Response of Native White Sorghum to Irrigation under Different Nitrogen-Fertility Levels and Seeding Rates in Lajas Valley, Puerto Rico[1]

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INTRODUCTION

Since sorghum (*Sorghum vulgare* Pers.) is quite resistant to drought, it has been grown mostly in areas of limited rainfall. However, sorghum responds well to irrigation and, at present, with the irrigation system established in the Lajas Valley, its culture has been shifted to irrigation agriculture. The native white variety of sorghum is the most extensively planted forage crop for silage in this region. This plant provided the solution for the scarcity of fodder during the long drought periods in this area.

Although sorghum can be used for grain and forage, it has been used mostly as forage specially for silage. According to Hughes *et al.* (*2*)[3] sorghum silage has largely replaced corn silage in Kansas, Nebraska, Texas, and Oklahoma. As they reported, the feeding value of silage made from corn and from sorghum is generally considered to be the same.

Sorghum is produced fairly well on all types of soil, growth being dependent upon the relative fertility and soil-moisture supply.

Limited research has been done with sorghum in Puerto Rico. It has been observed giving a good response to irrigation and fertilizers. However, there are no available data on the irrigation requirements, seeding rates, and fertilizer needs of this crop.

It may be concluded that our grasslands need better management and improvement practices in order to maintain a large livestock industry. Since sorghum is one of the most important forage crops in the area, it is proposed to study its irrigation requirements and fertilizer needs under different seeding rates in order to obtain optimum yields.

EXPERIMENTAL PROCEDURE

The experiment was planted May 22, 1961, and harvested every 77 days, the last harvest having been made on August 27, 1962. A split-plot design

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[3] Italic numbers in parentheses refer to Literature Cited, p. 112.

with whole units in latin square and subunits in 3 x 3 balanced lattices was used. The treatments included a combination of four irrigation treatments, three nitrogen levels, and three seeding rates with four replications. A sorghum variety, White Native, was planted with 3 feet between rows and 3 seeding rates. The plots were six rows (18 feet) wide and 18 feet long.

IRRIGATION

The following irrigation treatments were tried:

1. High moisture: Plots irrigated when the average soil-moisture suction in the active root-zone reached 0.7 atm.
2. Medium moisture: Plots irrigated when the average soil-moisture suction in the active root-zone reached 2 atm.
3. Low moisture: Plots irrigated when the average soil-moisture suction in the active root-zone reached 5 atm.
4. Nonirrigated: Plots were not irrigated after the crop was established.

Furrows about 4 inches deep and 3 feet apart were made in the whole experiment for the purpose of irrigation. Feeding ditches were made at the head of each irrigation block and used as equalizing bays by means of plastic dams placed at the end of each block. Plastic siphon tubes were used as flow controls for each furrow. A heavy irrigation was applied to the whole area after being planted. After each harvest a uniform irrigation was applied to all the irrigated plots.

PLANT POPULATION

The seeding rates tried were 10, 20, and 30 pounds of seed per acre. White Native sorghum variety was sown on top of the beds with a 3-foot distance between rows, the amount of seed used depending on the seeding rate. Seedlings were attacked by blackbirds (*Quiscalus niger brachypterus*). Reseedings were done on June 5, 6, and 7. The whole experiment was irrigated after being reseeded.

FERTILIZER

Nitrogen fertilizer in the form of ammonium sulfate (20.5-percent N) was applied at the rate of 40, 80, and 120 pounds per acre per crop. After each harvest the whole experiment was fertilized according to the treatments involved. 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 per year. All the fertilizer was broadcast along the planted row.

SOIL-MOISTURE CONTROL

Bulk-density determinations were made of soil samples taken from 3 to 6 and 18 to 21 inches depths.

Tensiometers (*3*) were installed in one of the high-moisture plots under 40 and 120 pounds of nitrogen treatment at 6-, 12-, 18-, and 24-inch depths, respectively. Those plots were irrigated when the average soil-moisture suction in the active root-zone became 700 cm. of water. Gypsum resistance blocks of the Bouyoucos type (*1*) were installed at 6-, 12-, 18-, and 24-inch depths in one of the medium-moisture, low-moisture, and nonirrigated plots under 40 and 120 pounds of nitrogen treatment, respectively. The irrigation of the medium-moisture and low-moisture plots were made when the average resistance readings equalled 2 and 5 atm. of suction, respectively.

About 2 inches of water were applied in each irrigation (table 1). Soil samples for moisture determination were taken during each growing period throughout the course of the experiment to calculate the moisture extracted from the root-zone in each moisture treatment. Duplicate soil samples were taken with a screw-type soil auger at the following depths: 0 to 6, 6 to 12, 12 to 18, and 18 to 24 inches. The soil samples were taken twice a week, especially 1 day before and 2 days after each irrigation in the plots receiving 80 and 120 pounds of nitrogen treatment under each irrigation level.

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 2 feet under each irrigation treatment was calculated for a growing period of five consecutive crops. A total of four samples under each moisture treatment at each different depth sampled 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 effective rainfall[4] to the water extracted during those periods.

CULTURAL PRACTICES

After each harvest the plots were weeded and fertilized according to the fertilizer treatments. Additional weedings were made as necessary to maintain the plots free of weeds. Insecticides were applied for insect control. Every 77 days the plots were harvested and weighed to determine green-forage production. Samples were taken to determine dry-matter percentage and protein content.

[4] If the rainfall was greater than 1 inch a day, the effective rainfall was assumed to be 66 percent of the total rainfall for that particular day.

TABLE 1.—*Irrigation frequencies used in the sorghum experiment at Lajas Substation, 1961–62*

Dates of irrigation for growing periods indicated	Results for indicated soil-moisture treatment[1]		
	High	Medium	Low
1961			
No. 1 (May 22 to Aug. 6)			
May 23–25	x	x	x
June 5–7	x	x	x
July 11	x	—	—
July 14	—	x	—
July 24	x	—	—
July 26	—	x	—
Aug. 1	—	—	x
Aug. 3	x	—	—
Total	5	4	3
No. 2 (Aug. 7 to Oct. 22)			
Aug. 10	x	x	x
Sept. 8	x	x	—
Oct. 17	x	x	x
Total	3	3	2
No. 3 (Oct. 23 to Jan. 7)			
1962			
Oct. 27	x	x	x
Dec. 18	x	—	—
Dec. 20	—	x	—
Dec. 29	x	—	—
Jan. 5	—	—	x
Total	3	2	2
No. 4 (Jan. 8 to Mar. 25)			
Jan. 10	x	x	x
Feb. 5	x	x	—
Feb. 23	x	x	x
Mar. 9	x	—	—
Mar. 12	—	x	—
Mar. 15	—	—	x
Mar. 19	x	—	—
Total	5	4	3

TABLE 1.—*Continued*

Dates of irrigation for growing periods indicated	Results for indicated soil-moisture treatment[1]		
	High	Medium	Low
No. 5 (Mar. 26 to June 10)			
Mar. 28	x	x	x
May 12	x	x	—
May 16	—	—	x
May 24	x	—	—
May 25	—	x	—
June 7	x	—	—
Total	4	3	2
No. 6 (June 11 to Aug. 26)			
June 15	x	x	x
July 10	x	x	—
July 12	—	—	x
July 20	x	—	—
July 24	—	x	—
July 30	x	—	x
Aug. 8	x	—	—
Aug. 9	—	x	—
Total	5	4	3

[1] The high-moisture, medium-moisture, and low-moisture plots were irrigated whenever the average soil-moisture suction in the active root-zone reached 0.7, 2.0, and 5.0 atm., respectively.

EXPERIMENTAL RESULTS

An evaluation was made of the soil-moisture data and the effects of irrigation, nitrogen fertilization, and plant population on dry-matter yields. The results of the first harvest were not taken into consideration because of blackbird damage to the seedlings and some difficulties encountered in drying the samples for dry matter determination. After this harvest the experiment was reseeded.

SOIL MOISTURE

An average bulk density of 1.30 gm./c.c. was determined for soil samples taken from 3- to 6-inch deep and 1.22 gm./c.c. for the 18- to 21-inch samples.

The rainfall distribution by days and months throughout the whole growing season and the 17-year monthly average at Lajas Substation are

TABLE 2.—*Inches of daily rainfall during the growth period of the sorghum experiment at Lajas, P.R., 1961–62*

Date	1961								1962							
	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.
1			0.01			0.52		0.27				0.02	0.85			
2	0.02		1.20			1.53										
3		0.16	.42				0.01	.27				.01				
4		.22					.02	1.58	0.02			.01				
5		.09	.10	0.12			1.03	.06		0.03						
6	.37					1.23										
7	.29	.05		.03		.10		.09			0.19		.02		0.04	
8				.03	0.02			.02				.02		0.45		
9				.08	1.03	.02	.09	.02	.07		.04			.01	.06	1.12
10			.03	.10		.06	.09									
11					.31		.38		1.15	.69			.03			
12														.23	.23	
13	.04		.02			.26	.22		.18				.02	.04	.16	
14	.04		.29		2.47	.05	.38									
15	.04		1.91	3.48		.24	.21		.02			.09	.08		.02	.64
16						.02	.02								.12	.03
17				.80	.67							.79		.30		
18				.09	1.08								.25	.23		1.32
19											.05					.05
20	.04			.05	.27		.02				.14					
21	.02					.05	.15				.17	.74			.08	.88
22		.16	.28	1.45	.24		.03					.07	.05	.52		2.10
23				.02				.02				.46				
24			.27	.21								.47		1.43		
25				.20	.04		.04					.02				
26				.41						.02		.25	1.45		.11	
27		.98		.46				.02		.10			1.36			
28				.50	2.10		.89	.11				3.53	.03			
29			.29		.04				.03		.09					
30						.36	.05				.13			.01	.91	.34
31						.86		.10								
Total	0.86	1.66	4.82	8.03	8.27	5.30	3.63	2.56	1.47	0.84	0.81	6.48	4.14	3.22	1.73	6.48
(17-year average)	3.40	2.53	4.21	6.35	7.24	5.41	4.12	3.14	2.33	1.34	2.04	3.72	3.40	2.53	4.21	6.35

shown in table 2. A close examination of the 17-year monthly average shows that the rainfall during the months of April, May, and June of 1962 was higher than the normal rainfall for that period. It also shows that the period of highest rainfall (rainy season) occurs during the months of July to November.

The consumptive use of water during short periods of time and throughout the course of the experiment is presented in tables 3 to 6. These tables show the water-used variation within each growing period. The total and daily average of water used by sorghum during each growing period under different moisture treatments is shown in table 7 and figure 1. This table, as well as figure 1, shows a seasonal effect on water used by sorghum. They also show the variation in water used among the different moisture treatments.

The highest average daily water used in the irrigated treatments observed was 0.227 inches during the period of August to October; the lowest was 0.112 inches during the period of January to March. The yearly water-used variation in the high-moisture plots was from a daily average of 0.254 inch during the period of August 7 to October 22, to 0.167 inch from October 23 to January 7, to 0.119 inch from January 8 to March 25, to 0.187 inch from March 26 to June 10, and 0.177 inch from June 11 to August 26. In the medium-moisture plots the average daily water used was 0.230, 0.137, 0.128, 0.168, and 0.151 inch for each respective growth period. The low-moisture plots exhibited a variation of 0.197, 0.128, 0.089, 0.167, and 0.156 inch per day for the respective growth periods. The total water used in inches during the 385-day growing period was 69.571 in the high-moisture, 62.657 in the medium-moisture, 56.811 in the low-moisture, and 40.767 in the nonirrigated plots.

EFFECTS OF IRRIGATION

Irrigation effects on yields at different levels of fertilizer are presented in table 8. As can be observed in this table irrigation did not increase yields significantly in the first two harvests. However, in the last three harvests irrigation increased forage yields in a highly significant way. The combined statistical analysis of five crops harvested shows a highly significant effect of irrigation on forage yields. As in the individual analysis, it shows that there were no significant differences in yields between the high-moisture, medium-moisture, and low-moisture plots. The average increase in yields attributed to irrigation was of 2,258, 2,031, and 2,374 pounds of dry matter per acre in harvests 4, 5, and 6, respectively, (derived from table 8). The average increase in total yields during 385 days due to irrigation was of 6,403 pounds of dry matter per acre.

EFFECTS OF NITROGEN FERTILIZATION

Table 8 also presents the effects of nitrogen fertilization on forage yields. This table and figure 2, as well as the statistical analysis of the data, show a highly significant quadratic effect of nitrogen concentration upon forage yields. There was a highly significant increase in yields for the 80-pound-

TABLE 3.—*Consumptive use of water by White Native sorghum in the high-moisture plots, by growing periods, August 7, 1961 to August 26, 1962*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (Aug. 7 to Oct. 22)			
Aug. 7 to Aug. 10[2]	4	1.008	0.252
Aug. 11 to Aug. 13	3	.744	.248
Aug. 14 to Aug. 20[2]	7	1.701	.243
Aug. 21 to Sept. 7	18	4.159	.231
Sept. 8 to Sept. 10[2]	3	.825	.275
Sept. 11 to Sept. 24	14	4.464	.319
Sept. 25 to Oct. 12	18	4.760	.264
Oct. 13 to Oct. 17[2]	5	1.000	.200
Oct. 18 to Oct. 22	5	.870	.174
Total	77	19.531	
No. 3 (Oct. 23 to Jan. 7)			
Oct. 23 to Oct. 29[2]	7	1.155	0.165
Oct. 30 to Nov. 12	14	2.197	.157
Nov. 13 to Nov. 26	14	2.074	.148
Nov. 27 to Dec. 17	21	3.020	.144
Dec. 18 to Dec. 19[2]	2	.396	.198
Dec. 20 to Dec. 28	9	2.019	.224
Dec. 29 to Jan. 2[2]	5	1.040	.208
Jan. 3 to Jan. 7	5	.983	.197
Total	77	12.884	
No. 4 (Jan. 8 to Mar. 25)			
Jan. 8 to Jan. 14[2]	7	0.245	0.035
Jan. 15 to Feb. 4	21	1.743	.083
Feb. 5 to Feb. 6[2]	2	.244	.122
Feb. 7 to Feb. 22	16	2.496	.156
Feb. 23 to Mar. 2	8	.704	.088
Mar. 3 to Mar. 8	6	.296	.049
Mar. 9 to Mar. 10[2]	2	.204	.102
Mar. 11 to Mar. 18	8	1.417	.177
Mar. 19 to Mar. 20[2]	2	.460	.230
Mar. 21 to Mar. 25	5	1.330	.266
Total	77	9.139	

TABLE 3.—*Continued*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 5 (Mar. 26 to June 10)			
Mar. 26 to Mar. 29[2]	4	0.520	0.130
Mar. 30 to Apr. 16	18	2.350	.130
Apr. 17 to May 10	24	5.681	.237
May 11 to May 13[2]	3	.546	.182
May 14 to May 23	10	1.571	.157
May 24[2]	1	.177	.177
May 25 to June 6	13	2.631	.202
June 7[2]	1	.228	.228
June 8 to June 10	3	.707	.236
Total	77	14.411	
No. 6 (June 11 to Aug. 26)			
June 11 to June 14[2]	4	0.232	0.058
June 15 to June 28	14	1.445	.103
June 29 to July 8	10	1.629	.163
July 9 to July 11[2]	3	.477	.159
July 12 to July 19	8	.873	.109
July 20 to July 22[2]	3	.495	.165
July 23 to July 29	7	1.528	.218
July 30 to July 31[2]	2	.324	.162
Aug. 1 to Aug. 7	7	.787	.112
Aug. 8 to Aug. 9[2]	2	.360	.180
Aug. 10 to Aug. 16	7	1.704	.243
Aug. 17 to Aug. 26	10	3.752	.375
Total	77	13.606	

[1] During the first growing period all plots were irrigated as frequently as necessary to establish the crop. The data are not included in this table.

[2] Consumptive-use data calculated by interpolation.

nitrogen treatment over the 40-pound treatment in all harvests; however, the 120-pound-nitrogen treatment outyielded the 80-pound in the last three crops only. The combined analysis of five harvests shows a significant quadratic effect on yields, the 80-pound outyielding the 40-pound and the 120-pound outyielding the 80-pound treatment. The total increase in yields due to an increase in nitrogen fertilizer from 40 to 80 pounds per acre per crop was 8,500 pounds of dry matter per acre in 385 days, while 40 more pounds over the 80-pound treatment increased the yields only by 2,561 pounds (derived from table 8).

TABLE 4.—*Consumptive use of water by White Native sorghum in the medium-moisture plots, by growing periods, August 7, 1961 to August 26, 1962*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (Aug. 7 to Oct. 22)			
Aug. 7 to Aug. 10[2]	4	0.668	0.167
Aug. 11 to Aug. 13	3	.533	.178
Aug. 14 to Aug. 20[2]	7	1.351	.193
Aug. 21 to Sept. 7	18	4.138	.230
Sept. 8 to Sept. 10[2]	3	.828	.276
Sept. 11 to Sept. 24	14	4.391	.314
Sept. 25 to Oct. 12	18	3.905	.217
Oct. 13 to Oct. 17[2]	5	.995	.199
Oct. 18 to Oct. 22	5	.880	.176
Total	77	17.689	
No. 3 (Oct. 23 to Jan. 7)			
Oct. 23 to Oct. 29[2]	7	1.043	0.149
Oct. 30 to Nov. 12	14	2.205	.158
Nov. 13 to Nov. 26	14	2.416	.172
Nov. 27 to Dec. 19	23	2.853	.124
Dec. 20 to Dec. 21[2]	2	.226	.113
Dec. 22 to Jan. 7	17	1.790	.105
Total	77	10.533	
No. 4 (Jan. 8 to Mar. 25)			
Jan. 8 to Jan. 14[2]	7	0.315	0.045
Jan. 15 to Feb. 4	21	1.726	.082
Feb. 5 to Feb. 6	2	.222	.111
Feb. 7 to Feb. 22	16	2.579	.161
Feb. 23 to Mar. 2[2]	8	1.280	.160
Mar. 3 to Mar. 11	9	1.600	.178
Mar. 12 to Mar. 14[2]	3	.492	.164
Mar. 15 to Mar. 25	11	1.621	.147
Total	77	9.835	
No. 5 (Mar. 26 to June 10)			
Mar. 26 to Mar. 29[2]	4	0.186	0.047
Mar. 30 to Apr. 16	18	2.286	.127
Apr. 17 to May 10	24	5.520	.230
May 11 to May 17[2]	7	1.316	.188
May 18 to May 24	7	1.186	.169
May 25 to May 31[2]	7	1.085	.155
June 1 to June 10	10	1.379	.138
Total	77	12.958	

TABLE 4.—*Continued*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 6 (June 11 to Aug. 26)			
June 11 to June 14[2]	4	0.332	0.083
June 15 to June 28	14	1.164	.083
June 29 to July 8	10	2.107	.211
July 9 to July 11	3	.474	.158
July 12 to July 23	12	1.184	.099
July 24 to July 25[2]	2	.328	.164
July 26 to Aug. 8	14	2.544	.182
Aug. 9 to Aug. 10[2]	2	.410	.205
Aug. 11 to Aug. 26	16	4.099	.256
Total	77	12.642	

[1] During the first growing period all plots were irrigated as frequently as necessary to establish the crop. The data are not included in this table.

[2] Consumptive-use data calculated by interpolation.

There was a significant interaction between irrigation and nitrogen fertilizer in the last two crops harvested. The combined analysis of five crops harvested shows a highly significant interaction between irrigation and nitrogen fertilizer applications (see fig. 2).

Nitrogen and irrigation effects on the protein content of the sorghum forage are shown on table 9. As can be observed nitrogen fertilization increased the protein content of the forage while irrigation decreased it. The largest differences were observed between the 40- and 80-pound-nitrogen treatments and between irrigated and nonirrigated treatments. The average protein content of the forage was 4.97, 6.18, and 7.18 percent for the 40-, 80-, and 120-pound-nitrogen treatments, respectively. In the high-moisture, medium-moisture, low-moisture, and nonirrigated plots the average protein content was 5.72, 5.76, 6.03, and 6.92 percent, respectively.

EFFECTS OF PLANT POPULATION

The effects of different seeding rates per acre on yields are shown in table 10. There was no significant differences in yields between the plots planted with 10, 20, and 30 pounds of seeds per acre under different nitrogen levels. At the 120-pound-nitrogen level an increase in seeding rate shows a slight increase in yields, but the differences were not significant. The interaction between nitrogen concentration and amount of seed per acre is nonsignificant also.

TABLE 5.—*Consumptive use of water by White Native sorghum in the low-moisture plots, by growing periods, August 7, 1961 to August 26, 1962*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (Aug. 7 to Oct. 22)			
Aug. 7 to Aug. 10[2]	4	0.636	0.159
Aug. 11 to Aug. 13	3	.530	.177
Aug. 14 to Aug. 20[2]	7	1.302	.186
Aug. 21 to Sept. 7	18	4.521	.251
Sept. 8 to Sept. 24	17	2.447	.144
Sept. 25 to Oct. 12	18	4.134	.230
Oct. 13 to Oct. 17[2]	5	.860	.172
Oct. 18 to Oct. 22	5	.732	.146
Total	77	15.162	
No. 3 (Oct. 23 to Jan. 7)			
Oct. 23 to Oct. 29[2]	7	1.092	0.156
Oct. 30 to Nov. 12	14	1.992	.142
Nov. 13 to Nov. 26	14	1.775	.127
Nov. 27 to Dec. 17	21	3.773	.180
Dec. 18 to Jan. 4	18	1.076	.060
Jan. 5 to Jan. 7[2]	3	.180	.060
Total	77	9.888	
No. 4 (Jan. 8 to Mar. 25)			
Jan. 8 to Jan. 14[2]	7	0.175	0.025
Jan. 15 to Feb. 4	21	.935	.044
Feb. 5 to Feb. 22	18	1.239	.069
Feb. 23 to Mar. 2[2]	8	1.048	.131
Mar. 3 to Mar. 14	12	2.162	.180
Mar. 15[2]	1	.145	.145
Mar. 16 to Mar. 25	10	1.149	.115
Total	77	6.853	
No. 5 (Mar. 26 to June 10)			
Mar. 26 to Mar. 29[2]	4	0.174	0.044
Mar. 30 to Apr. 22	24	2.965	.124
Apr. 23 to May 15	23	5.498	.239
May 16 to May 17[2]	2	.400	.200
May 18 to June 10	24	3.835	.160
Total	77	12.872	

TABLE 5.—*Continued*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 6 (June 11 to Aug. 26)			
June 11 to June 14[2]	4	0.548	0.137
June 15 to June 28	14	1.610	.115
June 29 to July 11	13	1.070	.082
July 12 to July 13[2]	2	.242	.121
July 14 to July 29	16	2.706	.169
July 30 to July 31[2]	2	.298	.149
Aug. 1 to Aug. 16	16	2.086	.130
Aug. 17 to Aug. 26	10	3.476	.348
Total	77	12.036	

[1] During the first growing period all plots were irrigated as frequently as necessay to establish the crop. The data are not included in this table.
[2] Consumptive-use data calculated by interpolation.

DISCUSSION

As in other forage species (*4*), a seasonal effect on the consumptive use of water by White Native sorghum was observed in this experiment (see fig. 1). As shown in figure 1 there was a higher water use for the period of August 1961 than for August 1962. This can be explained by the influence of heavier rainfall observed during the period of 1961 (see table 2), or probably by a decrease in growth attributable to cutting effects.

Irrigation did not increase forage yields during the period of August 7 to January 7. A look at table 2 shows that this period corresponds to the rainy season in Lajas Valley. From January 8 to August 26, irrigation increased yields significantly; however, there were no significant differences in yields between the irrigation treatments. The irrigations to the plots with 2 and 5 atm. of suction were made using Cel-WWD Boyoucos gypsum resistance blocks as the index. The calibration of these blocks shows a resistance of 910 and 1950 ohms, equivalent to 2.0 and 5.0 atm., respectively. Evidently these resistance readings are too low for the respective soil-moisture treatments with this type of unit. In other words, the irrigation treatments were not applied as intended. Although the high-moisture plots received 20 irrigations, the medium-moisture 16, and the low-moisture 12; the difference in moisture was insufficient to affect the sorghum yields significantly.

Since the forage yields were not affected between the irrigation treatments, and during the period of August 7 to January 7 irrigation did not increase yields significantly, the representative consumptive use of water

TABLE 6.—*Consumptive use of water by White Native sorghum in the nonirrigated plots, by growing periods, August 7, 1961 to August 26, 1962*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (Aug. 7 to Oct. 22)			
Aug. 7 to Sept. 7	32	5.324	0.166
Sept. 8 to Sept. 24	17	2.681	.158
Sept. 25 to Oct. 12	18	4.094	.227
Oct. 13 to Oct. 22	10	1.541	.154
Total	77	13.640	
No. 3 (Oct. 23 to Jan. 7)			
Oct. 23 to Nov. 12	21	1.328	0.063
Nov. 13 to Nov. 26	14	2.391	.171
Nov. 27 to Dec. 17	21	2.898	.138
Dec. 18 to Jan. 7	21	1.779	.085
Total	77	8.396	
No. 4 (Jan. 8 to Mar. 25)			
Jan. 8 to Feb. 4	28	0.900	0.032
Feb. 5 to Feb. 22	18	.782	.043
Feb. 23 to Mar. 14	20	.999	.050
Mar. 15 to Mar. 25	11	1.264	.115
Total	77	3.945	
No. 5 (Mar. 26 to June 10)			
Mar. 26 to Apr. 16	22	0.929	0.042
Apr. 17 to May 13	27	4.263	.158
May 14 to June 10	28	1.375	.049
Total	77	6.567	
No. 6 (June 11 to Aug. 26)			
June 11 to July 8	28	3.870	0.138
July 9 to July 29	21	1.284	.061
July 30 to Aug. 26	28	3.065	.109
Total	77	8.219	

[1] During the first growing period all plots were irrigated as frequently as necessary to establish the crop. The data are not included in this table.

by White Native sorghum can be assumed to be that of the nonirrigated plots from August 7 to January 7, and from January 8 to August 26 that of the low-moisture plots (see table 7). The total consumptive use in 385 days would be 53.797 inches, or an average of 0.140 inch per day, which is lower than the one determined by the author (*4*) for Guinea grass and Para grass in the same area. This probably can be explained by the limited 2-foot depth of sampling to calculate the moisture extracted from the root-zone, by the low-moisture treatment which was the representative one in

TABLE 7.—*Consumptive use of water by White Native sorghum by 77-day growing periods, August 7, 1961 to August 26, 1962*

Growing period[1]	Consumptive use (in inches) under indicated irrigation treatment— High moisture: Total	High moisture: Daily ave.	Medium moisture: Total	Medium moisture: Daily ave.	Low moisture: Total	Low moisture: Daily ave.	Nonirrigated: Total	Nonirrigated: Daily ave.	Average daily consumptive use in inches[2]
No. 2 (Aug. 7 to Oct. 22)	19.531	0.254	17.689	0.230	15.162	0.197	13.640	0.177	0.227
No. 3 (Oct. 23 to Jan. 7)	12.884	.167	10.533	.137	9.888	.128	8.396	.109	.144
No. 4 (Jan. 8 to Mar. 25)	9.139	.119	9.835	.128	6.853	.089	3.945	.051	.112
No. 5 (Mar. 26 to June 10)	14.411	.187	12.958	.168	12.872	.167	6.567	.085	.174
No. 6 (June 11 to Aug. 26)	13.606	.177	11.642	.151	12.036	.156	8.219	.107	.161
Total	69.571		62.657		56.811		40.767		
Average per day	0.181		0.163		0.148		0.106		

[1] During the first growing period all plots were irrigated as frequently as necessary to establish the crop. The data were not included in this table.

[2] The nonirrigated plots were not included in this average.

respect to water used in the dry season, or by the plant itself which shows a fast recovery after being irrigated.

Table 8 shows that the lowest average yield per harvest was during harvest No. 6, which is close to the average obtained during No. 4. Since, according to data with other forage grasses reported by the author (*4*), the lowest yields may be expected during the winter months, it seems likely that the reduction in yields during harvest No. 6, may have been caused by cutting effects of the original sorghum plants.

Nitrogen increased yields significantly; however, it had a significant quadratic effect on yields (see table 8 and fig. 2). In other words, the first 40 pounds of nitrogen over the initial fertilizer treatment had a linear relation of yield increase with respect to nitrogen-fertilizer additions; however, with the next 40 pounds of extra nitrogen the curve tended to level off. A look at table 8 shows that forage yields were increased by the 120-pound nitrogen treatment in harvests 4, 5, and 6. This evidently shows that a better use of the fertilizer is made during spring and summer.

Seeding rates over 10 pounds per acre did not increase forage yields significantly. But, as shown in table 10, there was a tendency to increase

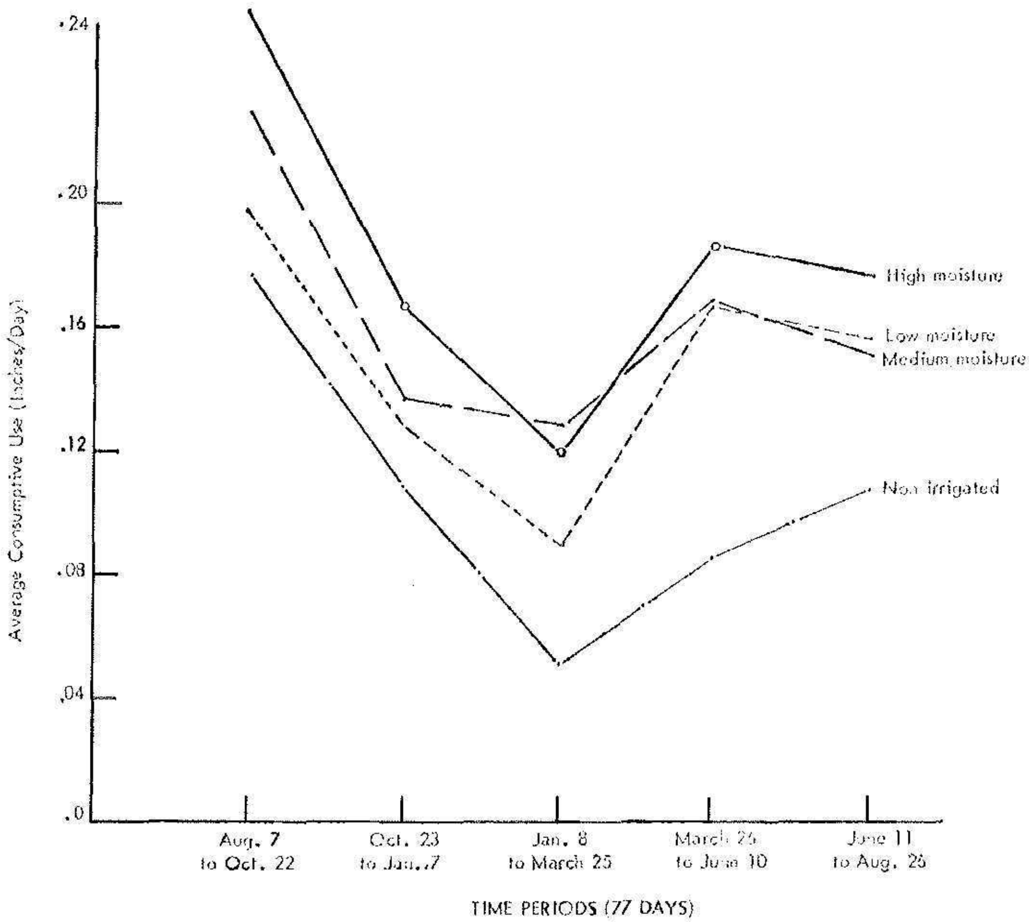

FIG. 1.—Seasonal effects on the consumptive use of water by White Native sorghum at Lajas Substation, 1961–62.

forage production with an increase in seeding rates at the 120-pound-nitrogen level. This suggests that the limiting factor on the response to higher seeding rates is the nitrogen fertility level.

In general, we can conclude that irrigation and nitrogen fertilizer applications, without high seeding rates, are necessary to obtain maximum yields of sorghum forage in Lajas Valley. Further research is necessary on the soil-moisture aspect, especially within the range of 5 to 15 atm., although it would be helpful to check the calibration of the gypsum resistance blocks and start with 2 atm. again.

TABLE 8.—*Effects of irrigation and nitrogen fertilization on the yields (pounds of dry matter per acre) of White Native sorghum at different periods of time from August 7, 1961 to August 26, 1962*

Harvest and irrigation treatment	Effect of indicated pounds of nitrogen applied per acre per crop			Mean
	40	80	120	
Harvest No. 2[1] (Oct. 23)				
High moisture	6,295	8,791	8,019	7,702
Medium moisutre	6,316	8,416	8,346	7,693
Low moisture	6,610	7,893	8,403	7,665
No irrigation	7,420	8,778	8,609	8,269
Mean	6,660	8,492	8,344	7,832
Harvest No. 3 (Jan. 8)				
High moisture	5,611	6,126	5,542	5,760
Medium moisture	5,381	6,183	5,977	5,847
Low moisture	5,548	6,017	5,636	5,734
No irrigation	5,451	5,890	5,717	5,686
Mean	5,498	6,054	5,718	5,757
Harvest No. 4 (Mar. 26–27)				
High moisture	4,062	6,008	6,945	5,672
Medium moisture	3,706	5,838	7,091	5,545
Low moisture	3,179	5,590	6,997	5,255
No irrigation	2,120	3,113	4,465	3,233
Mean	3,267	5,137	6,374	4,926
Harvest No. 5 (June 11–12)				
High moisture	4,885	7,671	8,633	7,063
Medium moisture	5,015	7,792	8,769	7,192
Low moisture	5,248	8,001	9,151	7,467
No irrigation	4,072	5,390	6,168	5,210
Mean	4,805	7,214	8,180	6,733
Harvest No. 6 (Aug. 27)				
High moisture	3,808	6,038	6,864	5,570
Medium moisture	3,872	5,841	7,024	5,579
Low moisture	3,521	5,735	6,464	5,240
No irrigation	2,266	3,188	3,814	3,089
Mean	3,367	5,200	6,042	4,870

[1] Results of the first harvest were not taken into consideration because of blackbird damage to the seedlings and difficulties encountered in drying the samples taken for dry-matter determination.

SUMMARY

A field experiment was conducted at Lajas Substation in order to study the effects of four irrigation and three nitrogen levels under three different seeding rates on dry-matter yields of White Native sorghum. The following irrigation treatments were tried:

High moisture, plots irrigated when the average soil-moisture suction in the active root-zone reached 0.7 atm.; medium moisture, irrigated when

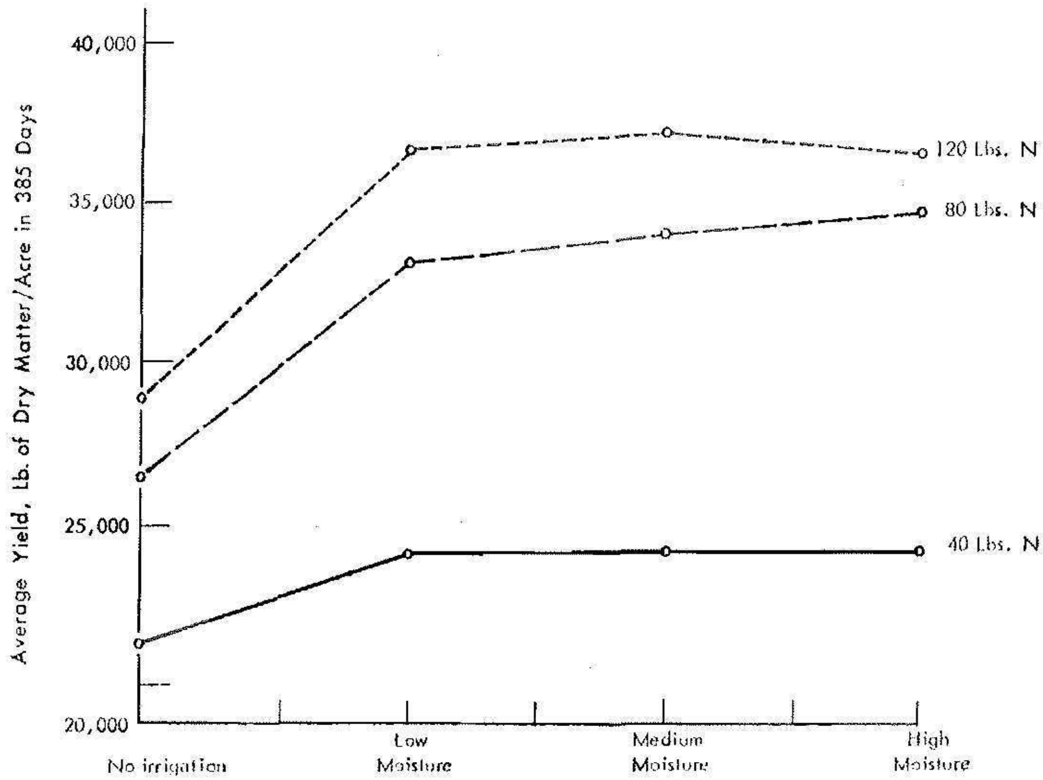

FIG. 2.—Effects of irrigation and nitrogen fertilizer applied on dry-matter yields of White Native sorghum at Lajas Substation, 1961–62.

the average soil-moisture suction reached 2.0 atm.; low moisture, irrigated when the average soil-moisture suction reached 5.0 atm., and nonirrigated plots were used as check. The nitrogen levels tested were 40, 80, and 120 pounds per acre per harvest. The seeding rates used were 10, 20, and 30 pounds per acre.

In general the results show that:

1. Irrigation increased forage yields significantly during the period of January to August. No response to irrigation was observed from September to December. The average increase in yields during 385 days attributable to irrigation was 6,403 pounds of dry matter per acre.

2. There was no significant difference in production between high-moisture, medium-moisture, and low-moisture plots. However, the calibration of the gypsum resistance blocks used as an index of irrigation show low

TABLE 9.—*Average protein content (percent) of White Native sorghum forage at different irrigation and nitrogen levels*[1]

Irrigation treatment	Effects of indicated pounds of nitrogen applied per acre per crop on the protein content of sorghum forage			Mean
	40 N	80 N	120 N	
High moisture	4.65	5.61	6.91	5.72
Medium moisture	4.74	5.96	6.59	5.76
Low moisture	4.85	6.13	7.11	6.03
No irrigation	5.64	7.03	8.10	6.92
Mean	4.97	6.18	7.18	6.11

[1] Average protein content of samples taken in 5 consecutive crops.

TABLE 10.—*Effect of irrigation, nitrogen fertilization, and plant population on the total yields (pounds of dry matter per acre) of White Native sorghum forage in 5 consecutive crops*

Irrigation treatment	Effect of quantity of seed planted per acre under indicated nitrogen levels, pounds per acre per crop									Mean
	40 N			80 N			120 N			
	10 lb. seed	20 lb. seed	30 lb. seed	10 lb. seed	20 lb. seed	30 lb. seed	10 lb. seed	20 lb. seed	30 lb. seed	
High moisture	24,932	24,487	24,563	34,712	34,606	33,372	35,187	35,943	36,899	31,633
Medium moisture	23,489	24,170	25,204	34,400	33,584	34,228	36,941	36,124	38,554	31,855
Low moisture	25,495	23,740	23,081	33,472	35,447	30,304	35,447	37,304	37,192	31,276
No irrigation	21,266	21,856	20,872	26,777	26,221	25,773	26,635	28,904	28,374	25,186
Mean	23,796	23,563	23,430	32,340	32,464	30,919	33,552	34,569	35,255	29,988

resistance readings as equivalent to 2 and 5 atm. Therefore, the irrigation treatments were not accomplished as intended.

3. The representative consumptive use of water in inches by White Native sorghum was as follows: 13.640 from August 7 to October 22; 8.396 from October 23 to January 7; 6.853 from January 8 to March 25; 12.872 from March 26 to June 10; and 12.036 from June 11 to August 26, with a total of 53.797 inches in 385 days.

4. There was a seasonal effect on the consumptive use of water, the high-

est average water used, 0.227 inch per day, being observed from August 7 to October 22, and the lowest, 0.112 inch per day, from January 8 to March 25.

5. Nitrogen fertilization had a highly significant quadratic effect on forage yields. The 80-pound-nitrogen treatment outyielded the 40-pound treatment in a highly significant way in all harvests made; however, the curve of forage yields versus nitrogen application tended to level off with 120-pound-nitrogen treatment. The 120-pound-nitrogen treatment outyielded the 80-pound treatment in the last three harvests only.

6. There was a significant interaction between irrigation and nitrogen fertilizer in the last two crops. The combined analysis of five crops harvested shows a highly significant interaction between irrigation and nitrogen fertilizer.

7. Seeding rates over 10 pounds per acre did not increase forage yields significantly.

8. Nitrogen fertilizer applications increased the protein content of the forage while irrigation decreased it.

RESUMEN

En la Subestación de Lajas se llevó a cabo un experimento de campo para estudiar el efecto de cuatro distintos nieveles de riego, tres de nitrógeno y tres distintas cantidades de semilla por acre, sobre la producción de materia seca del millo Blanco del País. Los tratamientos con riego fueron como sigue: Se mantuvo un alto contenido de humedad en ciertas parcelas, aplicándose les riego cuando el promedio de succión (tensión) en el área alrededor de las raíces alcanzaba 0.7 de atmósfera; un contenido mediano de humedad cuando el promedio de succión fue de 2.0 atmósferas y un bajo contenido de humedad cuando el promedio de succión fue de 5.0 atmósferas. Las parcelas sin riego sirvieron de testigo. Los niveles de nitrógeno fueron 40, 80 y 120 libras por acre, por corte. Se usaron 10, 20 y 30 libres de semilla por acre.

En términos generales, los datos obtenidos demostraron lo siguiente:

1. La aplicación de riego aumentó la producción de forraje durante los meses de enero a agosto, pero el aumento no fue significativo durante el período de septiembre a diciembre.

2. No hubo diferencia significativa entre la producción de las parcelas que recibieron riego. Sin embargo, la aplicación de riego no se hizo según indicaban los tratamientos, ya que los bloques de resistencia que se usaron como índice de riego no se calibraron debidamente.

3. El millo Blanco País requirió las siguientes cantidades de agua: 13.640 pulgadas de agosto 7 a octubre 22; 8.396 de octubre 23 a enero 7; 6.853

de enero 8 a marzo 25; 12.872 de marzo 26 a junio 10 y 12.036 de junio 11 a agosto 26, o sea, un total de 53.797 pulgadas durante 385 días.

4. La estación del año tuvo que ver con el consumo de agua. El mayor consumo, o sea, un promedio de 0.227 de pulgada por día, tuvo lugar de agosto 7 a octubre 22, y el más bajo, o sea, 0.112 de pulgada, de enero 8 a marzo 25.

5. La aplicación de nitrógeno tuvo un efecto cuadrático altamente significativo sobre la producción de forraje. Es decir, la aplicación de 80 libras de nitrógeno por acre, por cosecha, aumentó la producción al compararse con el tratamiento de 40 libras, en una forma altamente significativa en todas las cosechas. Sin embargo, al aplicarse 120 libras el aumento en producción fue reduciéndose en comparación con el tratamiento de 80 libras. El aumento en producción fue significativo solamente en las últimas tres cosechas.

6. Hubo una interacción significativa entre las aplicaciones de nitrógeno y riego durante las últimas dos cosechas, mientras que el análisis combinado de las cinco cosechas reveló que la interacción fue altamente significativa.

7. Cuando se sembraron más de 10 libras de semilla por acre, el aumento en la producción no fue significativo.

8. La aplicación de nitrógeno aumentó el contenido de proteína en el forraje, mientras que el riego lo disminuyó.

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