporation losses were undoubtedly lower on these plots because the soil surface was observed to remain moist longer after irrigation or rainfall. The water utilization efficiencies of the listed plots of Table 6 and the August irrigated plots of Table 5 would be expected to be about the same; however, the fact that they are identical is incidental. All of these plots were level, with no losses by runoff or deep percolation. Under these conditions the seasonal consumptive use and the water requirement are the same.

TABLE 6. DRILLED (10-INCH ROW SPACING) VERSUS LISTED (38-INCH ROW SPACING) EARLY HEGARI ON LEVEL-BORDERED PLOTS, AMARILLO STATION, 1949

Water utilization	Drilled	Listed
Number of irrigations	2	2
	Inches	
Aug. 1-2	4.0	4.0
Aug. 24-25	2.6	3.3
Depth of water applied	6.6	7.3
Rainfall from planting to harvest	8.6	8.6
Soil moisture depletion from planting to harvest	0.1	2.4
Seasonal consumptive use	15.3	18.3
	Pounds	
Grain yield per acre	4,010 (5,053)[1]	3,169 (3,395)[1]
Grain yield per acre-inch of water	262	173

[1]Actual yields on plots from which soil moisture data were obtained.

Four off-station irrigation studies with grain sorghum also were conducted on representative irrigated fields in 1949. Good irrigation practices were used but a uniform plan for the time of irrigation of all fields was not established. Good to high yields were obtained at all locations and with a narrow range of seasonal requirements if the Tahoka field is not considered, Table 7. This range of seasonal water requirements compares closely with the consumptive use by irrigated

TABLE 7. RESULTS OF IRRIGATION EXPERIMENTS WITH GRAIN SORGHUM ON THE HIGH PLAINS, 1949

Location	Floydada	Plainview	Tahoka	Hereford
Soil texture	Silty clay loam	Silty clay loam	Sandy loam	Silty clay loam
Irrigations after planting	3	2	2	2
Irrigation water applied after planting, inches	9.7	6.5	10.0	8.1
Rainfall, planting to harvest, inches	6.57	10.75	16.83	8.20
Soil-moisture decrease, planting to harvest, inches	0.2	negligible	0.6	3.6
Seasonal water requirement, inches	16.5	17.3	27.4[1]	19.9
Grain yield per acre, pounds	3,687	3,150	3,184	5,136
Grain yield per acre-inch of water, pounds	223	182	116	258

[1]There were losses by deep percolation of both rainfall and irrigation water at Tahoka; fertilizers were not used.

TABLE 8. SUMMARY OF CONSUMPTIVE USE DATA, YIELD AND WATER UTILIZATION EFFICIENCIES FOR GRAIN SORGHUM GROWN UNDER IRRIGATION, AMARILLO STATION, 1950

Irrigation	Irrigation water applied after planting, inches	Consumptive use, inches[1]	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
Preplanting irrigation only	0	16.5	1343	81
Preplanting irrigation, 1 on Aug. 18-19	4.0	18.4	1550	84

[1]A 5-inch preplanting irrigation was used. Consumptive use includes 15.62 inches of rainfall from planting to harvest and the decrease in soil moisture storage from planting to harvest.

TABLE 9. SUMMARY OF CONSUMPTIVE USE DATA, YIELD AND WATER UTILIZATION EFFICIENCIES FOR GRAIN SORGHUM GROWN UNDER IRRIGATION, AMARILLO STATION, 1951

Irrigation	Irrigation water applied after planting, inches	Consumptive use, inches[1]	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
None	0	17.1	1510	89
1 irrigation, July 20	4.0	20.5	2111	103
2 irrigations, July 20, Aug. 13	7.5	21.9	3355	153

[1]Preplanting irrigations were not required. Total water includes 9.38 inches of rainfall from planting to harvest and the decrease in soil moisture storage from planting to harvest.

grain sorghum measured at Amarillo in 1949. Deep percolation losses of the high seasonal rainfall and some losses of irrigation water by deep percolation greatly increased the water requirement measured at Tahoka.

Table 8 shows the results of the 1950 studies. Yields and water utilization efficiencies were lower than expected. These studies were conducted on a field newly prepared for irrigation, which had a much longer cropping history than the field used in 1949. Martin was used and although good stands were obtained, poor yields resulted from an inadequate supply of nitrogen.

The 1951 studies were conducted on the same plots as the 1949 studies. A weedy stand of sweet clover had occupied the plots in 1950. A summary of the data obtained in 1951 is given in Table 9. Greatly increased water utilization efficiencies were obtained with added irrigation in 1951.

Experiments at Tulia

Studies were conducted in 1953 and 1954 on Pullman silty clay loam soils near Tulia in Swisher county. This field had a 40-year cropping history, principally winter wheat in earlier years, and grain sorghum and cotton during the last 15 years. The field had been under irrigation for 7 years and commercial fertilizer (N,P) had been applied to the 1952 crop of cotton.

Previous work indicated that fixed irrigation schedules could not be followed to obtain maximum returns from the limited underground water resource. These studies incorporated four moisture levels, Tables 10 and 11. Each treatment included the use of a preplanting irrigation and was replicated three times in a randomized block. No runoff losses of rainfall or irrigation water were experienced from the level plots used.

Consumptive use values in Table 11 include 0.9 inch available water in the soil at the time of applying a 6.5-inch preplanting irrigation in late April, 3.77 inches of further rainfall before planting and 3.33 inches of rain during the growing season, a total of 14.5 inches. At planting, the soil profile was at field capacity to a depth of 60 inches throughout the field and to 72 inches at many sampling points. The 72-inch profile contained the following amounts of available moisture at harvest which were subtracted: treatment A—0 inch; treatment B—5.4 inches; treatment C—4.2 inches; and treatment D—6.0 inches.

Redbine-66 was planted in 40-inch spaced rows. Fertilizer was not used in either 1953 or 1954, but a fertilizer test with irrigated grain sorghum was conducted at the same location.[3 4]

The 1953 season was the hottest and driest on record for most vicinities on the High Plains. Dryland crops failed in nearly all localities. Only 2.71 inches of rainfall were measured from planting to harvest in Tulia. Yields of over 5,000 pounds of grain were obtained in these studies with treatments including three and four irrigations after planting.

TABLE 10. SUMMARY OF CONSUMPTIVE USE DATA, YIELD AND WATER UTILIZATION EFFICIENCIES FOR GRAIN SORGHUM GROWN UNDER IRRIGATION, TULIA, 1953

Irrigation	Irrigations after planting		Consumptive use, inches[1]	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
	Number	Inches			
A — Preplanting only	0	0	12.7	1110	87.3
B — Irrigation before 75% available water is exhausted from 0 to 24-inch depth to 9-15	3	10.9	23.6	5205	220.5
C — Irrigation before 50% available water is exhausted from 0 to 24-inch depth to 9-1	3	10.5	23.2	4230	184.2
D — Irrigation before 50% available water is exhausted from 0 to 24-inch depth to 9-15	4	14.1	26.8	5210	194.5
L.S.D. .05				52	
.01				79	

[1]Including 2.71 inches rainfall from planting to end of growing season.

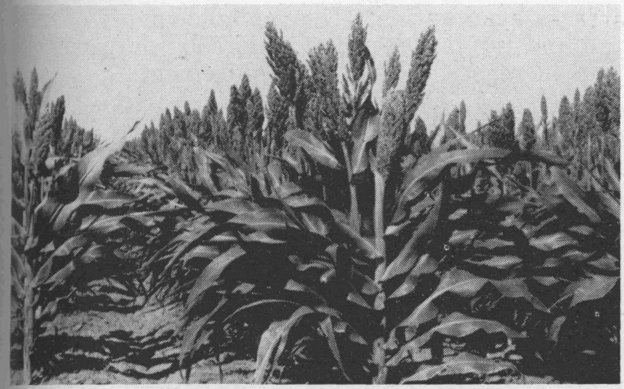

Figure 3. Grain sorghum on plot with above 25 percent available moisture maintained in the 0 to 24-inch depth until September 15, Tulia, September 29, 1953.

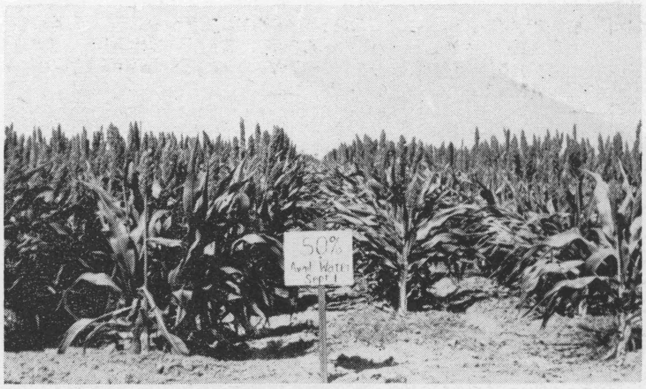

Figure 4. Grain sorghum on plot with above 50 percent available moisture maintained in the 0 to 24-inch depth until September 1, Tulia, September 29, 1953.

The preplanting only treatment (treatment A) produced grain but with a much lower water utilization efficiency. The highest water utilization efficiency in 1953 was obtained when 25 percent available moisture level was maintained in the 0 to 24-inch depth (treatment B). Plants receiving this particular treatment were stressed for water because of high temperature early in the season. They bloomed about a week later and had somewhat heavier heads of grain than plants in the other two treatments receiving summer irrigations. This condition did not occur again in 1954 with the same treatments. Plants on each of the three irrigation treatments receiving summer irrigations in 1953 are shown in Figures 3, 4 and 5. Growth was excellent on all of the three treatments. However, a reduced yield resulted when the September irrigation was withheld. The reduction in yield was attributed to a lack of available moisture within the 0 to 24-inch soil depth through September 15. No rainfall was received in August or September.

A comparison of the available moisture in storage during the 1953 season with 50 percent available moisture maintained in the 0 to 24-inch depth until September 15 (treatment D) and a preplanting irrigation only (treatment A) is shown in Figure 6. Rains contributed to the available moisture in storage only once during the season. Water use by the plants receiving only a preplanting irrigation was greatly reduced in early August because of lack of available moisture.

The 1954 season was similar to the 1953 season. Dryland crops failed in the Tulia vicinity. Lower yields were obtained in 1954 than in 1953 because of a nitrogen deficiency. Plots in another experiment that received 80 pounds of nitrogen, sidedressed at planting, yielded 5,340 pounds of grain per acre when maintained at 50 percent available moisture in the 0 to 24-inch depth until September 15 (treatment D).[4]

The sorghum in Figure 7 received a preplanting irrigation but had not been irrigated since planting. These plants had received less than 1 inch of rain by July 28, 1954. Figure 8 shows sorghum grown under identical conditions except

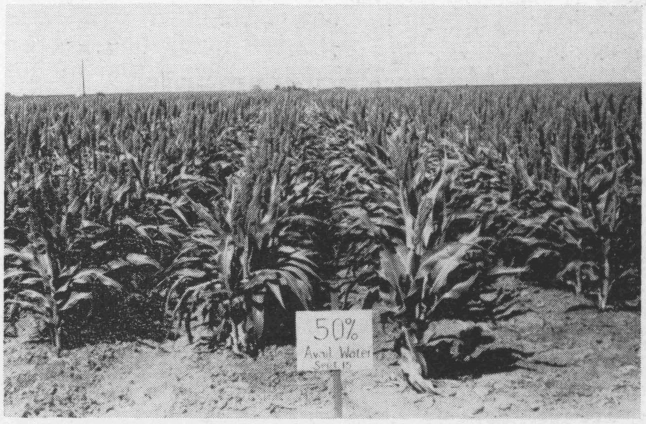

Figure 5. Grain sorghum on plot with above 50 percent available moisture maintained in the 0 to 24-inch depth until September 15, Tulia, September 29, 1953.

TABLE 11. SUMMARY OF CONSUMPTIVE USE, YIELD AND WATER UTILIZATION EFFICIENCY DATA FOR GRAIN SORGHUM GROWN UNDER IRRIGATION, TULIA, 1954

Irrigation	Irrigations after planting		Consumptive use, inches	Grain yield per acre, pounds	Grain yield per acre-inch of water, pounds
	Number	Inches			
A — Preplanting only	0	0	14.5	1283	88.5
B — Irrigation before 75% available water is exhausted from 0 to 24-inch depth to 9-15	3	12.0	21.1	2828	134.0
C — Irrigation before 50% available water is exhausted from 0 to 24-inch depth to 9-1	3	11.0	21.3	2993	140.5
D — Irrigation before 50% available water is exhausted from 0 to 24-inch depth to 9-15	4	15.0	23.5	3173	135.0
L.S.D. .05				672	
.01				1018	

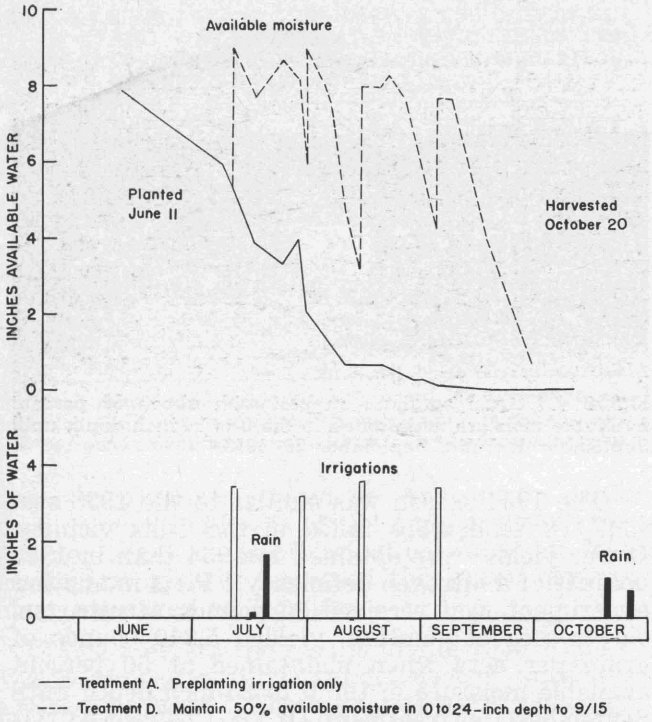

Figure 6. Available water in storage, irrigation water applied and rainfall with grain sorghum on Pullman silty clay loam, Tulia, 1953.

that a 4-inch irrigation was applied on July 21 before the available soil moisture in the 0 to 24-inch depth was depleted to 25 percent of storage capacity.

Water Requirements

The water requirement of grain sorghum is not a fixed value. In hot, dry years transpiration by the plant is higher than in cool, relatively humid seasons. Low relative humidities, high temperatures and wind movement also increase evaporation from the soil surface, adding further to the consumptive use. Other factors also can cause important differences in consumptive use and water requirement. Restricted soil moisture reduces transpiration. Frequent irrigation increases evaporation. Unavoidable runoff of rainfall and irrigation water or loss by deep percolation increases the water requirement.

Water used for crop growth may be supplied to the soil by precipitation or irrigation during or before the period of crop growth. Water use was determined in these studies by measuring the amount of available water in the soil at planting time or at the time of the preplanting irrigation, adding the rainfall and irrigations applied during the season and subtracting the amount of available water in the soil at harvest. The balance is the water required to produce the crop. A summary of the water requirements of grain sorghum at various locations on the High Plains for the 5-year period, 1949-51, 1953-54, is presented in Table 12.

In favorable years, such as 1949, the water requirement of high-yielding grain sorghum has been as low as 16 to 18 inches of water. In hot, dry years, such as 1953 and 1954, 24 inches of water were required to produce a maximum yield.

Water Management

Irrigation water and rainfall are equally valuable for crop production. An additional acre-inch of rainfall utilized is an acre-inch of irrigation water saved for a later irrigation application. In most years rainfall provides half the water requirement of grain sorghum. The final measure of efficient water use by the crop is in the pounds of grain obtained per acre-inch of water. Since water rather than land is limited, the highest possible yield per acre, irrespective of water use, is not necessarily the most profitable. The greatest return per acre-inch of water has been obtained by providing adequate amounts of water for vigorous crop growth throughout the season to plants adequately supplied with the necessary nutrients.

Consumptive Use

Water use by the grain sorghum plant begins with germination but is comparatively low for the first 2 or 3 weeks of development, averaging

TABLE 12. WATER REQUIREMENTS FOR GRAIN SORGHUMS AT VARIOUS LOCATIONS ON THE HIGH PLAINS, 1949-51, 1953-54

Year	Location	Rainfall, planting to harvest, inches	Irrigation applied after planting, inches	Soil moisture storage decrease, inches[1]	Water requirement, inches
1949	Floydada	6.57	9.74	0.19	16.50
	Plainview	10.75	6.50	0	17.25
	Tahoka[2]	16.83	10.00	0.60	27.43[2]
	Hereford	8.20	8.03	3.63	19.86
	Amarillo	8.56	6.54	2.09	17.19
	Amarillo	8.56	7.12	2.35	18.33
	Amarillo[3]	8.56	6.72	0.10	15.40
1950	Amarillo	15.62	4.00	1.20	18.42
1951	Amarillo	9.38	7.53	5.03	21.94
1953	Tulia	2.71	14.10	9.00	26.80
		2.71	11.90	9.00	23.60
1954	Tulia	3.33	15.00	6.10	23.50

[1]Available water in storage at planting minus available water in storage at harvest.
[2]Losses due to deep percolation of heavy rainfall following irrigation.
[3]Drilled in 10-inch spaced rows.

from 0.05 to 0.10 inch per day. Irrigation should not be necessary during this time even through periods of drouth, except for sandy soils with low water-holding capacities. Daily water use through July, August and early September averages about 0.25 inch.

The year-to-year variation in the use of water by grain sorghum at several locations by 10-day periods is shown in Figure 9. The 1950 growing season was considered favorable and moisture use did not reach an average of .25 inch per day during any of the 10-day periods.

There were no rains from planting until late July in 1953. Evaporation losses from the soil surface during June and July were low and consumptive use during the early stages of crop growth was low. Record high temperatures, evaporation following irrigation and increased transpiration provided extremely high water use during the latter part of July and August despite some relief provided by rains during July 18 to 21. June and July in 1954 were similar to 1953 except that small rains permitted greater evaporation losses which increased consumptive use. High temperatures in July and August 1954 again provided very high consumptive use, but a significant decrease was obtained in early August from several days of cool weather.

Preplanting Irrigations

Preplanting irrigations should be made to provide field capacity storage to a depth of 5 or 6 feet if the soil profile is that deep. Ten to 12 inches of irrigation water should be applied to Pullman silty clay loam soil, which has little available water in the profile. Amarillo and Lubbock station weather records show that preplanting irrigations are needed 2 years out of 3 to bring the soil to field capacity. Precipitation fails to remoisten the soil surface by planting time in only 1 year out of 20 following an early preplanting irrigation and subsequent drying of the surface soil at Amarillo. Precipitation fails to remoisten the surface soil for planting in less than 1 year out of 7 when winter preplanting irrigations are used at Lubbock.

Frequency of Irrigation

Rainfall usually provides half the water requirement of grain sorghum, but it is too undependable to eliminate the need for planning each irrigation in the water-management program. Irrigation may be delayed a few days and the necessary depth of application decreased following an effective and timely rain at any time during most seasons. Rains seldom are adequate to provide for consumptive use for a 2-week period during the irrigation season and thus completely eliminate an irrigation. Less than 10 percent of the rains during the growing season at Amarillo are 1 inch or more. Only one rain in excess of 1 inch can be expected during July and August at Amarillo. Monthly rainfall totaling 3 inches or more in any 1 month during the growing season

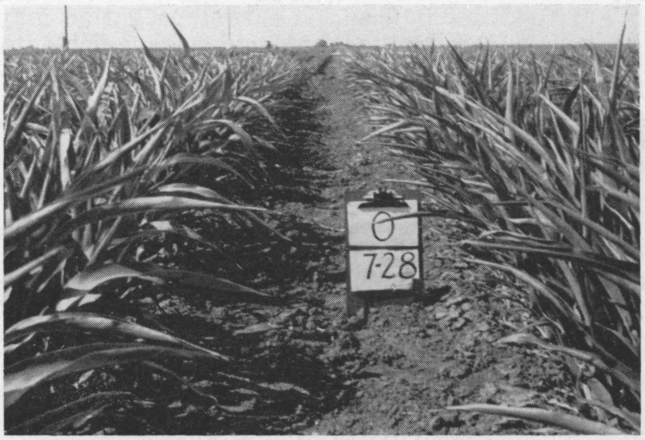

Figure 7. Sorghum that did not receive irrigation after planting was in severe stress by late July. All plots received a preplanting irrigation, Tulia, July 28, 1954

occurs in less than 1 year out of 3 at the Lubbock station. Runoff should be controlled so that the bigger rains expected during a season can be utilized more effectively.

A theory has existed that if sorghum is put in stress for water a deeper root system is produced. Another similar idea has been that "it doesn't hurt sorghum to wait for water." Both are without basis. At no time in the 5 years of studies, 1949-51, 1953-54, was there any evidence that sorghum plants in stress for moisture produced better or deeper root systems. More water may have remained in the soil profile on plots receiving additional irrigation, but the use of subsoil moisture was as great or greater by plants maintained with constantly adequate supplies of available moisture. Plants once in severe stress for moisture never produced as much grain as plants not in stress even though rainfall and later irrigation provided enough moisture to grow a plant of normal size. An adequate and continuous supply of available soil moisture must be maintained to produce the greatest return per acre-inch of water.

Figure 8. Sorghum plants that received the first irrigation following planting July 21, when available moisture in the 0 to 24-inch depth decreased to 25 percent, made rapid growth during the following week, Tulia, July 28, 1954.

If fertilizer is used, an earlier irrigation may be required to make the fertilizer available to the plants. The successful use of fertilizer requires adequate moisture throughout the season. Studies show that where nutrients are limited, the use of fertilizer provides a higher return of grain per acre-inch of water.[4]

In extremely hot weather small sorghum plants wilt and appear to need water even though ample supplies of moisture are available in the soil within 6 or 8 inches of the surface. An irrigation usually relieves this condition, probably by the cooling effect rather than by providing additional water to the plant. Generally, it is not possible to irrigate large acreages of the crop during this stage of development and no data are available to indicate the economic value of such irrigations.

The first irrigation should be planned about 3 weeks after planting if rainfall has not replenished an appreciable portion of the 2 to 3 inches of water used by the sorghum crop and lost by evaporation. At this stage of growth some available moisture should be maintained in the surface foot of soil. On the Pullman soils the readily available moisture in the 0 to 24-inch depth should be maintained above 50 percent of storage capacity. After this time, irrigation will be required at 10 to 14-day intervals until after blooming whenever rainfall is inadequate to maintain 25 to 50 percent available water in the 0 to 24-inch depth of soil. Sandy soils or shallow soils require more frequent applications. Extremely high temperatures may require more frequent irrigations.

In late July, August and September, the crop extracts water from depths below 3 feet. Except on the sandier soils it often is not practical to refill these depths during the growing season. Usually the available water at these depths is adequate to meet the withdrawal by the sorghum crop for the entire season without replenishment. An adequate preplanting irrigation to bring the entire rooting depth of the soil to field capacity is important if the moisture storage capacity and plant nutrients of the entire profile are to be utilized.

In most seasons two irrigations after planting are adequate for sorghum if the potential root zone is near field capacity at planting time. Timing of irrigations cannot be predicted, but in nearly every year there is a period of inadequate rainfall and a soil-moisture deficiency in late July requiring an irrigation at or before that time. Usually applications of 3.5 to 4.0 inches are adequate for the growing crop on clay or loam soils, with 2.0 to 2.5 inches per application on extremely sandy soils. More frequent irrigation is required on a sandy soil.

Except for late-planted crops, irrigation in late August or the first several days of September is as late as additional water benefits a properly irrigated grain sorghum crop. If it is desired to provide moisture in storage for a succeeding crop, later or heavier irrigations may be applied. Sorghum plants continue to use water after maturity until frost at the rate of about 0.08 inch per day. With an early harvested crop it might be possible to save 2 inches of water or more if the field were tilled to kill the plants a month before frost. The wind erosion hazard should be considered in connection with fall tillage of sorghum stubble.

An irrigation should be started early enough so that the last plants irrigated will not have suffered for moisture. This often makes it desirable to increase the amount of water applied at the first irrigation. A 2-inch irrigation may be ade-

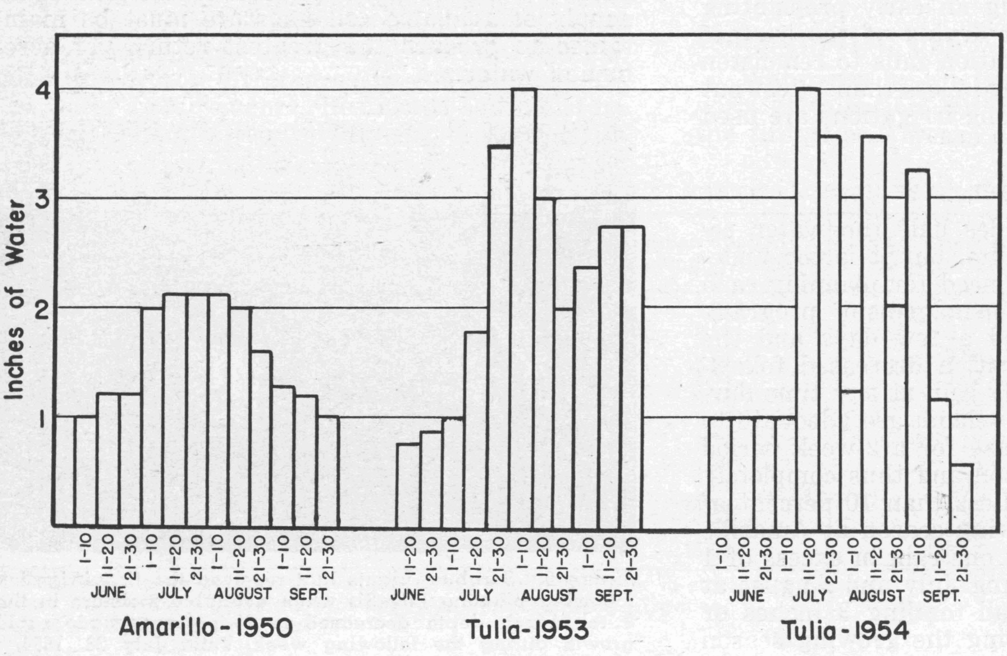

Figure 9. Consumptive use of water by 10-day periods for grain sorghum. The July 31 and August 31 data are included in the last 10-day period of the respective months.

quate to replenish the soil-moisture deficit when such an irrigation is started. An increased depth of application should be provided on each successive day to provide for the added consumptive use. If 10 days are required to irrigate the crop acreage, an application of 4 inches or more may be required to replenish the soil-moisture deficit on those portions of the field irrigated near the tenth day. Usually the next irrigation follows at a nearly uniform time interval and the soil-moisture deficit is approximately the same on each part of the field when it is irrigated. A uniform depth of water can be applied throughout the following irrigation unless substantial amounts of rainfall are received.

Depth of Application

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. Soil moisture should be determined for most effective irrigation. Experience, together with the use of a sharpshooter, soil tube or soil auger, are valuable for determining depths of water penetration and estimating moisture content, Figure 10. Over-irrigation wastes valuable water and time and is detrimental to the crop. Light irrigations have to be applied more frequently and have 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.

A soil must store water as well as supply nutrients for optimum grain sorghum production. Studies show that in most years sorghum plants extract water from depths of 5 to 6 feet. A soil storing 2 inches of water per foot of depth stores twice as much water in the same depth as a soil storing only 1 inch per foot of depth, and requires less frequent irrigations during dry periods.

Efficiency of Water Use

The greatest return per acre-inch of water is obtained from a crop sufficiently supplied with nutrients and given an adequate supply of available moisture from planting to the soft dough stage. A return of 200 pounds or more of grain per acre-inch of water may be expected in most years when the crop is not damaged by hail or other uncontrollable factors. "Stretching" the irrigation supply over more acres may guarantee a crop, but unless rainfall in conjunction with limited irrigation actually meet the optimum water requirements of the crop, a reduced return per acre-inch of water results. Since the monthly rainfall is below average in about 60 percent of the months, depending on rainfall is a poor risk.

Efficient water use also depends on delivery of equal and adequate amounts of water to all of the plants in the field.

Methods of Irrigation

The main requirement of an irrigation for the crop is to deliver the amount of water needed to the root zone of each plant. This requires good distribution. It is desirable to apply little more water than the root zones require and to lose as little as possible by runoff. This involves application efficiency. No other single factor has lowered the overall yields of grain sorghum fields on the Texas High Plains more than poor distribution of irrigation water.

Graded furrows are the most common means of irrigating sorghum on the High Plains. Satisfactory irrigation efficiencies and good distribution can be obtained by using the correct length of run and a size of furrow streams suited to soil conditions. Utilizing irrigation streams that are too large may cause erosion. Some irrigation water will leave the field as runoff with graded furrow irrigation. This runoff should not exceed 10 percent of the amount of water applied. Runoff water can be used for irrigating lower fields; centrifugal pumps have been used to lift it into another ditch for delivery to higher ground. No

Figure 10. Some equipment for obtaining soil samples to estimate available moisture includes an orchard auger, soil auger with soil tube attachment and a sharpshooter.

control of rainfall is provided with the graded-furrow system of irrigation.

Runoff starts when the intensity of the rainfall exceeds the water intake of the soil. This runoff is cumulative in that it increases as it proceeds down the furrow. A rain that exceeds soil intake by 1 inch for a duration of 1 hour would produce an average runoff approaching 1 cubic foot per second or 450 gallons per minute per acre of land. If a 20-acre field drained at one corner under such conditions, a runoff flow of 20 cubic feet per second or 9,000 gallons per minute might be attained.

This explains the erosion frequently noted along the lower ends of many fields following rain storms. Erosion alone is not the only loss. An inch of rainfall lost by runoff is the inch of water that could have been left stored in the soil following evaporation from the surface had that water remained on the field. The rains that really count run off too often.

Level furrows provide high irrigation application efficiencies and excellent distribution of water. There are no losses of irrigation water by runoff and often it is not necessary to cut back the furrow streams. Rainfall stays where it falls and runoff occurs only with infrequent heavy rains every few years. Good engineering and careful land leveling are required for level-furrow irrigation.

Planting in the bed or in a modified bed is desirable with either graded or level-furrow irrigation. This system of planting provides the best furrow cross section for early irrigation as well as an adequate furrow for conveying water throughout the season. Although planting in the furrow is the method used most on the High Plains, experiments at the Lubbock station show that better stands of sorghum are obtained by planting on the level or in a modified ridge. The seed are placed in soil where lower temperatures exist and stands may be lost by puddling and crusting of the soil in the furrow by rainfall before emergence of the plants.

Graded border strips also can be utilized for irrigating sorghums. Graded borders should be corrugated to provide better water control. Irrigation of graded borders should be similar to that of graded furrows. Problems of controlling irrigation runoff and water distribution should be considered as there is no effective control of runoff from rainfall.

Level borders have been used for the production of sorghum on the Amarillo station since 1949. Irrigation is simple and very high efficiencies are obtained with excellent water distribution. Narrow row spacings, just wide enough to permit cultivation, can be used. Narrower spacings, 10 inches at Amarillo, can be used, with the border ridges being planted but not cultivated.

Sprinkler irrigation is an efficient means of water application on soils that have high water intake rates. This method is commonly used in the Brownfield, Lamesa and Seminole vicinities on sandy soils.

Acknowledgment

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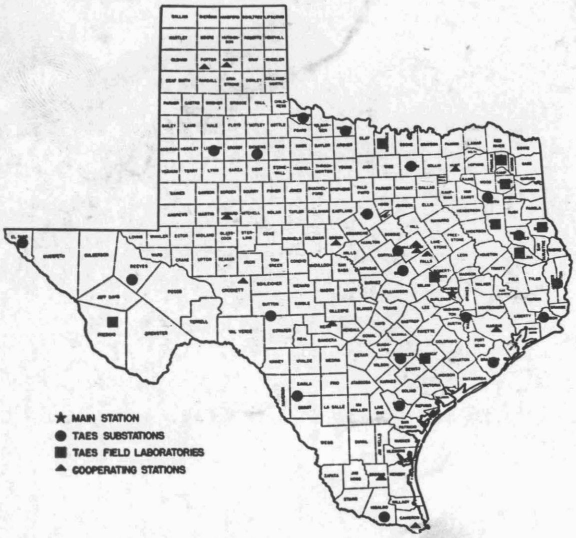

Location of field research units in Texas maintained by the Texas Agricultural Experiment Station and cooperating agencies

State-wide Research

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