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Cotton Irrigation in the Lower Rio Grande Valley

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TEXAS AGRICULTURAL EXPERIMENT STATION
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SUMMARY

Maximum growth and yield of cotton were obtained when the cotton crop was grown under a high level of moisture.

Maximum demand for moisture by cotton plants started during the flowering period and increased until most of the bolls were mature. Additions of irrigation water during critical water demand periods of plant growth (during and after the bloom stage) increased cotton yields.

Close spacings (6 inches) should be used where it is possible to maintain an ample supply of available soil moisture. Wider spacings (12 inches) may be considered where soil moisture may be limited during the peak demand periods in June and July.

Tensiometer data and soil moisture sampling data indicated that the maximum use of moisture was from the upper 2 feet of soil on both Willacy loam and fine sandy loam soils.

Proper timing in the irrigation of cotton to coincide with stages of maximum use and demand can reduce water use and produce higher yields.

Eighty percent or more of the cotton roots were found in the top 2 feet of soil.

Irrigation schedules under a low and an adequate supply of water are proposed. These should help the Lower Rio Grande Valley farmer plan the irrigation of cotton according to his water supply.

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Cotton Irrigation in the Lower Rio Grande Valley

*C. J. Gerard, M. E. Bloodworth, C. A. Burleson and W. R. Cowley**

COTTON ACCOUNTS FOR APPROXIMATELY 75 percent of the farm cash income in the Lower Rio Grande Valley. Research has been conducted at Substation No. 15 since 1949 to find answers to some of the problems of soil and water management in cotton production and to find ways of making more efficient use of the limited irrigation water.

Studies to determine the influence of irrigation differentials and plant spacings were conducted during 1949-50. The influence of irrigation levels also was studied during 1955-57. Results from the previous studies were given in Progress Reports 1217 (4), 1866 (2), 1940 (3) and 2016 (5).[1]

Objectives of these investigations varied, but generally were:

1. To determine the effects of moisture levels, plant spacings and date of planting on yield, growth and fiber characteristics of cotton.

2. To determine the time of maximum use and demand of water by cotton plants.

3. To determine seasonal and peak water use values for cotton.

4. To determine water management practices for the production of acceptable or economical yields of cotton with limited irrigation water.

CLIMATE

The Lower Rio Grande Valley is comprised of Cameron, Hidalgo, Willacy and Starr counties and is located at the southern tip of Texas. The climate is sub-tropical. Weather records for 39 years at the Lower Rio Grande Valley Experiment Station show an average annual precipitation of slightly more than 25 inches. However, the annual precipitation varies considerably from year to year. The highest recorded annual precipitation during this period was about 40.5 inches in 1941; the lowest recorded was 7.8 inches in 1956. Such variations in rainfall throughout the growing season emphasize the importance of irrigation in the agricultural economy of the area.

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[1]Numbers in parentheses refer to literature cited.

The average monthly rainfall over a period of years indicates that the highest amount occurs from April through October. These average monthly rainfall data range from 1.52 inches in April to 3.89 inches in September.

The average relative humidity is approximately 75 percent, but may range from 60 to 90 percent, depending on other climatic factors. Open-pan evaporation is approximately 0.15 inch per day (55 inches per year). However, the average daily loss varies from approximately 0.10 inch per day in January and December to 0.25 or 0.30 inch per day in July and August. The wind velocity is extremely variable, but the average is 3 miles per hour. Prevailing wind direction is from the southeast.

A 38-year record at the Weslaco station shows an average maximum temperature of 84.7° F. and an average minimum temperature of 63.2° F. A 25-year period shows an average annual growing season of 330 days, with the average first killing frost on December 20, and the last killing frost on January 25.

Climatic conditions favor the planting of cotton from February 1 to March 31. Pink bollworm infestations make it necessary for the farmers to harvest and destroy green cotton stalks before September 1 to aid in the control of this pest. These factors allow a growing period of 120 to 180 days for the cotton crop.

LOCATION AND SOILS

The irrigation experiments were conducted on Substation No. 15, 2 miles east of Weslaco, in Hidalgo county. The station is somewhat centrally located in the irrigated area of the Lower Rio Grande Valley.

The experiments were conducted on Willacy loam and fine sandy loam soils. The Willacy series is a deep, coarse to medium-textured, moderately permeable soil. The sub-soil has a depth of more than 10 feet in places and usually is classed as a sandy clay loam or clay loam. Moderate to good drainage and a deep sandy clay loam or clay loam sub-soil enables this soil to hold a good reserve of soil moisture. The top 5 feet of this soil will hold 9 to 11 inches of available soil moisture. The organic matter content of the surface 6 inches varies from 1 to 1.5 percent.

PROCEDURE

Moisture Levels—Plant Spacing

The influence of different moisture levels and plant spacings was investigated in 1949 and 1950. The experimental design was a randomized block consisting of 12 treatments. Coker 100 Wilt was planted on March 11, 1949 in 7-row plots, 72 feet in length. Coker 100 Wilt was planted on March 15, 1950 in 6-row plots, 72 feet in length. After stands were established, the cotton was thinned according to spacing treatments and the irrigation treatments listed in Table 1 were initiated. Plant spacing treatments of 6, 12 and 18 inches were superimposed on the moisture level treatments. The cotton was sidedressed with 50 pounds of nitrogen per acre in the form of ammonium nitrate. Infestations of thrips, red spiders, boll weevils and pink bollworms were controlled. The cotton was seeded, fertilized, cultivated and dusted with tractor-operated equipment. Cultural practices used on all plots were similar to those used by farmers in the area.

The moisture levels were high, medium, low and non-irrigated. They were based on available water retained by the soil between field capacity and the permanent wilting percentage, as determined by field and laboratory methods. The moisture levels used and moisture percentages at which irrigation water was applied are indicated in Table 1.

The time of irrigation in 1949 was determined by sampling the upper 2 feet of soil throughout the growing season. Plots of the various moisture levels were irrigated when the average soil moisture in this depth was reduced to the percentages shown in Table 1. Dates and amounts of water applied are listed in Table 2.

Differences in the percentage of soil moisture at maximum stress during 1949-50 were due primarily to the difference in the soil texture. Sufficient water was applied to each irrigation treatment to increase the soil moisture content to field capacity to a depth of 4 feet. Water was applied by level furrow irrigation. In 1949, water was measured onto the plots with 3 and 6-inch Parshall flumes; in 1950, water was measured with a 6-inch Sparling flow meter.

TABLE 1. MOISTURE LEVELS USED AND PERCENTAGES OF MOISTURE AT WHICH IRRIGATION WATER WAS APPLIED

Moisture level	Percentage of available moisture	Percentage of soil moisture at maximum allowable stress		Tensiometer gauge reading at max. allowable stress[1]
		1949	1950	
High	75	15.4	13.3	13
Medium	50	12.8	11.2	20
Low	25	10.1	9.1	66

[1]Vacuum gauge tensiometers were used for irrigation control in 1950. Gauge readings are in centimeters of water. (1036 centimeters of water, or 14.7 lb. per square inch pressure, equal 1 atmosphere.)

TABLE 2. DATES OF IRRIGATION, AMOUNTS OF WATER APPLIED AND EFFECTIVE RAINFALL ON MOISTURE LEVELS AND PLANT SPACINGS EXPERIMENT

Date of irrigation or rainfall	Moisture levels, inches applied			
	High	Medium	Low	Non-irrigated
	1949			
April 2	0.4[1]	0.4[1]	0.4[1]	0.4[1]
April 4	0.6[1]	0.6[1]	0.6[1]	0.6[1]
April 25	0.3[1]	0.3[1]	0.3[1]	0.3[1]
May 11	0.4[1]	0.4[1]	0.4[1]	0.4[1]
May 13	5.2			
May 27	2.9	2.9		
June 8	2.5	2.4	2.3	
June 9	0.8[1]	0.8[1]	0.8[1]	0.8[1]
June 12	0.3[1]	0.3[1]	0.3[1]	0.3[1]
June 20	3.2			
June 24	3.2	3.2		
June 28			3.2	
Total applied	17.0	8.5	5.5	
Rainfall, inches	2.8	2.8	2.8	2.8
Total water, inches	19.8	11.3	8.3	2.8
	1950			
April 16	0.7[1]	0.7[1]	0.7[1]	0.7[1]
May 5	3.1	3.1		
May 14	2.8			
May 19	1.1[1]	1.1[1]	1.1[1]	1.1[1]
May 21	2.4[1]	2.4[1]	2.4[1]	2.4[1]
May 28	4.9[1]	4.9[1]	4.9[1]	4.9[1]
June 1	0.5[1]	0.5[1]	0.5[1]	0.5[1]
June 2	1.0[1]	1.0[1]	1.0[1]	1.0[1]
June 16	3.0	3.0		
June 23			3.5	
June 28	3.5			
July 3		3.5		
July 15	4.0	4.0	4.0	
Total applied	16.4	13.6	7.5	
Rainfall, inches	10.6	10.6	10.6	10.6
Total water, inches	27.0	24.2	18.1	10.6

[1]Denotes rainfall. Rainfall less than .25 inch was not considered effective because of high evaporation rates during the growing season.

The cotton was defoliated on July 8, 1949 and on July 19, 1950, and was harvested by hand on July 14 and 26 and August 10 in 1949, and on July 14 and August 4 and 11 in 1950.

Moisture Level—Planting Date

Moisture levels and planting dates studied during 1955-57 are described in Table 3. Two planting dates, February 15 and March 15, were selected to study their effects on water use, growth rate, yield and quality of cotton.

Deltapine TPSA cotton was planted in 38-inch rows. Plots were 6 rows wide by 50 feet long and were replicated four times. In 1955 and 1956, 60 pounds of nitrogen and 60 pounds of phosphoric acid per acre were applied uniformily to the area; in 1957, the land was uniformily fertilized with 80 pounds of nitrogen and 80 pounds of phosphoric acid per acre. Pre-planting irrigations were applied during the middle of January and February for the early and late planting dates, respectively. After the cotton was thinned to approximately 6 inches, it was side-dressed with 40 pounds of nitrogen per acre, and the irrigation treatments were started.

Soil moisture levels were based on the amount of available water retained in the soil between field capacity (approximately 20 percent) and the permanent wilting percentage (approximately 10 percent). The same location was used during the 3 years of investigations. The same moisture levels were used in all 3 years; however, in 1957, a no-irrigation level, treatment F, was included.

The time for applying irrigation water to the different treatments was determined periodically by sampling the soil to a depth of 5 feet. Irrigation levels were based on the average soil moisture content of the top 2 feet of soil. Sufficient water was added at each irrigation to increase the soil moisture in the depleted zone of the treatments to field capacity. Amounts of water applied and total rainfall by years are presented in Table 4. Irrigation water was measured accurately onto each plot with a 6-inch Sparling flow meter. Seven-inch portable aluminum pipe with gates on two sides of each pipe section was used to convey water to individual plots.

TABLE 3. IRRIGATION TREATMENTS FOR COTTON GROWN ON WILLACY LOAM SOIL, 1955-57

Moisture level	Irrigation differential treatments	Percentage of soil moisture at maximum allowable stress[1]
A	Irrigate when the average moisture content of the top 2 feet of soil approaches 65 percent of field capacity at any time before bloom stage. Cut off irrigation water after blooms appear.	16.4 Early season
B	Irrigate when the average moisture content of the top 2 feet of soil reaches 35 percent of field capacity before bloom stage. Irrigate at bloom stage and cut off irrigation water.	12.8 Early season
C	Irrigate when the average moisture content of the top 2 feet of soil reaches 35 percent of field capacity before bloom stage. From bloom stage until most of the bottom bolls are mature and open, irrigate when the average moisture content of the top 2 feet of soil approaches 65 percent of field capacity.	12.8 Early season to 16.4 Late season
D	Irrigate when the average moisture content of the top 2 feet of soil reaches 35 percent of field capacity until the bottom bolls are hard and firm. From this boll maturity stage until approximately three-fourths of the bolls are mature, irrigate when the average moisture content of the top 2 feet of soil approaches 65 percent of field capacity.	12.8 Early season 16.4 Late season
E	Irrigate throughout the season when the average moisture content of the top 2 feet of soil reaches 20 percent of field capacity.	11.0 All season
F	No irrigation after preplanting irrigation.	

[1]Average soil moisture percentage in top 2 feet of soil, which were used as the moisture control zone.

TABLE 4. AMOUNTS OF WATER APPLIED TO DIFFERENT MOISTURE LEVEL TREATMENTS AND AMOUNTS OF RAINFALL DURING THE COTTON SEASON

Treatments	Inches of water					
	Feb. 15 planting date			March 15 planting date		
	1955	1956	1957	1955	1956	1957
A	6.0	8.1	10.4	6.2	6.1	5.0
B	4.7	5.0	6.0	3.0	4.2	5.6
C	21.6	21.1	23.3	16.2	17.3	24.0
D	22.4	15.5	17.8	14.6	10.7	17.6
E	6.9	7.7	7.4	7.0	5.7	7.8
F			0.0			0.0
Total rainfall	3.5	4.3	13.5	3.3	4.0	9.6

All treatments received scheduled irrigations with the exception of treatment D (March planting) in 1956. This exception was due to a water shortage in the irrigation district.

Cotton was seeded, fertilized, cultivated and dusted with tractor-operated equipment. Cultural practices used on all plots were similar to those used by farmers in the area. Cotton planted on March 15 usually was defoliated 5 to 15 days later than that planted on February 15. Harvesting February-planted cotton started in mid-July and usually was completed by August 5. Harvesting March-planted cotton started in mid-July and ended in mid-August.

RESULTS AND DISCUSSIONS

Moisture Levels—Plant Spacing

Effects of moisture levels and plant spacings on the yield of cotton during 1949-50 are indicated in Figures 1 and 2 and Table 5. High moisture level treatments in 1949 significantly increased cotton yield, but there was no significant increase in 1950 due to application of water. The 1950 results probably were due to the low and non-irrigated moisture treatments receiving rains during periods of maximum moisture demand by cotton plants. There were only 2.8 inches of effective rainfall during the 1949 growing season which made it a good year to study the influence of moisture levels on cotton yields. However, there were 10.6 inches of effective rainfall[2] dur-

[2]Rainfall less than .25 inch was not considered effective due to high evaporation rates during the growing season.

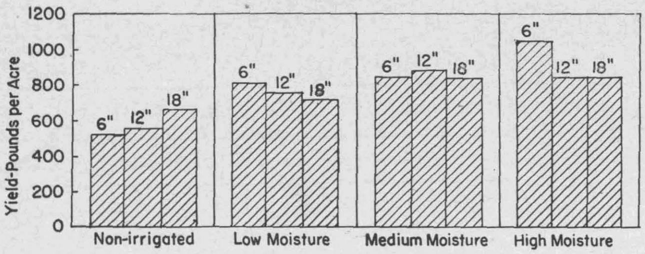


Figure 1. Yield of cotton as influenced by four moisture levels and three plant spacings, 1949.

ing the 1950 growing season which helps explain the increased yields obtained from the low-moisture level and non-irrigated plots.

Plant spacings failed to influence yields significantly in 1949, but the yields did indicate that close spacings would be preferable where a high level of moisture could be maintained. Wider spacings gave the best yields under high moisture stress. Cotton spaced 12 inches apart in 1950 yielded significantly higher than cotton spaced 6 and 18 inches apart. This difference was due largely to the average yields obtained from cotton planted 12 inches apart under all moisture treatments. Cotton spaced 6 inches apart in 1950 gave relatively high yields on high and medium-moisture treatments and relatively low yields on low and non-irrigated treatments. Cotton spaced 18 inches apart during 1949-50 gave relatively high yields on low and non-irrigated plots and relatively low yields at high and medium-moisture levels.

There was a trend in 1949 toward increased plant height at wider spacings. Plant height was not increased significantly in 1950 by the different moisture levels. However, the height of cotton spaced 6 and 18 inches seemed to vary considerably with moisture levels during this season. Growth rates of cotton in 1950 on the low and non-irrigated plots were retarded because of lack of moisture until the rains in May and June. Growth rates on the high and medium-moisture level plots were retarded considerably following the high rainfall period in 1950. This retardation in growth perhaps was because the soil in the root zone was near and above field capacity for some time; therefore, insufficient soil aeration may have affected growth during this period.

The root system under the various moisture treatments in 1949 appeared to vary in direct re-

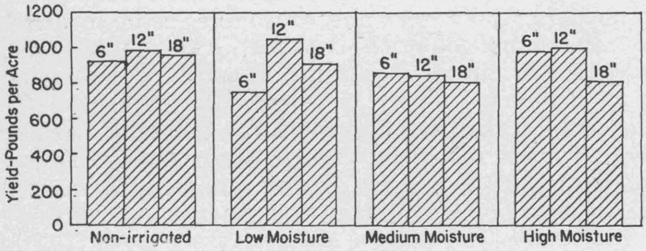


Figure 2. Yield of cotton as influenced by four moisture levels and three plant spacings, 1950.

lationship to the amount of top growth produced. This indicates that restricted moisture does not necessarily result in deeper root penetration.

Soil moisture data taken throughout the 1949-50 seasons indicated that the maximum use of moisture began with flowering and increased until most of the bolls were mature. Soil moisture sampling indicated that the moisture percentage in the root zone was approximately the same and at times higher with the 6-inch plant spacings than with the 12 and 18-inch plant spacings. Closely spaced plants developed somewhat smaller root systems and afforded more shading for the soil surface. The shading effect probably was instrumental in lowering the soil temperature, which in turn decreased soil moisture evaporation.

Tensiometric[3] data obtained in 1950, Figures 3, 4, 5 and 6, indicate the rate of moisture used by the cotton plant as influenced by different moisture levels. These plotted data show that the maximum amount of moisture used by cotton plants was obtained from the first and second feet. Soil sampling data in 1949 and early investigations by Adams, *et al* (1) and Harris and Hawkins (7) indicated similar results.

Moisture levels in 1949 and 1950 had a pronounced influence on the date of maturity. The non-irrigated plots matured early. Maturity of cotton in the high and meduim-moisture level plots was delayed.

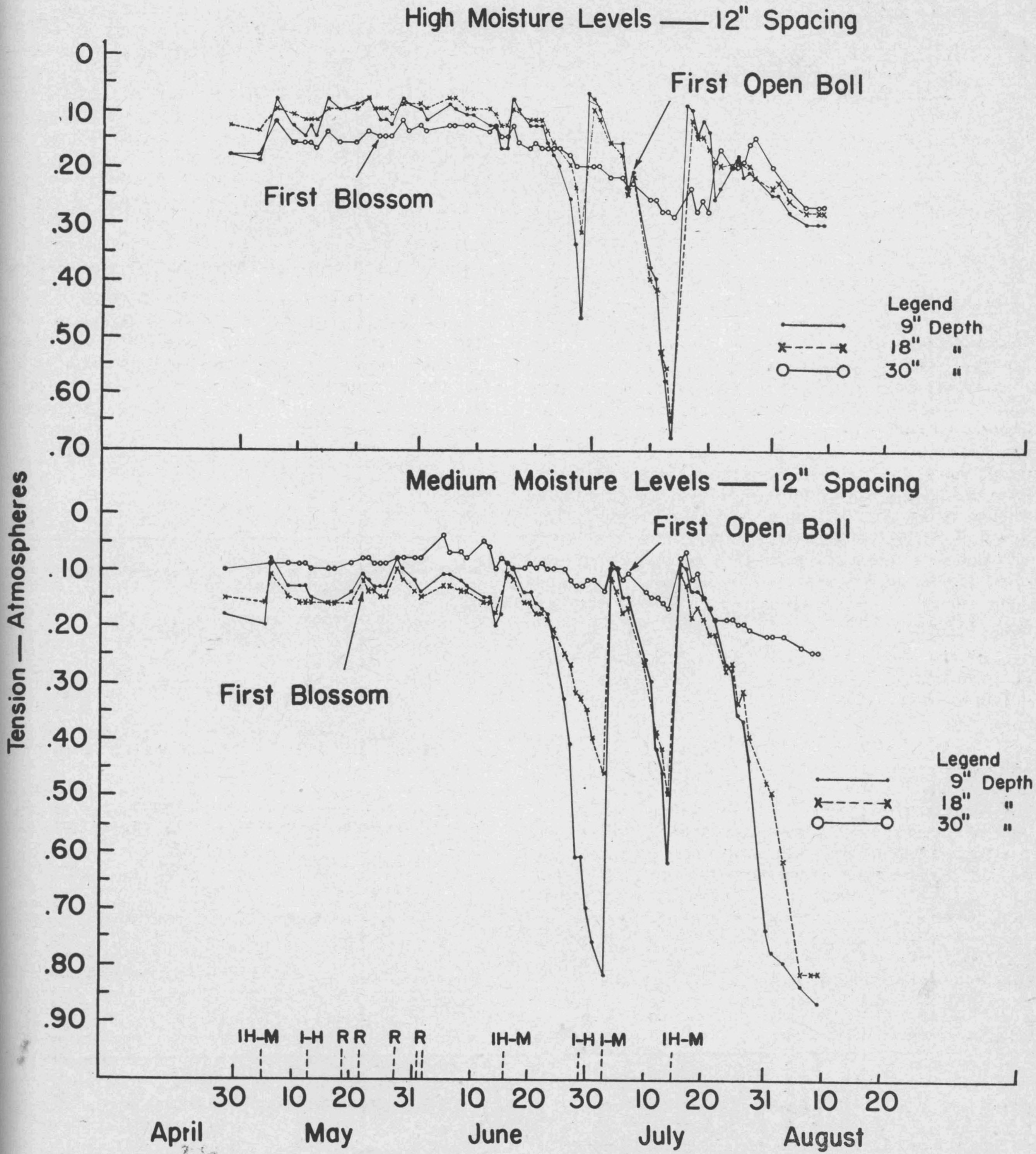
The influence of plant spacings on maturity is not consistent with years and moisture levels. However, the average from 2 years' data seem to indicate that cotton spaced 12 inches apart

[3]All tensiometers were read between 8:00 and 8:30 a.m. to minimize the effect of temperature (6) on the readings.

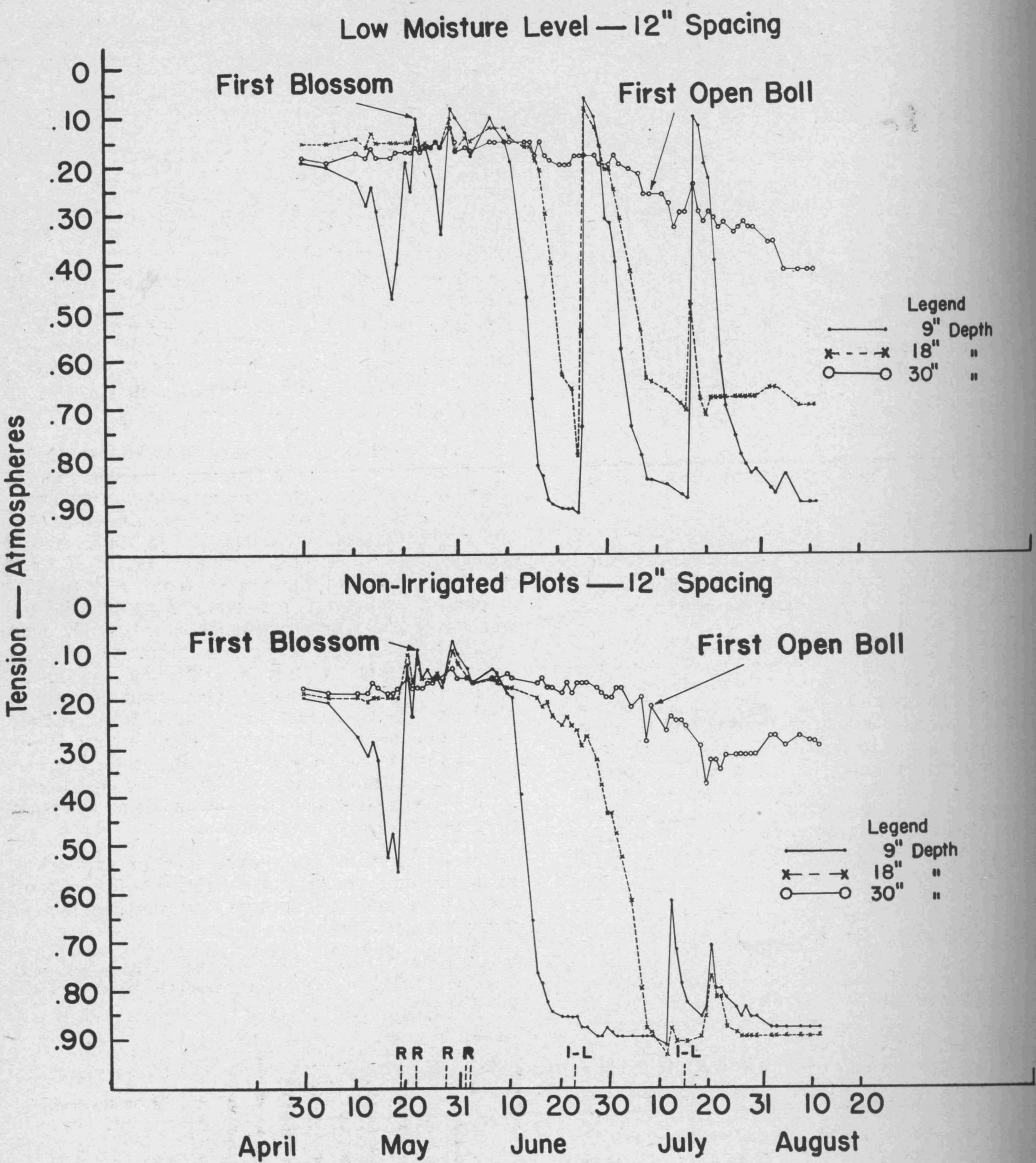
TABLE 5. HARVEST DATA OF COTTON, COKER 100 WILT, UNDER DIFFERENT MOISTURE LEVELS AND PLANT SPACINGS, 1949 AND 1950.

Moisture levels	Spacing, inches	Lint percent		Bolls per pound		Staple length[1]		Yield of lint, pounds per acre	
		1949	1950	1949	1950	1949	1950	1949	1950
High	6	32.3	35.1	67	89	35	34	1029	967
	12	32.7	35.0	62	76	34	35	826	987
	18	32.7	36.2	66	81	34	34	827	800
Medium	6	33.1	34.5	68	88	33	35	832	842
	12	32.6	35.5	65	80	33	35	869	833
	18	33.0	36.1	67	79	33	35	827	796
Low	6	33.6	34.2	72	88	34	34	790	744
	12	34.1	35.6	74	85	33	34	745	1042
	18	33.9	35.2	70	80	33	35	703	896
Non-irrigated	6	34.1	35.4	84	86	32	35	508	916
	12	33.8	36.8	79	87	32	34	542	969
	18	33.9	37.0	76	79	33	34	649	943
L.S.D. (0.05) moisture								102	N.S.
L.S.D. (0.05) spacings								N.S.	Sign[2]

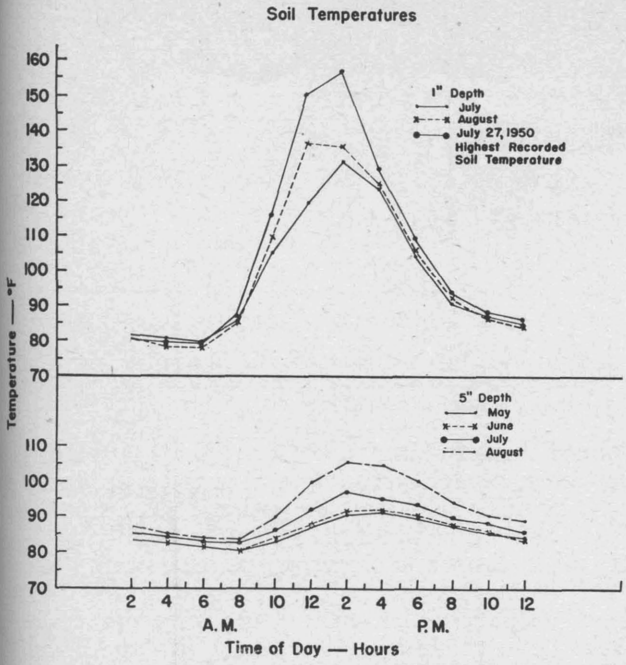
[1]Expressed in thirty-seconds of an inch.
[2]Cotton planted 12 inches apart yielded significantly higher than cotton planted 6 and 18 inches apart.



Figures 3 and 4. Tensiometer data obtained from units set at depths of 9, 18 and 30 inches. Irrigation and rainfall dates are shown for the high and medium moisture levels. Also see Figures 5 and 6.



Figures 5 and 6. Tensiometer data obtained from units set at depths of 9, 18 and 30 inches. Irrigation and rainfall data are shown for the low-moisture level and the non-irrigated plots. Also see Figures 3 and 4.



Figures 7-A and 7-B. Soil temperatures recorded at depths of 1 and 5 inches during the cotton-growing season.

matured earlier than cotton spaced 6 and 18 inches apart. Average maturity data for cotton spaced 6 and 18 inches apart seem to be similar, but the results are not consistent with years or moisture levels.

Soil temperatures were obtained at depths of 1 and 5 inches with 24-hour recording soil thermographs. The results are presented in Figures 7-A and 7-B and Table 6. Highest soil temperatures were found to occur between 12:00 noon and 2:00 p. m. each day, with the coolest period from 4:00 to 6:00 a. m. Irrigation water was effective in keeping the soil temperature well below pre-irrigational level for 4 days. The cooling effect and the increase in humidity received from applications of irrigation water probably benefited plant growth.

Moisture Levels—Planting Date

The effect of moisture levels and planting dates on yields during 1955-57 are indicated in Figure 8 and Table 7. Moisture levels significantly influenced cotton yields. Treatments C, D and E provided irrigation water for the cotton plants during the period of maximum use and demand for soil moisture. Cotton on treatment E was to be irrigated when the average moisture content of the top 2 feet of soil reached 20 percent of field capacity. In the 3 years of investigation, treatment E received a pre-planting irrigation and one additional irrigation during the growing season, which always occurred in June or July. Treatments A and B provided irrigation water for the cotton plants early in the season, prior to the period of maximum use and demand for soil moisture.

TABLE 6. AVERAGE AIR AND SOIL TEMPERATURES DURING THE COTTON GROWING SEASON IN THE LOWER RIO GRANDE VALLEY

Month	Average maximum temperature, °F			Average minimum temperature, °F		
	Air	Soil		Air	Soil	
		5" depth	1" depth		5" depth	1" depth
April	86.8	88.0		68.5	80.6	
May	92.1	92.0		72.9	80.8	
June	93.0	92.0		74.0	81.0	
July	95.7	97.6	130	75.0	83.3	79.5
August	97.8	107.3	134	73.5	86.0	77.4

Treatments C, D and E gave significantly higher yields than treatments A and B. The 3-year average for treatment D is lower than treatment E because of the low average yield of treatment D planted on March 15, 1956, which failed to receive one scheduled irrigation at the end of the season because of a water shortage.

As expected, cotton responded differently to water level treatments in different years. Years with low rainfall during the growing of the crop, such as 1955 and 1956, favored treatments C, D and E over treatments A and B. In 1955, the increased yields from treatments C, D and E over treatments A and B ranged from 132 to 178 pounds of lint cotton per acre. In 1956, the increased yields from treatments C, D[4] and E over treatments A and B ranged from 47 to 179 pounds. High rainfall in 1957 caused much smaller yield differences. Treatment E, which received only one irrigation plus a pre-planting irrigation, gave high cotton yields during 1955-57. Many of the 1957 rains occurred during the period of maximum use and demand when no irrigations were scheduled and cotton yields in treatment A, therefore, were high.

The responses of treatment E or any other moisture level treatment to higher additions of fertilizer is not fully known, but the problem is under investigation.

[4]Treatment D, planted March 15, 1956, is not considered because it failed to receive one scheduled irrigation late in the season.

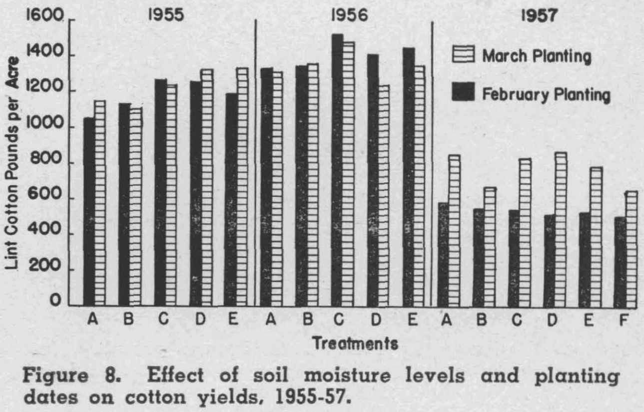


Figure 8. Effect of soil moisture levels and planting dates on cotton yields, 1955-57.

TABLE 7. SUMMARY OF YIELD DATA FOR COTTON-IRRIGATION-PLANTING DATE EXPERIMENTS CONDUCTED ON A WILLACY LOAM SOIL[1]

Treatments and planting dates		Pounds of lint cotton per acre			
		1955	1956	1957[2]	Average
A	Feb. 15	1050	1329	588	988
	March 15	1143	1318	855	1104
	Average	1097	1324	722	1046
B	Feb. 15	1135	1344	551	1009
	March 15	1104	1359	670	1043
	Average	1120	1352	611	1026
C	Feb. 15	1263	1523	539	1107
	March 15	1240	1483	825	1181
	Average	1252	1503	682	1144
D	Feb. 15	1228	1412	509	1049
	March 15	1322	1236	870	1142
	Average	1275	1324	690	1096
E	Feb. 15	1197	1449	529	1057
	March 15	1339	1349	782	1156
	Average	1268	1399	656	1107
F[3]	Feb. 15			505	
	March 15			643	
	Average			574	

[1]Significance: Water levels (0.01), years (0.01), dates (0.01), date x year interaction (0.01), water levels x years (0.01).
[2]March planting date in 1957 was on the 22nd rather than the 15th.
[3]Treatment F was not investigated in 1955-56.

Planting dates had a significant influence on cotton yield. Yield differences between planting dates in 1955 and 1956, as indicated in Figure 8 and Table 7, were extremely small. The 1955 data seem to be slightly in favor of the February planting. The significant influence of planting dates on yield is almost entirely due to the differences obtained in 1957. Yields of the March-planted cotton in 1957 were much higher than for the February-planted cotton.

Some factors which may favor delaying cotton planting until March 1 to 15 are: (1) cotton planted in March (late) requires less water than cotton planted in February (early), (2) March-planted cotton may be exposed to less cold, damp weather which often reduces cotton growth and yield; (3) results seem to indicate that March-planted cotton produces as much or more cotton

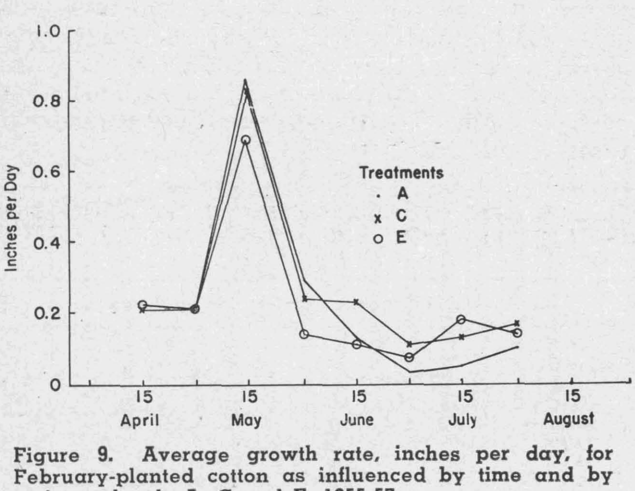


Figure 9. Average growth rate, inches per day, for February-planted cotton as influenced by time and by moisture levels A, C and E, 1955-57.

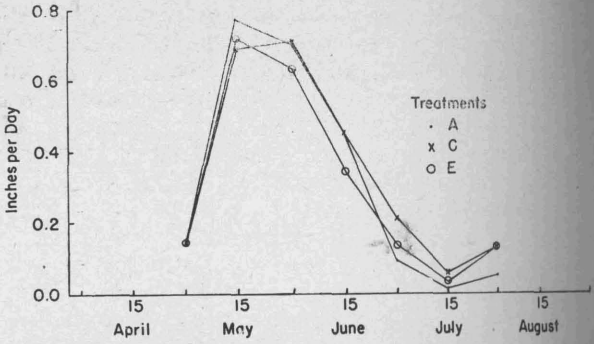


Figure 10. Average growth rate, inches per day, for March-planted cotton as influenced by time and moisture levels A, C and E, 1955-57.

than February-planted cotton; and (4) planting cotton in March probably will reduce production cost, notably in fewer irrigations. The need for reseeding March-planted cotton probably is less frequent than for February-planted cotton. However, February-planted cotton matures 7 to 10 days earlier, which makes the problem of boll weevil control less serious than with the March-planted cotton. Cotton planted in February, on the average, can be harvested completly before the occurrence of tropical storms in August, thus reducing field losses and poor grades.

Years significantly influenced yields, as indicated in Figure 8. Yields in 1957 were significantly less than during 1955-56. Such a reduction may have been due to unfavorable climatic conditions for insect control as well as plant growth and development.

The average growth rates in inches per day by cotton, as influenced by moisture treatments A, C and E and the two planting dates, are indicated in Figures 9 and 10. These are average growth rates for cotton grown during 1955-57.

Planting dates, as indicated in Figures 9 and 10, had the following influence on growth rate: (1) February-planted cotton grew faster during April and early May than March-planted cotton; (2) maximum growth of cotton planted in February and March occurred in the middle of May, with cotton planted in February having the greater growth rate during this period; and (3) cotton planted in March had greater growth during late May and June than cotton planted in February. Cotton planted in March had a longer high-growth period than cotton planted in February. This high-growth rate began in the middle of May and ended in the middle of June. Higher average soil and air temperatures during the growth period of March-planted cotton probably were important contributing factors.

Moisture treatments A, C and E, as indicated in Figures 9 and 10, had the following influence on growth rate: (1) cotton grown on treatment A had greater growth than cotton grown on treatment C until early June; (2) cotton grown on treatment C had greater growth than cotton grown on treatment A from early June until the end of the growing season; and (3) the early growth rate of cotton under treatment E was markedly less than under treatments A and C during the early part of the season. However, the rate of growth of cotton under treatment E was greater than cotton grown under treatment A from June 15 to the latter part of July. Early irrigation of cotton (treatment A) resulted in good vegetative growth and a good potential crop. However, the cotton plants must receive water during the period of maximum use and demand if this potential crop is to be fulfilled. This suggests that cotton plants often are over-irrigated while young and under-irrigated during critical periods of high moisture demand.

Daily evapo-transpiration by cotton plants as influenced by time throughout the growing season, planting dates and moisture levels are shown in Table 8. This is the average evapo-transpiration, with the exception of treatment F, for the cotton crops grown in 1955-57. The maximum evapo-transpiration for February-planted cotton usually occurred in June. The evapo-transpiration for March-planted cotton was somewhat similar, but the maximum evapo-transpiration usually occurred in July. The average daily evaporation from an open pan for the cotton growing season also is shown in Table 8. Each irrigation caused a marked increase in evapo-transpiration. Treatment A received an average of two irrigations, treatment B only one irrigation. Treatment C received an average of four irrigations, but sometimes five irrigations were applied. Treatment D received an average of three irrigations. Treatment E received one irrigation late in the season; treatment F received no irrigation. The evapo-transpiration data indicate maximum use and demand for soil moisture by cotton plants occurred just prior to or during bloom stage and continued until most of the bolls were mature.

Root development and distribution by cotton plants under different moisture levels are reported in Table 9. Soil cores for root distribution studies were obtained with a Kelley soil sampling machine (8). Eighty percent or more of the cotton roots were in the top 2 feet of soil regardless of the moisture level imposed. Treatments A and B, which grew under high moisture levels during the early part of the season and were permitted to "dry out" during fruiting stages, seemed to develop shallower root systems. The most extensive root system occurred in treatment E, followed by treatments D and C.

The amount of soil moisture removed by cotton plants below 2 feet seemed to vary with years and probably would be influenced by some of the following factors: time, amount of water applied and number of irrigations; amount and time of rainfall during the growing season; date of planting; soil fertility level; and cotton variety. Sampling data during 1955-57 indicated that the maximum amount of moisture used by cotton plants

TABLE 8. AVERAGE DAILY EVAPO-TRANSPIRATION RATES IN INCHES BY COTTON AS INFLUENCED BY MOISTURE LEVEL TREATMENTS AND PLANTING DATES

	— — — February 15 — planting date[1] — — —					
Treatment	Feb.	March	April	May	June	July
A	0.05	0.07	0.13	0.25	0.10	0.11
Average irrigation dates—April 18 and May 6						
B	0.04	0.08	0.09	0.21	0.11	0.08
Average irrigation date—May 10						
C	0.04	0.07	0.08	0.22	0.48	0.36
Average irrigation dates—May 10, June 2, 16 and 27						
D	0.04	0.07	0.08	0.11	0.48	0.32
Average irrigation dates—June 1, 18 and 26						
E	0.04	0.09	0.08	0.06	0.20	0.20
Average irrigation date—June 10						
F[2]	0.05	0.11	0.10	0.09	0.12	0.12
	— — — March 15 — planting date[1] — — —					
A		0.04	0.06	0.20	0.16	0.12
Average irrigation dates—May 7 and 25						
B		0.06	0.06	0.14	0.17	0.09
Average irrigation date—May 20						
C		0.05	0.06	0.16	0.42	0.36
Average irrigation dates—May 21, June 8, 18 and July 3						
D		0.04	0.04	0.12	0.27	0.35
Average irrigation dates—June 10, 30 and July 7						
E		0.05	0.05	0.09	0.19	0.23
Average irrigation date—June 25						
F[2]		0.08	0.08	0.08	0.17	0.07
Average evaporation from open pan[3]	0.13	0.17	0.18	0.20	0.23	0.27

[1]Average dates of first blooms for February and March-planted cotton were May 3 and 19, respectively.
[2]1 year average (1957). Other treatments show averages for 1955-57.
[3]From Class A standard Weather Bureau type.

was obtained from the upper 2 feet of soil, the same as in 1949 and 1950. Further investigations will be necessary before the value of subsoil moisture can be evaluated fully.

Summary data of boll size, percent lint, staple length and harvesting dates are shown in Table 10. Cotton quality varied slightly with moisture treatments and planting dates. Lint percent and boll size were greater in the February-planted cotton than in the March-planted cotton. Harvesting dates and percentage harvested at different dates for respective years are shown. Completion of harvesting usually was delayed approximately 7 to 10 days by planting on March 15 rather than on February 15. Applications of water during formation of blooms or bolls, or both, (treatments C, D and E) seemed to delay maturity.

TABLE 9. EFFECT OF SOIL MOISTURE DIFFERENTIALS ON ROOT DEVELOPMENT AND DISTRIBUTION ON COTTON PLANTS IN 1955

Soil depth, feet	Percentage of total roots by treatments				
	A	B	C	D	E
0-1	67.2	74.0	57.5	58.0	53.6
1-2	19.3	18.3	25.5	24.1	27.0
2-3	6.7	4.9	6.6	9.5	11.6
3-4	4.8	2.8	6.2	5.9	4.9
4-5	2.0	0.0	4.0	2.5	2.9

TABLE 10. PERCENT LINT, BOLL SIZE, STAPLE LENGTH AND HARVEST DATES INFORMATION FOR COTTON IRRIGATION-PLANTING DATE EXPERIMENT CONDUCTED ON WILLACY LOAM SOIL

Treatments and planting dates	Percent lint			Bolls per pound			Staple length		Percent harvested by dates, 1955				Percent harvested by dates, 1956			Percent harvested by dates, 1957					
	1955	1956	1957	1955	1956	1957	1955	1956	7/14	7/15	8/4	8/18	7/12	7/24	8/8	7/12	7/18	7/30	8/5	8/8	8/20
A. Feb. 15	35.9	36.8	34.7	79	76	81	34	34	76.6	19.2	4.2		74.0	21.9		48.8	16.2		35.0		
March 15[1]	34.0	35.4	35.1	80	78	82	35	34	31.6	44.4	20.5	3.5		67.9	24.4			64.3		15.6	20.1
B. Feb. 15	35.7	36.5	35.6	80	74	80	34	34	62.2	29.8	8.0		76.5	19.4		42.8	20.4		37.1		
March 15[1]	34.3	35.4	34.9	83	78	81	34	34	36.1	39.7	17.7	6.5		65.3	31.3			60.0		17.6	22.4
C. Feb. 15	35.7	37.1	35.8	78	75	78	34	34	46.3	35.9	17.8		66.8	26.0		39.4	21.4		39.2		
March 15[1]	34.4	34.9	34.9	81	78	78	34	36	20.2	46.0	28.4	5.4		55.6	37.0			52.8		20.2	27.0
D. Feb. 15	36.6	37.1	36.5	78	78	81	34	34	45.3	36.3	18.4		74.3	21.0		41.3	19.5		39.2		
March 15[1]	34.8	36.5	35.8	79	83	76	34	35	19.9	41.2	25.9	9.4		74.7	21.9			52.0		23.8	24.0
E. Feb. 15	36.2	37.8	35.8	82	78	82	34	33	63.6	25.7	10.7		74.3	18.7		60.6	14.2		25.2		
March 15[1]	35.2	37.4	34.9	78	81	78	34	33	29.2	42.2	22.7	5.9		76.2	20.6			49.8		27.7	22.5
F. Feb. 15			35.9			81										42.2	16.3		41.5		
March 15[1]			35.8			83												71.7		15.7	12.6

[1]March planting date in 1957 was on the 22nd. instead of the 15th.

IRRIGATION SCHEDULE

From the yield and evapo-transpiration data, as influenced by plant spacings, planting dates and moisture regimes, it is possible to formulate irrigation schedules or plans for the Lower Rio Grande Valley. These schedules or plans will have to be modified by local farmers to fit their particular soil and water conditions. Some of the factors which will influence the irrigation schedule are: type of soil; available water holding capacity of soil; amount and quality of available water for irrigation; soil depth; presence of water table or restricting layers in the soil; soil fertility and cropping history. The exact influence of some of these factors on the irrigation schedule is not known, but a knowledge of them will help formulate a more intelligent irrigation schedule for a specific farming situation. The county agricultural agent or Soil Conservation Service technician can help formulate an irrigation schedule by identifying the soil and furnishing information on its available water holding capacity. Extension leaflets 355 (9) and 357 (10) will help the farmer decide the soil texture and estimate its available water holding capacity.

Irrigation schedules are outlined for what usually is considered a "low" supply and an "adequate" supply of irrigation water. The proposed schedules are made with the following assumptions: that the soil is deep (5 feet or more) with no water table or restricting zones and holding 10 or more available inches of soil moisture; that good quality water is available; that the cotton grower follows recommended fertilizer practices and plants seed of adapted cotton varieties; and that the soil profile was filled with a pre-planting irrigation.

TABLE 11. AVERAGE MOISTURE USED PER DAY AND ACCUMULATIVE MOISTURE USED BY COTTON PLANTED ON MARCH 15, 1956, AND RECEIVING ONE IRRIGATION DURING CRITICAL MOISTURE DEMAND PERIOD

Time	Days after planting	Moisture use: Daily use inches per day	Moisture use: Accumulated use inches[1] (A)	Rainfall inches (B)	A—B
March 15-31	16	0.05	0.80	0.15	0.65
April 1-15	31	0.05	1.55	0.31	1.24
April 15-30	46	0.05	2.30	1.39	0.91
May 1-15	61	0.09	3.65	1.97	1.68
May 15-31[2]	77	0.09	5.09	1.97	3.12
June 1-15	92	0.19	7.94	1.97	5.97
June 15-21	98	0.19	9.08	2.02	7.06[3]
June 21-30	107	0.19	1.71	1.44	0.27
July 1-15	122	0.23	5.16	1.60	3.56
July 15-31[4]	138	0.23	8.84	1.94	6.90

[1]Accumulated use = daily use x number of days in period plus moisture use in earlier periods. Example for April 1-15 = (0.05) (15) plus 0.80 = 1.55 inches.
[2]First blooms occurred on May 19.
[3]Approximate time to irrigate (June 21 or 22) with 7 inches per acre.
[4]Cotton was defoliated on August 2.

Low Water Supply—One Irrigation

Since the cotton grower has a limted supply of water he should plant his cotton in March. Table 11 was taken from the 1956 data.

Based on Table 11, the cotton grower should irrigate when approximately 7 inches of water have been removed from the soil. The first irrigation occurred about 30 days after the first blooms appeared and 98 days after planting, according to the proposed schedule. This may be of help as an irrigation guide for farmers in areas outside the Lower Rio Grande Valley. Modifications or adjustments should be made for climatic and soil conditions of different areas. The 1957 crop was not selected for an example since it was a rather wet year.

Adequate Water Supply—Three Irrigations

Since the cotton grower under this condition has filled his soil profile with a pre-planting irrigation and has three more irrigations to finish his crop, the time of planting is not as critical as in the former case. Plans for February and March-planted cotton are proposed. Tables 12 and 13 illustrate how accumulative moisture use can serve as a guide for irrigation under conditions where an adequate amount of water is available.

February-planted cotton received its first irrigation about 30 days after blooms appeared, but the March planting received its first irrigation about 15 days after blooms appeared. Early-planted cotton should be irrigated when the accumulated water use minus the rainfall equal about 6 inches. However, March-planted cotton should be irrigated when this is equal to or near 5 inches. Daily use of water by cotton, as indicated in Tables 11, 12 and 13, is proportional to the amount of water available to the cotton plants. If a farmer has water for only two irrigations rather than three, it probably would be desirable to delay his first irrigation until the accumulative water use minus rainfall is about 6.5 to 7 inches in the case of February-planted cotton. The second irrigation could be applied when the accumulative water use minus rainfall is about 6 inches.

Assuming that only two irrigations are possible, it probably would be desirable for the farmer to delay his planting date. For March-planted cotton, it probably would be more desirable to delay the two irrigations until the accumulative water use minus rainfall is equal to 6 inches. The daily water use in inches per day would be slightly less for two than for three irrigations. An average of the daily use for the respective periods in Tables 12 and 13 probably would be closer to the actual losses and could be used as a guide of moisture use. For example, the daily loss for a schedule of two irrigations for June would be approximately 0.23[5] inch per day.

Schedules or plans for four irrigations could be patterned from Table 12 or Table 13, depending on whether it is February or March-planted cotton. The additional irrigation could be used 20 to 30 days before the irrigation dates listed in Tables 12 or 13. The daily use in inches per day for four irrigations could be obtained from the column listed as treatment C in Table 8.

Soils possessing low water-holding capacity, shallow top-soil or restricted zones or a high water table would need more frequent light irrigations. However, the evapo-transpiration data could be used as a guide in setting up irrigation schedules for such conditions. The use of poor quality water also would make it necessary to irrigate more frequently with excess amounts for leaching salts if sub-surface drainage permits.

DEFINITION OF TERMS

Available soil moisture refers to the water retained in the soil between the limits of field capacity and the permanent wilting percentage and is available for plants.

[5]0.19 = evapo-transpiration rate for 1 irrigation (March-planted cotton). 0.27 = evapo-transpiration rate for 3 irrigation (March-planted cotton). (0.19 + 0.27) ½ = 0.23 inch per day.

TABLE 12. AVERAGE MOISTURE USED PER DAY AND ACCUMULATIVE MOISTURE USED BY COTTON PLANTED ON FEBRUARY 15, 1956, AND RECEIVING THREE IRRIGATIONS DURING CRITICAL MOISTURE DEMAND PERIOD

Time	Days after planting	Moisture use		Rainfall, inches (B)	A—B
		Daily use, inches per day	Accumulated use, inches[1] (A)		
Feb. 15-28	13	0.04	0.52	0.29	0.23
March 1-15	28	0.07	1.57	0.38	1.19
March 15-31	44	0.07	2.69	0.52	2.17
April 1-15	59	0.08	3.89	0.68	3.21
April 15-30	74	0.08	5.09	1.76	3.33
May 1-15[2]	89	0.11	6.74	2.34	4.40
May 15-31	105	0.11	8.50	2.34	6.16[3]
June 1-13	118	0.48	6.24	0.00	6.24[3]
June 13-15	120	0.48	0.96	0.96	0.96
June 15-20	125	0.48	7.68	1.49	6.19[3]
June 1-15	140	0.32	4.80	0.16	4.64
July 15-26[4]	151	0.32	8.32	0.50	7.82

[1]Accumulated use = daily use x number of days in period plus moisture used in earlier periods.
[2]First blooms occurred on May 1.
[3]Approximate time to irrigate.
[4]Cotton was defoliated on July 26.

Field capacity is the quantity of water retained in the soil after gravitational water has drained away following an irrigation or heavy rain (1 to 3 days after an irrigation or rain).

Permanent wilting percentage refers to the soil moisture remaining in the soil after the plants have withdrawn all they can and wilt permanently.

Moisture percentage refers to the moisture in the soil based on the weight of the oven-dry soil. Oven-dry soil refers to a soil that has been heated at 110° C. for 24 hours.

TABLE 13. AVERAGE MOISTURE USED PER DAY AND ACCUMULATIVE MOISTURE USED BY COTTON PLANTED ON MARCH 15, 1956, AND RECEIVING 3 IRRIGATIONS DURING CRITICAL MOISTURE DEMAND PERIOD

Time	Days after planting	Moisture use		Rainfall, inches (B)	A—B
		Daily use, inches per day	Accumulated use, inches[1] (A)		
March 15-31	16	0.04	0.64	0.15	0.49
April 1-15	31	0.04	1.24	0.31	0.93
April 15-30	46	0.04	1.84	1.39	0.45
May 1-15	61	0.12	3.64	1.97	1.67
May 15-31[2]	77	0.12	5.56	1.97	3.59
June 1-5	82	0.27	6.91	1.97	4.94[3]
June 5-15	92	0.27	2.70	0.00	2.70
June 15-30	107	0.27	6.75	1.49	5.26[3]
July 1-15	122	0.35	5.25	0.16	5.09[3]
July 15-31[4]	138	0.35	5.25	0.34	4.91

[1]Accumulated use = daily use x number of days in period plus moisture used in earlier periods.
[2]First blooms occurred on May 19.
[3]Approximate time to irrigate.
[4]Cotton was defoliated on August 2.

Transpiration refers to the water absorbed by the crop or plants and evaporated from plant surfaces.

Evaporation refers to the moisture loss from a fallow or barren soil.

Evapo-transpiration refers to the total moisture used in evaporation and transpiration.

Tensiometers are instruments used to measure tension, conditions of water or moisture content in the soil. Soil moisture tensiometer readings above 0.85 atmospheres are not considered reliable.

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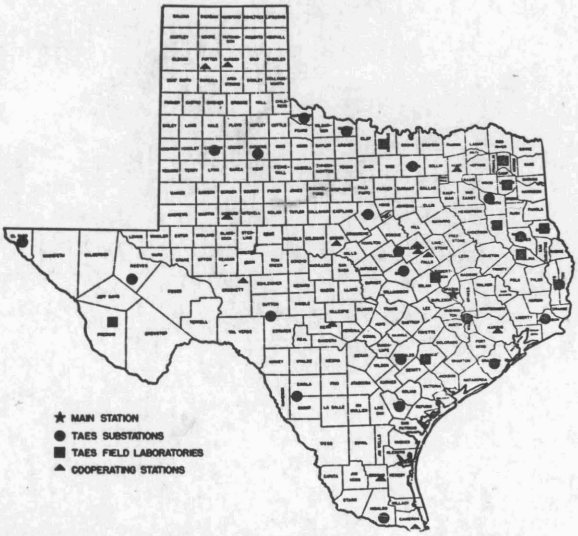

Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

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