Effects of Irrigation at Different Growth Stages, and of Nitrogen Levels on Corn Yields in Lajas Valley, P.R.[1]

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INTRODUCTION

Some years ago concern was expressed over the rate at which new lands were being developed for agriculture. Recently there has been a change in thinking and the new limit to expansion is not land, but water. Agricultural production can be increased to a maximum on lands already developed by a proper combination of irrigation with other improved cultural practices. Competition for available water by industries, cities, and farms, and the relatively large quantity of water needed for agriculture justify studies to improve the efficiency of water use in agriculture. The limit of water-application efficiency can be reached only when a proper evaluation of plant needs is available. Inadequate soil moisture at critical stages of crop growth often limits crop production. Some studies have been made in the United States by Robins and Domingo (*4*)[3] wherein they found that moisture depletion to near the wilting percentage by field corn at certain physiologic growth stages markedly reduced grain yields. In Mexico, Fernández and Laird (*2*) concluded on the basis of their data that moisture deficits during the tasseling stage reduced corn yields significantly. Since climatic and soil conditions may modify the results obtained under different conditions, two experiments were conducted at the Lajas Substation to evaluate the effect of irrigation at different growth stages on the production of field corn in the Lajas Valley.

EXPERIMENTAL PROCEDURE

The first experiment was planted March 16, 1957 and harvested July 22, 1957; the second was planted April 15, 1958 and harvested August 19, 1958. A cubic lattice design was used in both experiments. The treatments included a combination of 9 irrigation levels and 3 nitrogen levels, with 4 replications, on a total of 108 plots. A uniform population of 19,400 plants

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[3] Italic numbers in parentheses refer to Literature Cited, p. 105.

per acre was used. A field-corn variety, Mayorbela, was planted with 3 feet between rows and 9 inches between plants. Two seed were placed in each hole, thinning to one plant per hole after the plants emerged. The plots were 6 rows (18 feet) wide and 18 feet long. The entire experiment covered an area of about 240 feet wide by 180 feet long.

The soil used was classified as Santa Isabel clay. This is one of the predominant soil types in Lajas Valley. No crops had been planted on this site during the last few years.

The soil moisture retained at different tensions and other physical properties were determined (table 1).

TABLE 1.—*Moisture-release data (percentage by weight) for Santa Isabel clay soil, Lajas, P.R.*

Moisture tension (atmospheres)	Soil moisture at—	
	Soil depth of 3 to 6 inches	Soil depth of 18 to 21 inches
0.1	41.3	43.7
.3	38.3	39.7
.6	37.2	37.3
1.0	35.8	35.2
2.0	34.3	34.0
15.0	21.4	22.7
Bulk density[1]	1.03	1.24

[1] Grams per cubic centimeter.

IRRIGATION

The following irrigation treatments were tested:

No. 1. Irrigated when 20 percent of the available moisture had been depleted from the active root zone.

No. 2. Irrigated when 60 percent of the available moisture had been depleted from the active root zone.

No. 3. Not irrigated after the crop was established.

No. 4. Irrigated as in treatment No. 1 until hard-dough stage; no irrigation thereafter.

No. 5. Irrigated as in treatment No. 1 until silking stage; no irrigation thereafter.

No. 6. Irrigated as in treatment No. 1 until tasseling stage; no irrigation thereafter.

No. 7. Not irrigated after the crop was established until hard-dough stage and as in treatment No. 1 thereafter.

No. 8. Not irrigated after the crop was established until silking stage and as in treatment No. 1 thereafter.

No. 9. Not irrigated after the crop was established until tasseling stage and as in treatment No. 1 thereafter.

The soil was plowed and harrowed several times until a good seedbed was obtained. The whole area was divided into 108 plots 20 feet wide by 20 feet long by means of ditches made around each plot. A basin was made of each plot by means of border ridges about 8 inches high. The plot (basin) was filled with water at each irrigation by means of fire hoses that were connected to the irrigation pipelines. A heavy irrigation was applied to the whole area after each experiment was planted. Subsequent irrigations were made according to the treatments involved.

FERTILIZER

The nitrogen-fertilizer treatments used were 0, 60, and 120 pounds of nitrogen per acre as ammonium sulfate (20.5-percent N) and were applied when the corn plants were about 8 inches high. Phosphorus and potassium in the form of superphosphate (20.5-percent P_2O_5), and muriate of potash (61-percent K_2O), respectively, were applied to the whole experiment at the rate of 200 pounds each of P_2O_5 and K_2O per acre. All the fertilizer was placed in a small furrow opened about 3 inches on both sides of the corn plant.

SOIL-MOISTURE CONTROL

Disturbed and undisturbed soil samples were taken from 3 to 6 and from 18 to 21 inches deep at the site where the experiments were conducted. The soil moisture retained by the undisturbed soil samples at different tensions in the low-tension range was determined in the pressure plate. The moisture retained by the disturbed soil samples at higher tensions was determined in the pressure membrane apparatus (*5*). Bulk-density determinations were made at each depth.

Tensiometers (*3*) were installed close to the corn plants in the highest fertility plots with irrigation treatment No. 1 at 6-, 12-, 18-, and 24-inch depths. In the plots with irrigation treatments Nos. 7, 8, 9 a tensiometer was installed at a depth of 12 inches in a high-fertility plot. Readings of the instruments were taken every day.

Irrigation of the plots under irrigation treatment No. 1 were made when the average soil-moisture tensions in the active root zone became 750 cm. of water. Gypsum resistance-blocks of the Bouyoucos type (*1*) and custom-made models were installed in the second experiment at 6-, 12-, 18-, 24-, 30-, and 36-inch depths in the plots under irrigation treatments Nos. 1, 2, and 3. The irrigations of the plots under irrigation treatment No. 2 were made when the average available soil moisture in the active root zone dropped to 28.8 percent. About 2 inches of water were applied whenever

TABLE 2.—*Irrigation frequencies used in the corn experiments at Lajas Substation*

Dates of irrigation for—	Moisture treatment No.—[1]								
	1	2	3	4	5	6	7	8	9
Experiment No. 1, 1957:									
Mar. 18–19	×	×	×	×	×	×	×	×	×
Apr. 3–4	×	×	—	×	×	×	—	—	—
Apr. 16–17	×	×	—	×	×	×	—	—	—
May 1	×	—	—	×	×	×	—	—	—
May 7–8	×	×	—	×	×	×	—	—	—
May 15–16	×	—	—	×	×	—	—	—	—
May 24–26	×	×	—	×	—	—	—	×	×
June 7–8	×	—	—	—	—	—	×	×	×
June 14–15	×	×	—	—	—	—	×	×	×
June 25–26	×	—	—	—	—	—	×	×	×
Total	10	6	1	7	6	5	4	5	5
Experiment No. 2, 1958:									
Apr. 16–17	×	×	×	×	×	×	×	×	×
May 20–21	×	×	—	×	×	×	—	—	—
May 27–28	×	—	—	×	×	×	—	—	—
June 18–19	×	—	—	×	—	—	—	×	×
July 16–17	×	—	—	—	—	—	×	×	×
Total	5	2	1	4	3	3	2	3	3

[1] Irrigation treatments were as follows: 1, Irrigated when 20 percent of the available moisture had been depleted from the active root zone. 2, Irrigated when 60 percent of the available moisture had been depleted from the active root zone. 3, Not irrigated after the crop was established. 4, Irrigated as was treatment No. 1 until hard-dough stage; no irrigation thereafter. 5, Irrigated as was treatment No. 1 until silking stage; no irrigation thereafter. 6, Irrigated as was treatment No. 1 until tasseling stage; no irrigation thereafter. 7, Not irrigated after the crop was established until hard-dough stage; like treatment No. 1 thereafter. 8, Not irrigated after the crop was established until silking stage; like treatment No. 1 thereafter. 9, Not irrigated after the crop was established until tasseling stage; like treatment No. 1 thereafter. × means one irrigation.

an irrigation was performed (table 2). Soil samples for moisture determination were taken during the whole growing season to indicate the irrigation of the plots under treatment No. 2 and to calculate the moisture extracted from the root zone in each moisture treatment.

In experiment No. 1 the soil samples were taken with a soil auger at the following depths: 0 to 9, 9 to 15, 15 to 21, 21 to 27, 27 to 33, and 33 to 39 in ches. In experiment No. 2 duplicate soil samples were taken at three depths: 3 to 9, 15 to 21, and 27 to 33 inches. The soil samples were taken twice a week in the plots under a fertilizer application of 0, 60, and 120 pounds of nitrogen per acre with irrigation treatments Nos. 1, 2, and 3, respectively. Soil samples were taken in the plots under treatments Nos. 4, 5, 6, 7, 8, and 9 when their initial irrigation treatments were changed.

All samples were weighed and placed in an oven for 24 hours at 105°C., and the percentage of moisture was determined on an oven-dry-weight basis. The water extracted from the top 3 feet of soil in the plots with each irrigation treatment was calculated for short periods throughout the whole growing season. A total of six samples under each moisture treatment was used to calculate the water extracted during those short periods and throughout the whole growing season. The consumptive use of water was calculated by adding the rainfall to the water extracted during those periods.

CULTURAL PRACTICES

Weedings were made as necessary to maintain the plots free of weeds. Every 10 days the whole experiment was sprayed with DDT (50-percent wettable) at the rate of 4 pounds per 100 gallons of water to control worm attack. When the kernels were dry, the central 12-foot-long sections of the central four rows of each plot were harvested. Percentage moisture of the kernel was determined.

EXPERIMENTAL RESULTS

An evaluation was made of the soil-moisture data and the effects of irrigation at different growth stages on corn yields.

SOIL MOISTURE

The rainfall distribution during the growth period of each experiment is shown in table 3. As can be calculated from this table, the rainfall for the March–July period in 1957 totaled 4.54 inches, which was 10.73 inches below the 10-year average for Lajas. However, in 1958, the April–August period totaled 27.06 inches which was 9.10 inches above the average. In that period only the rainfall in May was below the average.

The consumptive use of water during short periods of time and throughout the whole growing season of both experiments is presented in tables 4 to 14.

As shown in tables 4, 5, and 6, the total consumptive use in 125 days in the first experiment varied from 26.07 inches in the frequently irrigated plots (treatment No. 1) to 21.64 and 7.59 in the intermediately irrigated

TABLE 3.—*Inches of daily rainfall during the growth period of both experiments at Lajas, P.R., 1957–58*[1]

Date	1957					1958				
	March	April	May	June	July	April	May	June	July	August
1	0.02							0.49	0.79	
2	.14	0.12					0.13	.12	1.07	1.15
3				0.01			.28	.47		.28
4				.03	0.04		.46			
5							.10	.05	.39	2.20
6					.02	0.17	.30	.25	.40	
7							.02	1.53	1.08	
8		.02								.05
9							.23	.06	.49	.10
10						.11		.02		.22
11						.07				.10
12			0.29	.28				.75		.07
13	.05		.04			.07	.06			.10
14		.10				.03				
15						.16		.12		
16		.02	.22	.05					.20	.07
17	.09					.03				.05
18				.16		.73	.01			
19		.13		.13		1.10	.10			
20		.63				1.02		.76	.20	
21			.08						1.54	
22			.21			.23		0.7	.03	.21
23						.25				
24		.06	.04	.21	.08	.02		.05	.70	
25		.13	.48	.06		.53		.01		
26		.03								
27									.10	
28			.28				.44		.10	.60
29			.01						.02	
30			.01	.07	.20	.22	.46	.07		
31										2.60
Total	0.30	1.24	1.66	1.00	0.34	4.74	2.59	4.82	7.11	7.80
10-year (average)	2.91	2.19	2.81	2.43	4.93	2.19	2.81	2.43	4.93	5.60

[1] Data from raingage located in the northeast section of the Lajas Substation farm.

(treatment No. 2) and nonirrigated plots (treatment No. 3), respectively. Tables 7, 8, and 9 show the consumptive use of water in 125 days in the plots that were frequently irrigated from planting to the hard-dough (treatment No. 4), to the silking (treatment No. 5), and to the tasseling stages (treatment No. 6), respectively. It varied from 23.29 inches in the plots irrigated until the hard-dough stage, to 21.79 and to 19.25 inches in the plots irrigated until the silking and tasseling stage, respectively. Tables 10 and 11 show the consumptive use of water in the plots that were frequently irrigated from the hard-dough, (treatment No. 7), the silking

TABLE 4.—*Consumptive use of water by field corn in the frequently irrigated plots throughout the whole growing season (treatment No. 1) of the first experiment, by periods, Mar. 19 to July 21, 1957*

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[1]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 4[1]	3	.510	.170
Apr. 5 to Apr. 11	7	1.545	.221
Apr. 12 to Apr. 22[1]	11	2.607	.237
Apr. 23 to Apr. 29	7	1.764	.252
Apr. 30 to May 2[1]	3	1.050	.350
May 3 to May 6	4	1.696	.424
May 7 to May 9[1]	3	.951	.317
May 10 to May 13	4	.709	.177
May 14 to May 16[1]	3	.825	.275
May 17 to May 23	7	2.672	.382
May 24 to May 27[1]	4	1.200	.300
May 28 to June 6	10	1.561	.156
June 7 to June 10[1]	4	1.008	.252
June 11 to June 13	3	.894	.298
June 14 to June 17[1]	4	.948	.237
June 18 to June 24	7	.948	.135
June 25 to June 27[1]	3	.411	.137
June 28 to July 18	21	3.021	.144
July 19 to July 21[1]	3	.450	.150
Total	125	26.069	

[1] Consumptive-use data calculated by inter- and extrapolation.

(treatment No. 8), and tasseling stages (treatment No. 9) to harvesttime. As can be observed the total consumptive use in 125 days was of 13.25 inches in the plots frequently irrigated after the hard-dough stage, and 13.62 in those plots frequently irrigated after the silking and tasseling stages. The consumptive use of water in 125 days in the second experiment is presented in tables 12, 13, and 14. It was 30.20 inches in the frequently irrigated plots throughout the whole growing season (treatment No. 1) and in the frequently irrigated plots until the hard-dough stage (treatment No. 4); 23.50 in the intermediately irrigated (treatment No. 2), the frequently irrigated until the silking (treatment No. 5), and the tasseling stages (treatment No. 6); and 21.47 in the nonirrigated plots (treatment No. 3), the frequently irrigated plots after the tasseling (treatment No. 9), silking (treatment No. 8), and hard-dough stages (treatment No. 7).

In the intermediately irrigated plots (treatment No. 2) of the first experiment conducted, the average consumptive use of water during the first

TABLE 5.—*Consumptive use of water by field corn in the intermediately irrigated plots throughout the whole growing season (treatment No. 2) of the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 4[2]	3	.510	.170
Apr. 5 to Apr. 11	7	1.545	.221
Apr. 12 to Apr. 22[2]	11	2.607	.237
Apr. 23 to Apr. 29	7	1.764	.252
Apr. 30 to May 6	7	1.286	.184
May 7 to May 9[2]	3	.669	.223
May 10 to May 13	4	.990	.248
May 14 to May 23	10	1.859	.186
May 24 to May 27[2]	4	1.028	.257
May 28 to June 6	10	3.211	.321
June 7 to June 13	7	1.259	.179
June 14 to June 17[2]	4	.572	.143
June 18 to June 27	10	.978	.098
June 28 to July 18	21	1.833	.087
July 19 to July 21[2]	3	.228	.076
Total	125	21.638	

[1] Consumptive-use data from Mar. 19 to Apr. 29 are the same as for the frequently irrigated, plots. All soil-moisture samples taken under each moisture treatment were combined to calculate the moisture extracted during that period.

[2] Consumptive-use data calculated by inter- and extrapolation.

52 days after planting was 0.186 inches per day, increasing to an average of 0.253 inches per day during the period of 53 to 80 days after planting, and decreasing to an average of 0.108 inch daily from 81 to 125 days after planting (derived from data in table 5). In the second experiment, as derived from data in table 14, the average water use in the nonirrigated plots (treatment No. 3) during the first 58 days after planting was 0.165 inches per day, increasing to 0.292 inch per day from 59 to 77 days after planting, and decreasing to 0.132 inch daily from 78 to 125 days after planting.

TABLE 6.—*Consumptive use of water by field corn in the nonirrigated plots throughout the whole growing season (treatment No. 3) of the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 11	10	.757	.076
Apr. 12 to Apr. 29	18	1.351	.075
Apr. 30 to May 6	7	.604	.086
May 7 to May 13	7	.387	.055
May 14 to June 6	24	1.259	.052
June 7 to June 20	14	.442	.032
June 21 to July 18	28	1.325	.047
July 19 to July 21[2]	3	.165	.055
Total	125	7.589	

[1] Consumptive-use data from Mar. 19 to Apr. 1 are the same as for the frequently and intermediately irrigated plots. All soil-moisture samples taken under each moisture treatment were combined to calculate the moisture extracted during that period.

[2] Consumptive-use data calculated by extrapolation.

TABLE 7.—*Consumptive use of water by field corn in the frequently irrigated plots until the hard-dough stage with no irrigation thereafter (treatment No. 4) for the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 4[2]	3	.510	.170
Apr. 5 to Apr. 11	7	1.545	.221
Apr. 12 to Apr. 22[2]	11	2.607	.237
Apr. 23 to Apr. 29	7	1.764	.252
Apr. 30 to May 2[2]	3	1.050	.350
May 3 to May 6	4	1.696	.424
May 7 to May 9[2]	3	.951	.317
May 10 to May 13	4	.709	.177
May 14 to May 16[2]	3	.825	.275
May 17 to May 23	7	2.672	.382
May 24 to May 27[2]	4	1.268	.317
May 28 to June 10	14	3.048	.218
June 11 to July 18	38	3.104	.082
July 19 to July 21[2]	3	.246	.082
Total	125	23.294	

[1] Consumptive-use data from Mar. 19 to May 23 are the same as for the frequently irrigated plots (treatment No. 1).

[2] Consumptive-use data calculated by inter- and extrapolation.

TABLE 8.—*Consumptive use of water by field corn in the frequently irrigated plots until the silking stage with no irrigation thereafter (treatment No. 5) for the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 4[2]	3	.510	.170
Apr. 5 to Apr. 11	7	1.545	.221
Apr. 12 to Apr. 22[2]	11	2.607	.237
Apr. 23 to Apr. 29	7	1.764	.252
Apr. 30 to May 2[2]	3	1.050	.350
May 3 to May 6	4	1.696	.424
May 7 to May 9[2]	3	.951	.317
May 10 to May 13	4	.709	.177
May 14 to May 16[2]	3	.825	.275
May 17 to May 23	7	2.672	.382
May 24 to June 10	18	3.486	.194
June 11 to July 18	38	2.477	.065
July 19 to July 21[2]	3	.195	.065
Total	125	21.786	

[1] Consumptive-use data from Mar. 19 to May 23 are the same as for the frequently irrigated plots (treatment No. 1).

[2] Consumptive-use data calculated by inter- and extrapolation.

TABLE 9.—*Consumptive use of water by field corn in the frequently irrigated plots until the tasseling stage with no irrigation thereafter (treatment No. 6) for the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 4[2]	3	.510	.170
Apr. 5 to Apr. 11	7	1.545	.221
Apr. 12 to Apr. 22[2]	11	2.607	.237
Apr. 23 to Apr. 29	7	1.764	.252
Apr. 30 to May 2[2]	3	1.050	.350
May 3 to May 6	4	1.696	.424
May 7 to May 9[2]	3	.951	.317
May 10 to May 13	4	.709	.177
May 14 to June 10	28	4.444	.159
June 11 to July 18	38	2.477	.065
July 19 to July 21[2]	3	.195	.065
Total	125	19.247	

[1] Consumptive-use data from Mar. 19 to May 13 are the same as for the frequently irrigated plots (treatment No. 1).

[2] Consumptive-use data calculated by inter- and extrapolation.

TABLE 10.—*Consumptive use of water by field corn in the nonirrigated plots until the hard-dough stage with frequent irrigation thereafter (treatment No. 7) for the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 11	10	.757	.076
Apr. 12 to Apr. 29	18	1.351	.075
Apr. 30 to May 6	7	.604	.086
May 7 to May 13	7	.387	.055
May 14 to June 6	24	1.259	.052
June 7 to June 10[2]	4	.464	.116
June 11 to June 13	3	.404	.135
June 14 to June 17[2]	4	.608	.152
June 18 to June 24	7	1.262	.180
June 25 to June 27[2]	3	.540	.180
June 28 to July 18	21	3.778	.180
July 19 to July 21[2]	3	.540	.180
Total	125	13.253	

[1] Consumptive-use data from Mar. 19 to June 6 are the same as for the nonirrigated plots (treatment No. 3).
[2] Consumptive-use data calculated by inter- and extrapolation.

TABLE 11.—*Consumptive use of water by field corn in the nonirrigated plots until the silking stage with frequent irrigation thereafter (treatment No. 8) for the first experiment, by periods, Mar. 19 to July 21, 1957*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Mar. 19 to Mar. 20[2]	2	0.186	0.093
Mar. 21 to Apr. 1	12	1.113	.093
Apr. 2 to Apr. 11	10	.757	.076
Apr. 12 to Apr. 29	18	1.351	.075
Apr. 30 to May 6	7	.604	.086
May 7 to May 13	7	.387	.055
May 14 to May 27[2]	14	1.050	.075
May 28 to June 13	17	1.776	.104
June 14 to June 17[2]	4	.728	.182
June 18 to June 24	7	1.580	.226
June 25 to June 27[2]	3	.606	.202
June 28 to July 18	21	3.046	.145
July 19 to July 21[2]	3	.435	.145
Total	125	13.619	

[1] Consumptive-use data from Mar. 19 to May 13 are the same as for the nonirrigated plots (treatment No. 3). The consumptive-use data throughout the whole growing season are the same as for the plots not irrigated until the tasseling stage with frequent irrigation thereafter (treatment No. 9).
[2] Consumptive-use data calculated by inter- and extrapolation.

Figures 1 and 2 show the irrigations, rainfall, and the available soil moisture in the active root zone of the plots under the different irrigation treatments during the growing season of the first experiment conducted. As shown in figure 1, there was available moisture at each horizon throughout the whole growing season in the frequently irrigated plots (treatment No. 1). In the plots that were frequently irrigated until the hard-dough stage (treatment No. 4) and in which the last irrigation was applied on May 24, the available moisture decreased after May 28, reaching a low level on June 10. In the plots irrigated frequently until the silking stage (treatment No. 5), in which the last irrigation was applied on May 15, the available moisture dropped after May 17 to a critical level on June 10. In the plots irrigated frequently until the tasseling stage (treatment No. 6), to

TABLE 12.—*Consumptive use of water by field corn in the frequently irrigated plots throughout the whole growing season (treatment No. 1) for the second experiment, by periods, Apr. 16 to Aug. 18, 1958*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Apr. 16 to Apr. 21[2]	6	1.062	0.177
Apr. 22 to May 1	10	2.254	.225
May 2 to May 13	12	1.865	.155
May 14 to May 18	5	.732	.146
May 19 to May 22[2]	4	.788	.197
May 23 to May 25	3	.714	.238
May 26 to May 28[2]	3	.696	.232
May 29 to June 5	8	1.784	.223
June 6 to June 12	7	2.893	.413
June 13 to June 16	4	1.404	.351
June 17 to June 22[2]	6	2.286	.381
June 23 to July 1	9	3.801	.422
July 2 to July 14	13	2.405	.185
July 15 to July 17[2]	3	.600	.200
July 18 to July 22	5	1.030	.206
July 23 to July 28	6	1.585	.264
July 29 to Aug. 3	6	1.225	.204
Aug. 4 to Aug. 10[2]	7	1.435	.205
Aug. 11 to Aug. 17	7	1.437	.205
Aug. 18[2]	1	.205	.205
Total	125	30.201	

[1] Consumptive-use data throughout the whole growing season are the same as for the frequently irrigated plots until the hard-dough stage, with no irrigation thereafter (treatment No. 4).

[2] Consumptive-use data calculated by inter- and extrapolation.

which the last irrigation was applied on May 7, the available moisture decreased from May 10 with practically no available moisture remaining by June 6 (fig. 2). Figure 2 also shows that there was always available moisture throughout the whole growing season in the intermediately irrigated plots (treatment No. 2).

TABLE 13.—*Consumptive use of water by field corn in the intermediately irrigated plots throughout the whole growing season (treatment No. 2) for the second experiment, by periods, Apr. 16 to Aug. 18, 1958*[1]

Period	Consumptive-use data	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Apr. 16 to Apr. 21[2]	6	1.062	0.177
Apr. 22 to May 1	10	2.254	.225
May 2 to May 13	12	1.865	.155
May 14 to May 18	5	.732	.146
May 19 to May 22[2]	4	.856	.214
May 23 to May 28	6	1.745	.291
May 29 to June 5	8	1.173	.147
June 6 to June 12	7	2.600	.371
June 13 to June 22	10	2.057	.206
June 23 to July 1	9	2.827	.314
July 2 to July 14	13	1.490	.115
July 15 to July 28	14	1.475	.105
July 29 to Aug. 10[2]	13	1.924	.148
Aug. 11 to Aug. 17	7	1.251	.179
Aug. 18	1	.193	.193
Total	125	23.504	

[1] Consumptive-use data from Apr. 16 to May 18 are the same as for the frequently irrigated plots (treatment No. 1). The consumptive-use data throughout the whole growing season are the same as for the frequently irrigated plots until the silking stage with no irrigation thereafter (treatment No. 5) and for the frequently irrigated plots until the tasseling stage with no irrigation thereafter (treatment No. 6).

[2] Consumptive-use data calculated by inter- and extrapolation.

EFFECTS OF IRRIGATION

In the second experiment there was no statistically significant difference in production due to irrigation (table 15). In the first experiment irrigation increased yields in a highly significant way (table 15). As shown in table 15, in the first experiment, the frequently irrigated plot throughout the whole growing season (treatment No. 1) outyielded in a highly significant way the nonirrigated plots (treatment No. 3), the nonirrigated plots until the hard-dough (treatment No. 7), the silking (treatment No. 8), and the tasseling stages (treatment No. 9) under the 0, 60, and 120 pounds of nitrogen applied per acre. However, in the plots receiving 120 pounds of nitrogen per acre, the frequently irrigated plots throughout the whole growing season (treatment No. 1) outyielded the plots frequently irrigated until the tasseling stage (treatment No. 6) at the 1-percent level of significance, and the plots frequently irrigated until the silking stage (treatment No. 5) at the 5-percent level. There was no significant difference in

TABLE 14.—*Consumptive use of water by field corn in the nonirrigated plots throughout the whole growing season (treatment No. 3) for the second experiment, by periods, Apr. 16 to Aug. 18, 1958*[1]

Period	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*Inches*	*Inches*
Apr. 16 to Apr. 21[2]	6	1.062	0.177
Apr. 22 to May 1	10	2.254	.225
May 2 to May 13	12	1.865	.155
May 14 to May 18	5	.732	.146
May 19 to May 28	10	1.617	.162
May 29 to June 5	8	1.065	.133
June 6 to June 12	7	.989	.141
June 13 to June 22	10	2.892	.289
June 23 to July 1	9	2.662	.296
July 2 to July 14	13	1.026	.079
July 15 to July 28	14	2.112	.151
July 29 to Aug. 10	13	1.976	.152
Aug. 11 to Aug. 17	7	1.062	.152
Aug. 18[2]	1	.154	.154
Total	125	21.468	

[1] Consumptive-use data from Apr. 16 to May 18 are the same as for the frequently irrigated plots (treatment No. 1). The consumptive-use data throughout the whole growing season are the same as for the nonirrigated plots until the hard-dough stage (treatment No. 7), nonirrigated plots until the silking stage (treatment No. 8), and the nonirrigated plots until the tasseling stage (treatment No. 9).

[2] Consumptive-use data calculated by extrapolation.

production between the plots frequently irrigated throughout the whole growing season (treatment No. 1), the plots frequently irrigated until the hard-dough stage (treatment No. 4), and the intermediately irrigated plots (treatment No. 2).

As can be observed in table 15 and in figures 3 and 4, the difference in production between the frequently irrigated plots throughout the whole growing season (treatment No. 1) and those receiving irrigations after the corn reached the tasseling (treatment No. 9), silking (treatment No. 8), and hard-dough stages (treatment No. 7), was higher than between the

Erratum An erroneous placement of the date scale on figures 1 and 2 of vol. 45, No. 2, necessitated the reprinting of these figures. This sheet should be substituted for pages 99 and 100 of the April issue.

frequently irrigated plots throughout the whole growing season (treatment No. 1) and those receiving irrigation until the tasseling (treatment No. 6), silking (treatment No. 5) and hard-dough stages (treatment No. 4). As

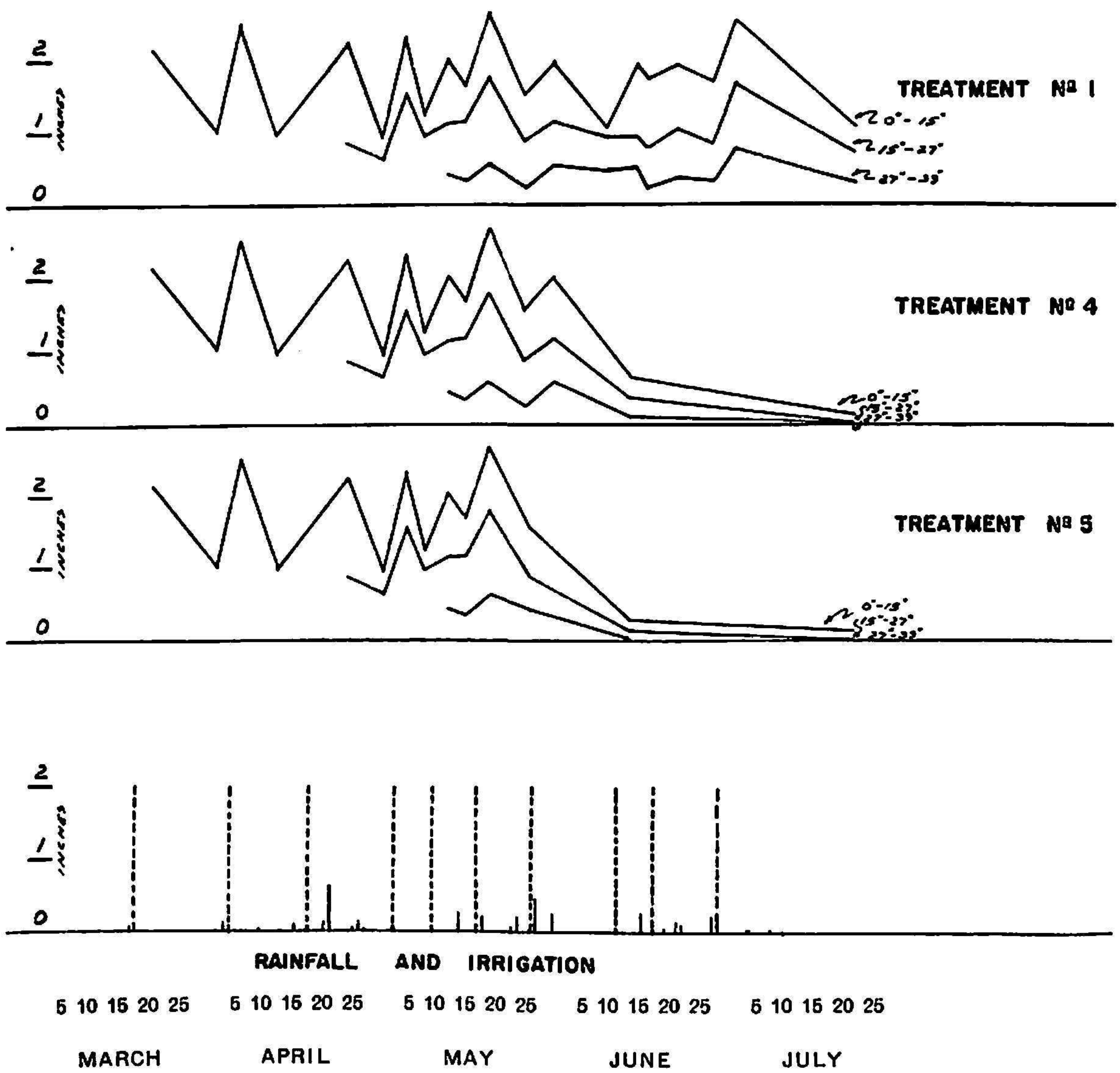

FIG. 1.—Available water as indicated by soil sampling, in the 0 to 15-, 15 to 27-, and 27 to 39-inch horizons of the frequently irrigated plots throughout the whole growing season (top), the frequently irrigated plots until the hard-dough stage (treatment No. 4), and the frequently irrigated plots until the silking stage (treatment No. 5). The rainfall (heavy lines) and the irrigations applied (broken lines) are shown below.

derived from data of table 15, there was a reduction in yields of 12.91, 9.28, and 6.35 hundredweights per acre in the plots where the irrigation was discontinued at the tasseling (treatment No. 6), silking (treatment No. 5), and hard-dough stages (treatment No. 4), respectively.

Table 15 also shows that nitrogen increased the corn yields in the irrigated plots.

DISCUSSION

Soil-moisture deficits from the tasseling to the hard-dough stages definitely had an influence on corn-yield reductions. There was a significant reduction

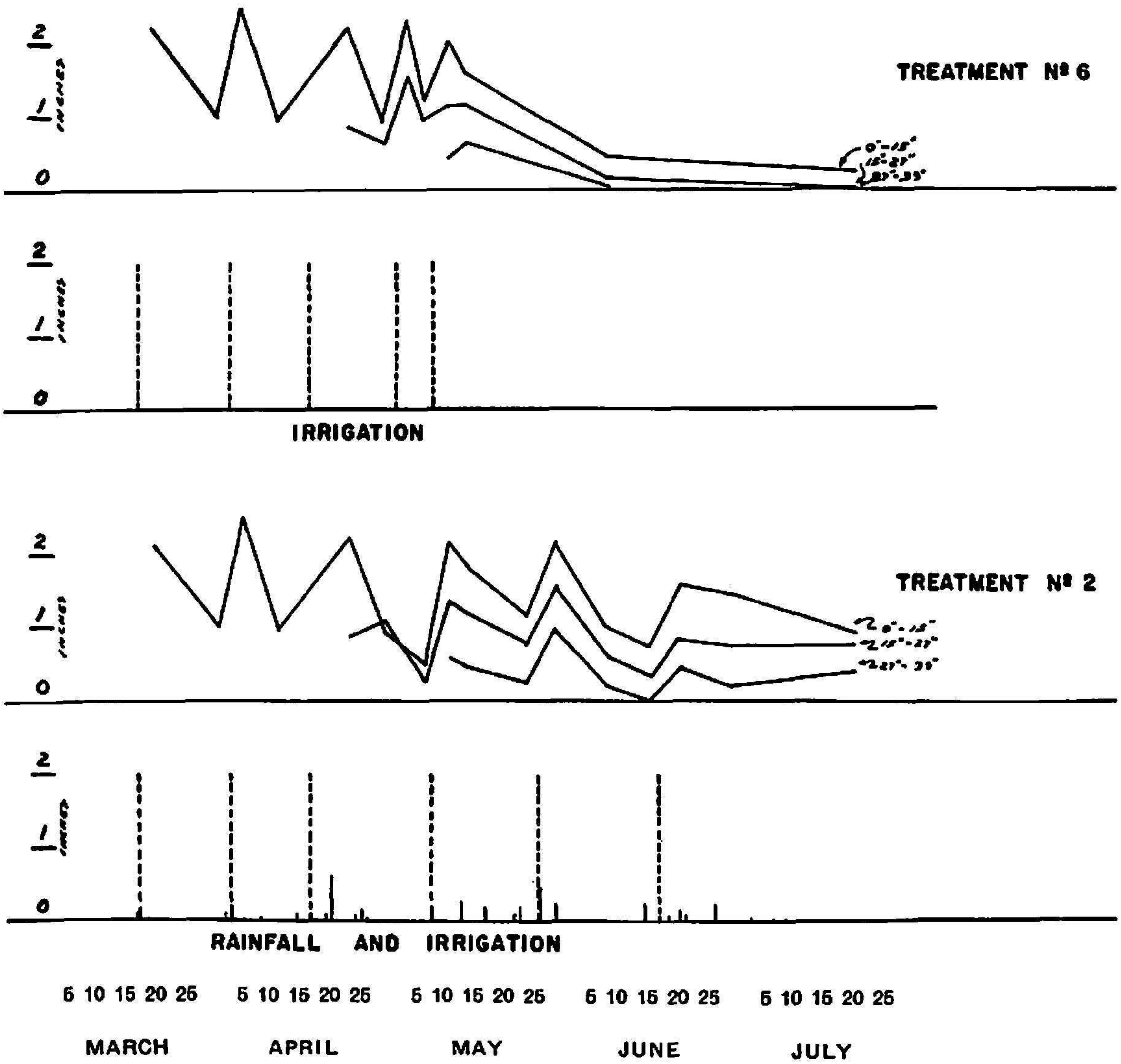

FIG. 2.—Available water as indicated by soil sampling, in the 0 to 15-, 15 to 27-, and 27 to 39-inch horizons of the frequently irrigated plots until the tasseling stage (top) and the intermediately irrigated plots (treatment No. 2). The central chart presents the irrigations applied to the frequently irrigated plots until the tasseling stage (top figure). The bottom chart presents the rainfall (heavy lines) and the irrigations (broken lines) applied to the intermediately irrigated plots (treatment No. 2).

in yield of 22.5 and 16.2 percent in the plots where the irrigations were discontinued at the tasseling and silking stage, respectively. Robins and Domingo (*4*) found that soil-moisture deficits for periods of 1 or 2 days during the tasseling or pollination period resulted in as much as 22-percent yield reductions.

As in other corn experiments conducted during the same period (*6*), the maximum consumptive use occurred during the tasseling to hard-dough stages, decreasing in the last 45 days of the growing season. However, there was some difference in the total consumptive use in the other experiments reported and these also. This may have been caused by the different method used in soil sampling and the different set-up of the experimental plots used.

TABLE 15.—*Effect of irrigation at different growth stages and nitrogen fertilizer on the yield per acre (hundredweights) of 15-percent-moisture shelled corn grown in Santa Isabel clay at Lajas, P.R., 1957–58*

Irrigation treatment[1] No.	Effects of indicated pounds of nitrogen applied per acre, in experiment—					
	No. 1			No. 2		
	0	60 lb.	120 lb.	0	60 lb.	120 lb.
1	26.41	45.22	57.32	29.58	37.90	40.99
2	27.32	41.68	52.72	25.41	36.09	35.85
3	13.01	14.67	14.07	23.99	39.26	35.09
4	27.47	40.47	50.97	25.26	38.12	37.60
5	25.50	37.06	48.04	30.86	35.39	42.05
6	25.41	39.87	44.41	27.16	37.15	37.45
7	13.25	17.09	19.21	36.69	30.04	39.72
8	23.38	20.42	25.26	37.66	34.49	35.85
9	22.32	22.69	24.90	32.91	34.18	33.12

[1] The irrigation treatments were as follows: 1, Irrigated when 20 percent of the available moisture had been depleted from the active root zone. 2, Irrigated when 60 percent of the available moisture had been depleted from the active root zone. 3, Not irrigated after the crop was established. 4, Irrigated as in treatment No. 1 until hard-dough stage; no irrigation thereafter. 5, Irrigated as in treatment No. 1 until silking stage; no irrigation thereafter. 6, Irrigated as in treatment No. 1 until tasseling stage; no irrigation thereafter. 7, Not irrigated after the crop was established until hard-dough stage; as in treatment No. 1 thereafter. 8, Not irrigated after the crop was established until silking stage; as in treatment No. 1 thereafter. 9, Not irrigated after the crop was established until tasseling stage; as in treatment No. 1 thereafter.

Although, for lack of irrigation water, the irrigation levels were not maintained as originally planned, as shown in figures 1 and 2, more available moisture was maintained throughout the whole growing season in the frequently irrigated plots (treatment No. 1) than in the intermediately irrigated plots (treatment No. 2). However, the differences in corn yields were not statistically significant. There were significant yield reductions in the plots where the available moisture was maintained low from the tasseling to the hard-dough stages (May 23 to June 10). In the plots where the available moisture decreased after the hard-dough stage (June 10) the reductions in

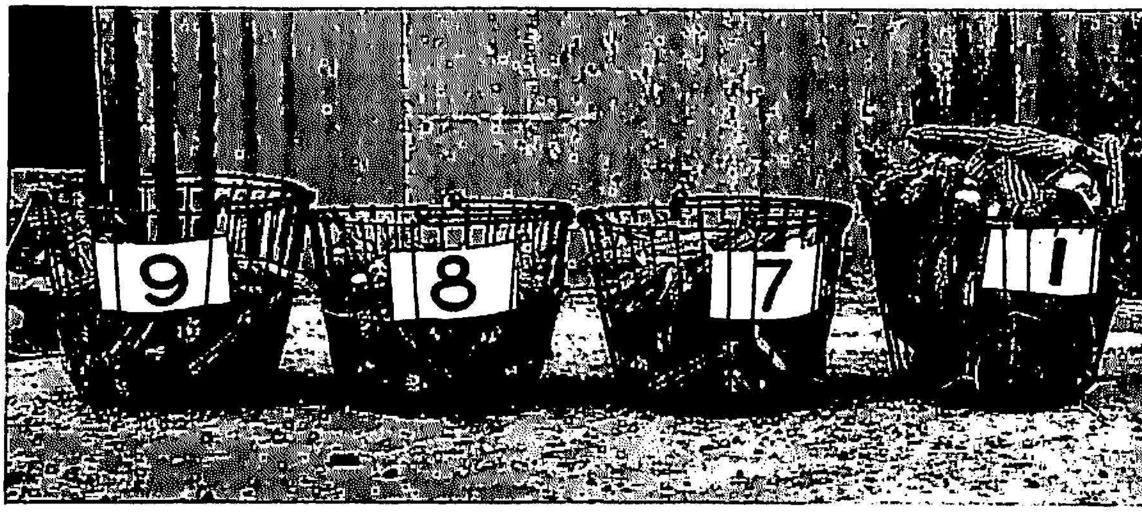

FIG. 3.—Response of corn to irrigation at different growth stages when fertilized at a rate of 120 lb. of nitrogen per acre in experiment No. 1: 9, Not irrigated after the crop was established until the tasseling stage; 8, not irrigated after the crop was established until the silking stage; 7, not irrigated after the crop was established until the hard-dough stage, each one being irrigated after reaching the respective growth stage; 1, frequently irrigated throughout the whole growing season.

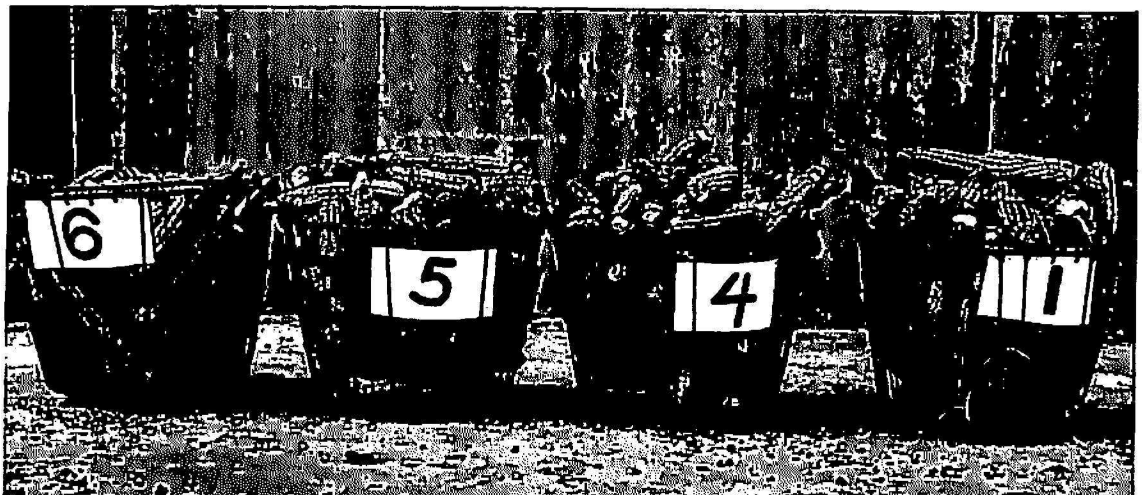

FIG. 4.—Response of corn to irrigation at different growth stages when fertilized at a rate of 120 lb. of nitrogen per acre in experiment No. 1: 6, Frequently irrigated from planting to the tasseling stage; 5, frequently irrigated from planting to the silking stage; 4, frequently irrigated from planting to the hard-dough stage, but unirrigated after reaching the respective growth stage; 1, frequently irrigated throughout the whole growing season.

yields were not significant. In other words, there was no significant difference in corn yields between the frequently irrigated plots (10 irrigations applied) and the plots frequently irrigated until the hard-dough stage (7 irrigations), with no more irrigations thereafter.

Figures 1 and 2 also show that the available moisture in the 27- to 39-inch horizon was maintained very low. This was probably due either to deficient irrigations applied, or to a different moisture-holding capacity, since no moisture-release data were determined for that horizon. Because the physical characteristics of the 27-to-39-inch horizon were very similar to the 15-to-27-inch horizon, the same soil-moisture characteristics were used to calculate the available moisture on both.

As in the other experiments reported (*6*) nitrogen increased yields, and there was an interaction between irrigation and nitrogen. Further work is still needed, especially at different moisture levels throughout the available-moisture range with other growth stages being included.

SUMMARY

Two field experiments using nine irrigation and three nitrogen levels were conducted at Lajas Substation in order to determine the effects of irrigation at different growth stages on the production of field corn. Some plots were frequently irrigated, irrigated when 20 percent of the available moisture had been depleted from the active root zone; and intermediately irrigated, irrigated when the depletion was 60 percent throughout the whole growing season. Other plots were frequently irrigated from planting to the tasseling, silking, and hard-dough stages, not being irrigated thereafter; while others still were not irrigated after the crop was established until the tasseling, silking, and hard-dough stages; these plots were frequently irrigated thereafter. Nonirrigated plots were used as checks. The nitrogen levels tested were 0, 60, and 120 pounds per acre.

The data indicated that:

1. There was a response to irrigation in the first experiment conducted; however, in the second experiment 23 inches of well-distributed rainfall overshadowed the irrigation effects.
2. There was no significant difference in production between the frequently and the intermediately irrigated plots.
3. The frequently irrigated plots throughout the whole growing season (10 irrigations applied) significantly outyielded all the plots under other irrigation treatments, except those irrigated frequently until the hard-dough stage (7 irrigations) with no irrigation thereafter, and the intermediately irrigated plots throughout the whole growing season (6 irrigations).
4. There were reductions in yields of 12.91 and 9.28 hundredweights per acre in the plots where the irrigations were discontinued at the tasseling and silking stages, respectively.
5. The maximum consumptive use of water occurred during the tasseling to hard-dough stages, decreasing in the last 45 days of the growing season.

6. There was a positive response to nitrogen applications, there being an interaction between irrigation and nitrogen.

RESUMEN

Dos experimentos de campo para estudiar el efecto de la aplicación de riego a distintas etapas de crecimiento en combinación con tres niveles de nitrógeno en la producción de maíz fueron llevados a cabo en la Subestación de Lajas. Se usaron los siguientes tratamientos de riego: Frecuente, cuando el 20 por ciento del agua asimilable había sido usada; intermedio, cuando el 60 por ciento del agua asimilable había sido usada; y testigo, parcelas sin riego. Además, se les aplicaron riego frecuente a otras parcelas hasta las siguientes etapas de crecimiento: Espigamiento, barba y hasta que el grano estuvo formado y duro (a los 80 días de sembrado), suspendiéndose el riego una vez llegó a su respectiva etapa de crecimiento. En otras parcelas se empezó la aplicación de riego frecuente una vez el maíz llegó a las etapas de crecimiento antes mencionadas, continuándose el riego hasta la cosecha. A estas parcelas, al igual que a las parcelas testigos, se les hizo una aplicación de riego inicial para establecer las plantas. Los niveles de nitrógeno incluídos fueron 0, 60 y 120 libras por acre. Los resultados obtenidos fueron los siguientes:

1. La aplicación de riego aumentó significativamente la producción de maíz en el primer experimento llevado a cabo; sin embargo, en el segundo experimento no hubo diferencia significativa en la producción debido a que cayeron 23 pulgadas de lluvia bien distribuídas durante el período de crecimiento.

2. No hubo diferencia significativa entre la producción de las parcelas regadas frecuentemente y las regadas con menos frecuencia.

3. Hubo una diferencia significativa entre la producción de las parcelas regadas frecuentemente durante todo el período de crecimiento (10 riegos aplicados) y la producción de las demás parcelas con otros tratamientos de riego, con la excepción de las parcelas regadas frecuentemente hasta que el grano estuvo formado y duro (a las cuales se les aplicaron 7 riegos) y las parcelas con riego intermedio (6 riegos).

4. Hubo una reducción en los rendimientos de 12.91 y 9.28 quintales por acre en las parcelas que se les suspendió el riego en el estado de espigamiento y barbas, respectivamente.

5. El consumo de agua máximo fue durante el período del espigamiento hasta que el grano estuvo formado y duro, disminuyendo en los últimos 45 días del período de crecimiento.

6. Hubo un aumento significativo en la producción de maíz con la aplicación de nitrógeno, exhibiendo una interacción entre riego y nitrógeno.

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