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Effects of Irrigation and Nitrogen Levels on the Yields of Guinea Grass, Para Grass, and Guinea Grass-Kudzu and Para Grass-Kudzu Mixtures in Lajas Valley[1]

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INTRODUCTION

It is becoming increasingly clear that irrigation will continue to become more important in today's agriculture. Although the future expansion of irrigated acreages may not be as rapid as that of the past several years, there is need for considering important questions related to the place of irrigation in agricultural production. There is a serious lack of information presently available to farmers and agricultural workers on many problems they confront in making effective use of irrigation. This is partly due to the limited research and experience with irrigation in Puerto Rico.

Since the Lajas Valley is under irrigation and one-third of it is dedicated to cattle raising, especially dairy cattle, it seems wise to determine how to increase the efficiency of forage production. Grass provides one of the main sources of food for livestock, and it seems certain that, despite recent developments in grain feeding, the crop will retain its importance for ruminants. Pastures can provide cheap nutritious feed for much of the year, with judicious management and maintenance of soil fertility. Nitrogen is critically important for intensive grass production, and the highest yield level can be provided only by large amounts.

Guinea grass, *Panicum maximum*, is one of the most important grasses of the area. It is very resistant to dry conditions, and produces an abundance of good palatable roughage. There are no available data concerning its performance under irrigation.

Rivera Brenes (*3*)[3] found that Para grass, *Panicum purpurascens*, and

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[3] Italic numbers in parentheses refer to Literature Cited, p. 412.

Guinea grass were similar as measured by gains of the animals, yields, and carrying capacity. He (*3,4*) also found that tropical kudzu (*Pueraria javanica*) is a highly desirable crop to use in conjunction with Para and Guinea grasses for pasture mixtures. Samuels (*5*) reported that tropical kudzu had become important in Puerto Rico as a valuable legume for livestock and the control of soil erosion.

Because the use of irrigation requires heavier nitrogen fertilization, and to determine whether part of this nitrogen could be supplied by tropical kudzu, it was included in this study. Another objective was to evaluate Guinea grass, Para grass, and the mixture of each grass with tropical kudzu under different irrigation and nitrogen fertilizer treatments.

EXPERIMENTAL PROCEDURE

TREATMENTS

An experiment was conducted at Lajas Substation Farm. The field was planted March 9, 1959, and harvested every 2 months after the first harvest on June 29. Seven crops were harvested, the last on June 27, 1960.

The plots were irrigated after several plowings and harrowings, and planted 2 days later in furrows at a 3-foot distance. All plantings were made on the bank. The Guinea grass plots were planted with stools at a 1.5-foot distance, and Para grass with stalks lying along a shallow ditch open on the top of the bank. In the grass-legume mixtures, one bank was planted with each respective grass alternated with one bank of tropical kudzu drilled along a shallow ditch open at the top of the bank. After planting, frequent irrigations were carried out on all plots to establish the crop.

The treatments included a combination of three irrigation levels, three nitrogen levels, and four forage combinations, with four replications. The experimental design was a split-split plot. The fertilizer treatments were grouped in subblocks of 3 plots under each forage treatment which, in turn, were grouped in blocks of 12 plots under each irrigation treatment, there being 3 blocks within each replication. The plots consisted of six rows, 18 feet wide and 18 feet long. Two guard rows were left on each side of the experiment.

IRRIGATION

Three irrigation treatments were tried: Frequent, irrigated when the average soil-moisture suction in the active root zone reached 0.7 atm.; intermediate, irrigated when the average soil-moisture suction in the active root zone reached 2 atm.; no irrigation, 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 made at the head of each irrigation block were 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 to establish the crop. Subsequent irrigations were made according to the treatments involved.

FERTILIZERS

The nitrogen-fertilizer treatments used were 0, 400, and 800 pounds per acre per year, subdivided in six equal parts, each one being applied after each harvest. Sixty-six pounds of nitrogen fertilizer were applied to establish the crop in the control plots that were supposed to receive no nitrogen. After the first harvest no more nitrogen was applied to these plots. The nitrogen was applied as ammonium sulfate (20.5 percent of N). Phosphorus and potassium in the form of superphosphate (20.5 percent of P_2O_5), and muriate of potash (61 percent of K_2O), were applied to the whole experiment at the rate of 400 pounds of P_2O_5 and 600 pounds of K_2O per acre per year, respectively. This amount subdivided in six equal parts was applied after each harvest, as was done with the nitrogen fertilizer. All the fertilizer was placed in a small furrow opened about 3 inches at both sides of the plant.

FORAGES

The forage treatments consisted of Guinea grass and Para grass alone, and mixtures of Guinea grass and of Para grass with tropical kudzu. One bank was planted with grass and an alternate one with kudzu in the legume-grass mixture plots. All plots were intended to be harvested every 60 days.

SOIL-MOISTURE CONTROL

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

Tensiometers (*2*) were installed in one of the highest fertility Guinea grass and Para grass plots of the frequently irrigated blocks at 6-, 12-, 18-, and 24-inch depths. One group of tensiometers was placed on the top of the furrow on each grass. Irrigations of the frequently irrigated plots were made when the average soil-moisture suction in the active root zone became 700 cm. of water. Gypsum resistance blocks of the Bouyoucos type (*1*), and homemade models were installed at 6-, 12-, 18-, and 24-inch depths in the frequently, intermediately, and nonirrigated plots. The irrigations of the intermediately irrigated plots were made when the average resistance reading became 2 atm. of suction. 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 whole year to calculate the moisture extracted from

TABLE 1.—*Irrigation frequencies used in the forage-crop experiment at Lajas Substation, P. R. 1959–60*

Dates of irrigations for growing period—	Irrigation treatment[1]	
	Frequent	Intermediate
No. 1 (Mar. 9 to June 28)		
1959:		
Mar. 11–12	×	×
Mar. 24–25	×	×
Apr. 1–2	×	×
Apr. 14–15	×	×
May 20	×	×
May 29	×	—
June 4	×	×
June 10	×	—
June 16	×	×
June 23	×	—
Total	10	7
No. 2 (June 29 to Aug. 26)		
July 2	×	×
July 22	×	—
Aug. 4	×	—
Aug. 5	—	×
Total	3	2
No. 3 (Aug. 27 to Oct. 27)		
Sept. 2	×	×
Sept. 25	×	—
Oct. 1	—	×
Oct. 9	×	—
Oct. 19	×	×
Total	4	3
No. 4 (Oct. 28 to Dec. 28)		
Nov. 2	×	—
Nov. 3	—	×
Dec. 7	×	—
Total	2	1
No. 5 (Dec. 29 to Feb. 24)		
Dec. 31	×	×
1960:		
Feb. 2	×	—
Feb. 8	—	×
Feb. 12	×	—
Feb. 20	×	—
Total	4	2

TABLE 1—*Continued*

Dates of irrigations for growing period—	Irrigation treatment[1]	
	Frequent	Intermediate
No. 6 (Feb. 25 to Apr. 24)		
Feb. 27	×	×
Mar. 12	×	—
Mar. 19	—	×
Mar. 25	×	—
Apr. 2	×	×
Apr. 20	×	—
Total	5	3
No. 7 (Apr. 25 to June 26)		
Apr. 28	×	×
May 16	×	—
May 18	—	×
May 28	×	—
June 2	—	×
June 4	×	—
June 11	×	—
June 15	—	×
June 18	×	—
June 24	×	—
Total	7	4

[1] Frequent, irrigated when the average soil-moisture suction in the active root-zone reached 0.7 atm.; intermediate, irrigated when the average soil-moisture suction in the active root-zone reached 2 atm.

the root-zone in each moisture treatment. Duplicate soil samples were taken with a soil auger at the following depths: 0 to 6, 6 to 12, 12 to 18, and 18 to 24 inches, in the Para grass plots. Additional samples from 24 to 30, and 30 to 36 inches deep were taken in the Guinea grass plots. The soil samples were taken twice a week, 1 day before and 2 days after each irrigation in the plots of one of the replications having Para grass and Guinea grass under each irrigation and nitrogen-fertilizer treatment.

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 in the Para grass plots and from the top 3 feet in the Guinea grass plots with each irrigation treatment was calculated for each growing period throughout a year. A total of six samples under each moisture treatment was used to calculate the water extracted during those short periods and throughout the whole year. The consumptive use of water was calculated by adding the effective[4] rainfall 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. Nearly every 60 days the plots were harvested and the harvest weighed to determine green-forage production. Samples were taken to determine the dry-matter percentage and the protein content.

EXPERIMENTAL RESULTS

An evaluation was made of the soil-moisture data and the effects of irrigation and nitrogen application on the yields of Para grass, Guinea grass, and their mixtures with tropical kudzu. The results thereof were as follows:

SOIL MOISTURE

An average soil-bulk density of 1.27 gm./cc. was determined for the 3-to-6 and 18-to-21 inch-deep samples taken.

The rainfall distribution by days and months throughout the whole growing season and the 17-year monthly average at Lajas Substation are shown in table 2. A close examination of the 17-year monthly averages shows that the highest occurred in the period of July to November. However, during the growing period of this experiment, the total rainfall for July, September, and October was under the 17-year monthly average. The total rainfall during January, April, and May was above average.

The consumptive use of water during short periods of time and throughout the year for both grasses under the intermediate and nonirrigated plots is presented in tables 3 to 6. As shown in these tables the highest average daily consumptive use occurred during the last month of each respective 2-month growing period. Table 7 and figure 1 present the consumptive use of water during approximately 2-month periods and throughout the whole year under each irrigation treatment. There is a seasonal variation in the consumptive use of water by Guinea grass and Para grass. A variation in consumptive use also is shown between the frequently irrigated, the intermediately irrigated, and the nonirrigated plots. A close examination of table 7 shows that the peak water-use rate by Guinea grass occurred during the growth period of April 25 to June 26, with an average of 0.219 and 0.209 inch per day for the frequently and intermediately irrigated plots, respectively.

[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 2.—*Inches of daily rainfall during the growth period of the forage-crop experiment at Lajas, P.R., 1959–60*

Date	1959										1960					
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1						0.05		0.15							0.11	0.02
2	0.01				0.43	.01		.04				0.06			.08	
3	.23		1.21								1.06	.24				.17
4		1.06	.14			.05					1.18			0.90	.03	.03
5		.27						.04	0.56	0.07				.63		
6		.56	.10			.27										.08
7		.01	1.51	0.12		.57		.01		.06		.09			.26	.12
8			.10			.04		.25		.05		.05				.01
9							0.43	.01	.42		.01	.01			.52	.03
10		.06			.18		.01	.20		.20						.19
11						.16	.02	.01	.57							.02
12	.06													2.28		
13			.04									.05		.11		
14					.54		.01		.23		.17				.11	
15							.65	.11	2.09	1.34		.02	0.64			
16		.17				1.07	.57	.01		.02		.10	.30	.11		.01
17		.08				.28	.10		1.39	.12	.07					.07
18		.02	.01			1.13	.01			.09	1.63		.05			.56
19			.03		.02	2.30				.08	.17		.11	.02	.35	
20		.13			.35		.15			.40				.13		.25
21			.54			.40	.07							.32		
22			.04		.65					.02					2.67	
23						.27		.22			.13					
24					.03				.29					.10		
25						.01					.04		.02	.19		
26		.55											.03			.05
27		.45							.65		.07					.16
28		.29					.27	.06	.01							.05
29		1.00	.28	.12			.23	.02	.05		.08					.25
30		.20	.03				.49		.03				.30	.04		.04
31			.06		.65			.49								
Total	0.30	4.85	4.09	0.24	2.85	6.61	3.01	1.62	6.29	2.45	4.61	0.62	1.45	4.83	4.13	2.11
17-year (average)	2.04	3.72	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

The lowest water rate used by Guinea grass was observed during the growth period of December 29 to February 24 with a daily average of 0.157 inch for the frequently irrigated and 0.134 inch for the intermediately irrigated plots. It can be observed that the peak water used by Para grass occurred during the growth period of June 29, to August 26, with

TABLE 3.—*Consumptive use of water by Guinea grass in the intermediately irrigated plots of the forage-crop experiment at Lajas, P.R., by growing periods, June 29, 1959 to June 26, 1960*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (June 29 to Aug. 26)			
June 29 to July 5[2]	7	0.784	0.112
July 6 to July 9	4	.126	.032
July 10 to July 19	10	1.123	.112
July 20 to July 27	8	1.167	.146
July 28 to Aug. 4	8	1.368	.171
Aug. 5 to Aug. 6[2]	2	.378	.189
Aug. 7 to Aug. 13	7	1.431	.204
Aug. 14 to Aug. 26	13	4.085	.314
Total	59	10.462	—
No. 3 (Aug. 27 to Oct. 27)			
Aug. 27 to Aug. 30	4	0.282	0.070
Aug. 31 to Sept. 3[2]	4	.400	.100
Sept. 4 to Sept. 17	14	2.262	.162
Sept. 18 to Sept. 29	12	1.939	.162
Sept. 30 to Oct. 2[2]	3	.642	.214
Oct. 3 to Oct. 8	6	1.465	.244
Oct. 9 to Oct. 18	10	2.054	.205
Oct. 19 to Oct. 20[2]	2	.422	.211
Oct. 21 to Oct. 27	7	1.577	.216
Total	62	10.977	—
No. 4 (Oct. 28 to Dec. 28)			
Oct. 28 to Nov. 1	5	0.575	0.115
Nov. 2 to Nov. 4	3	.363	.121
Nov. 5 to Nov. 12	8	1.066	.133
Nov. 13 to Nov. 17	5	1.898	.380
Nov. 18 to Nov. 26	9	1.450	.161
Nov. 27 to Dec. 15	19	2.133	.112
Dec. 16 to Dec. 28	13	2.625	2.020
Total	62	10.110	—
No. 5 (Dec. 29 to Feb. 24)			
Dec. 29 to Jan. 4[2]	7	1.050	.150
Jan. 5 to Jan. 14	10	1.434	.143
Jan. 15 to Jan. 28	14	1.846	.132
Jan. 29 to Feb. 7	10	1.526	.153
Feb. 8 to Feb. 9[2]	2	.268	.134
Feb. 10 to Feb. 24	15	1.637	.109
Total	58	7.761	—

TABLE 3—*Continued*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 6 (Feb. 25 to Apr. 24)			
Feb. 25 to Feb. 28[2]	4	0.504	0.126
Feb. 29 to Mar. 3	4	.516	.129
Mar. 4 to Mar. 17	14	1.850	.132
Mar. 18 to Mar. 20[2]	3	.411	.137
Mar. 21 to Mar. 31	11	1.537	.140
Apr. 1 to Apr. 3[2]	3	.540	.180
Apr. 4 to Apr. 18	15	3.458	.230
Apr. 19 to Apr. 24	6	.754	.126
Total	60	9.570	—
No. 7 (Apr. 25 to June 26)			
Apr. 25 to Apr. 29[2]	5	0.645	0.129
Apr. 30 to May 17	18	3.009	.167
May 18 to May 22[2]	5	1.040	.208
May 23 to June 1	10	2.337	.234
June 2 to June 3[2]	2	.422	.211
June 4 to June 14	11	2.054	.187
June 15 to June 16[2]	2	.512	.256
June 17 to June 26	10	3.163	.316
Total	63	13.182	—

[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] Consumptive-use data calculated by interpolation.

a daily average of 0.207 inch in the frequently irrigated and 0.198 inch in the intermediately irrigated plots. The lowest water-used rate for Para grass was exhibited during the growth period of December 29 to February 24 with an average of 0.127 and 0.110 inch per day for the frequently and intermediately irrigated plots, respectively.

EFFECTS OF IRRIGATION

Table 8 presents the irrigation effect on yields at different levels of fertilizer under different forage crops for seven harvests. As shown, irrigation increased forage yields in all harvests. The statistical analysis of the data shows that irrigation effect on forage yields was highly significant in all harvests, with the exception of No. 4 in which there was no significant irrigation effect on Guinea grass yields, and No. 5 where the irrigation effect was not significant on Para grass yields. There was no statistical difference in forage yields between the frequently and intermediately irrigated plots in all harvests made.

TABLE 4.—*Consumptive use of water by Guinea grass in the nonirrigated plots of the forage-crop experiment at Lajas, P.R., by growing periods, June 29, 1959 to June 26, 1960*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (June 29 to Aug. 26)			
June 29 to July 5[2]	7	0.224	0.032
July 6 to July 30	25	.794	.032
July 31 to Aug. 9	10	1.765	.176
Aug. 10 to Aug. 26	17	2.922	.172
Total	59	5.705	—
No. 3 (Aug. 27 to Oct. 27)			
Aug. 27 to Sept. 24	29	2.339	0.081
Sept. 25 to Oct. 27	33	3.939	.119
Total	62	6.278	—
No. 4 (Oct. 28 to Dec. 28)			
Oct. 28 to Nov. 12	16	1.027	0.064
Nov. 13 to Nov. 17	5	.288	.058
Nov. 18 to Nov. 26	9	.675	.075
Nov. 27 to Dec. 20	24	3.226	.134
Dec. 21 to Dec. 28	8	1.594	.199
Total	62	6.810	—
No. 5 (Dec. 29 to Feb. 24)			
Dec. 29 to Jan. 7	10	0.902	0.090
Jan. 8 to Jan. 28	21	3.090	.147
Jan. 29 to Feb. 11	14	.929	.066
Feb. 12 to Feb. 24	13	1.659	.128
Total	58	6.580	—
No. 6 (Feb. 25 to Apr. 24)			
Feb. 25 to Mar. 3	8	0.594	0.074
Mar. 4 to Mar. 10	7	.085	.012
Mar. 11 to Mar. 31	21	1.229	.058
Apr. 1 to Apr. 18	18	3.570	.198
Apr. 19 to Apr. 24	6	.543	.090
Total	60	6.021	—
No. 7 (Apr. 25 to June 26)			
Apr. 25 to May 22	28	1.587	0.057
May 23 to June 26	35	3.646	.104
Total	63	5.233	—

[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.

TABLE 5.—*Consumptive use of water by Para grass in the intermediately irrigated plots of the forage-crop experiment at Lajas, P.R., by growing periods, June 29, 1959 to June 26, 1960*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (June 29 to Aug. 26)			
June 29 to July 5[2]	7	0.840	0.120
July 6 to July 9	4	.666	.166
July 10 to July 19	10	1.365	.136
July 20 to July 27	8	1.174	.147
July 28 to Aug. 4	8	1.201	.150
Aug. 5 to Aug. 6[2]	2	0.442	.221
Aug. 7 to Aug. 13	7	2.001	.286
Aug. 14 to Aug. 26	13	4.024	.310
Total	59	11.713	—
No. 3 (Aug. 27 to Oct. 27)			
Aug. 27 to Aug. 30	4	0.335	0.084
Aug. 31 to Sept. 3[2]	4	.480	.120
Sept. 4 to Sept. 17	14	2.751	.196
Sept. 18 to Sept. 29	12	1.263	.105
Sept. 30 to Oct. 2[2]	3	.462	.154
Oct. 3 to Oct. 8	6	1.206	.201
Oct. 9 to Oct. 18	10	1.866	.187
Oct. 19 to Oct. 20[2]	2	.432	.216
Oct. 21 to Oct. 27	7	1.663	.238
Total	62	10.458	—
No. 4 (Oct. 28 to Dec. 28)			
Oct. 28 to Nov. 1	5	0.510	0.102
Nov. 2 to Nov. 4[2]	3	.390	.130
Nov. 5 to Nov. 12	8	1.340	.168
Nov. 13 to Nov. 17	5	1.580	.316
Nov. 18 to Nov. 26	9	1.381	.153
Nov. 27 to Dec. 15	19	1.843	.097
Dec. 16 to Dec. 28	13	1.775	.136
Total	62	8.819	—
No. 5 (Dec. 29 to Feb. 24)			
Dec. 29 to Jan. 4[2]	7	0.742	0.106
Jan. 5 to Jan. 14	10	1.206	.121
Jan. 15 to Jan. 28	14	1.989	.142
Jan. 29 to Feb. 7	10	.668	.067
Feb. 8 to Feb. 9[2]	2	.170	.085
Feb. 10 to Feb. 24	15	1.598	.106
Total	58	6.373	—

TABLE 5—*Continued*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 6 (Feb. 25 to Apr. 24)			
Feb. 25 to Feb. 28[2]	4	0.488	0.122
Feb. 29 to Mar. 3	4	.464	.116
Mar. 4 to Mar. 17	14	1.422	.102
Mar. 18 to Mar. 20[2]	3	.357	.119
Mar. 21 to Mar. 31	11	1.459	.133
Apr. 1 to Apr. 3[2]	3	.558	.186
Apr. 4 to Apr. 18	15	3.859	.257
Apr. 19 to Apr. 24	6	.551	.092
Total	60	9.158	—
No. 7 (Apr. 25 to June 26)			
Apr. 25 to Apr. 29[2]	5	0.730	0.146
Apr. 30 to May 17	18	2.942	.163
May 18 to May 22[2]	5	.900	.180
May 23 to June 1	10	1.898	.190
June 2 to June 3[2]	2	.358	.179
June 4 to June 14	11	1.818	.165
June 15 to June 16[2]	2	.384	.192
June 17 to June 26	10	2.160	.216
Total	63	11.190	—

[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] Consumptive-use data calculated by interpolation.

Table 9 presents the total annual yields of the different forage crops under different irrigation and fertilizer treatments. This table and the combined statistical analysis of the data also show that irrigation increased forage yields in a significant way, but the difference in yields between the frequently and intermediately irrigated plots was not significant. The average increase in yields produced by irrigation was 1,688, 804, 141, 597, 2,201, and 3,360 pounds of dry matter per acre for the growth periods of July to August, September to October, November to December, January to February, March to April, and May to June, respectively, as derived from table 8. The average increase in total annual yields from irrigation was 8,804 pounds of dry matter per acre.

EFFECTS OF NITROGEN FERTILIZATION

In all harvests nitrogen fertilization increased forage yields in a highly significant way. As shown in table 8 the plots receiving 400 pounds of

TABLE 6.—*Consumptive use of water by Para grass in the nonirrigated plots of the forage-crop experiment at Lajas, P.R., by growing periods, June 29, 1959 to June 26, 1960*

Growing period[1]	Consumptive-use interval	Total consumptive use	Average daily consumptive use
	Days	*In.*	*In.*
No. 2 (June 29 to Aug. 26)			
June 29 to July 5[2]	7	0.322	0.046
July 6 to July 30	25	1.144	.046
July 31 to Aug. 9	10	1.552	.155
Aug. 10 to Aug. 26	17	2.953	.174
Total	59	5.971	—
No. 3 (Aug. 27 to Oct. 27)			
Aug. 27 to Sept. 24	29	2.552	0.088
Sept. 25 to Oct. 27	33	3.278	.099
Total	62	5.830	—
No. 4 (Oct. 28 to Dec. 28)			
Oct. 28 to Nov. 12	16	1.285	0.080
Nov. 13 to Nov. 17	5	.600	.120
Nov. 18 to Nov. 26	9	1.160	.129
Nov. 27 to Dec. 20	24	2.770	.115
Dec. 21 to Dec. 28	8	1.434	.179
Total	62	7.249	—
No. 5 (Dec. 29 to Feb. 24)			
Dec. 29 to Jan. 7	10	1.617	0.162
Jan. 8 to Jan. 28	21	1.903	.091
Jan. 29 to Feb. 11	14	.944	.067
Feb. 12 to Feb. 24	13	1.911	.147
Total	58	6.375	—
No. 6 (Feb. 25 to Apr. 24)			
Feb. 25 to Mar. 3	8	0.722	0.090
Mar. 4 to Mar. 10	7	.106	.015
Mar. 11 to Mar. 31	21	1.389	.066
Apr. 1 to Apr. 18	18	2.803	.156
Apr. 19 to Apr. 24	6	.543	.090
Total	60	5.563	—
No. 7 (Apr. 25 to June 26)			
Apr. 25 to May 22	28	1.876	0.067
May 23 to June 26	35	3.989	.114
Total	63	5.865	—

[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.

nitrogen per acre per year outyielded the unfertilized plots, the former having been outyielded by those receiving 800 pounds of nitrogen per acre per year. During the first growing period the plots receiving no nitrogen and those receiving 400 pounds of nitrogen per acre per year were fertilized at the rate of 400 per acre per year to establish the crop. Table 8 also shows that the increase in yields of the 400 pounds of nitrogen over the no-nitrogen treatments was greater than the 800 over the treatment with 400 pounds of nitrogen.

The combined analysis of seven harvests shows a highly significant interaction between irrigation and nitrogen fertilization on yields. However, this interaction was not significant for harvests Nos. 1, 3, and 4. As derived

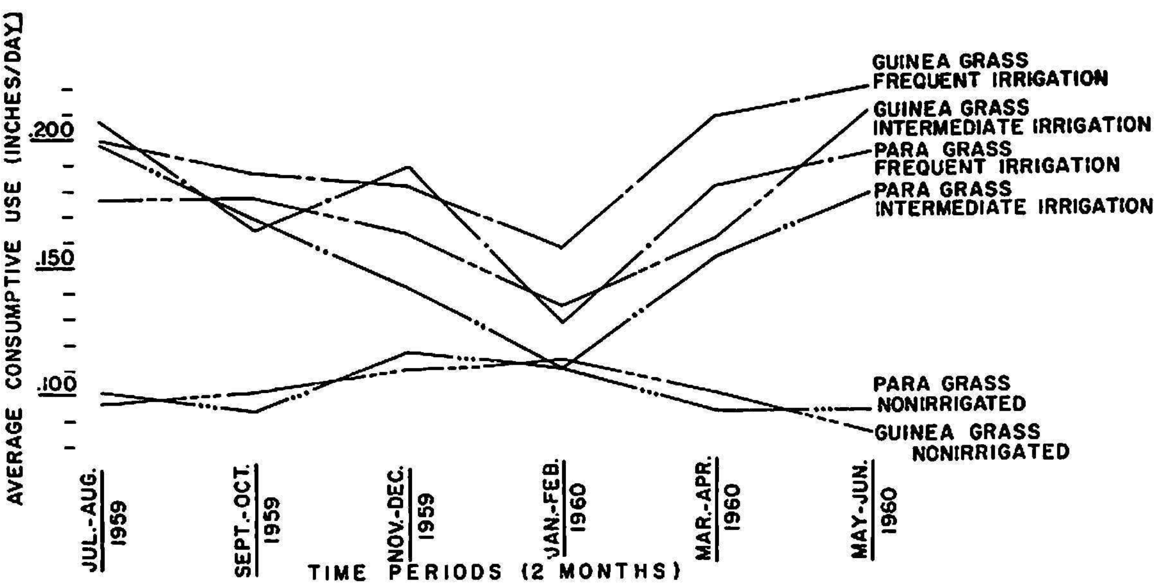

FIG. 1.—Yearly fluctuation in consumptive use of water by Guinea grass and Para grass under different irrigation treatments.

from table 9, there was an average increase of 10,864 pounds of dry matter per acre yearly for the irrigated Guinea grass plots when fertilized at the rate of 400 pounds of nitrogen per acre per year, while in the unfertilized plots under the same irrigation treatment the increase in yields was 3,406 pounds.

FORAGE EFFECTS

There was a significant difference in forage production between Guinea grass, Para grass and their respective mixtures with kudzu. Tropical kudzu had a good growth during the first growing period, *i.e.*, until harvest No. 1 (see fig. 2), but in subsequent harvests it was practically eliminated. Guinea grass outyielded Para grass in the first harvest where the growing period was of 112 days. However, Para grass outyielded Guinea grass in a highly significant way in the combined analysis of the last 6 harvests.

TABLE 7.—*Consumptive use of water by forage crops, by 2-month growing periods, in the forage-crop experiment at Lajas, P.R., 1960*

Growing period[1]	Consumptive use (in inches) under indicated irrigation treatment by forage—												Average daily consumptive use (in inches)[2]
	Guinea grass						Para grass						
	Frequently irrigated		Intermediately irrigated		Nonirrigated		Frequently irrigated		Intermediately irrigated		Nonirrigated		
	Total	Daily average	Total	Daily average	Total	Daily average	Total	Daily average	Total	Daily average	Total	Daily average	
No. 2 (June 29 to Aug. 26)	11.792	0.200	10.462	0.177	5.705	0.097	12.211	0.207	11.713	0.198	5.971	0.101	0.196
No. 3 (Aug. 27 to Oct. 27)	11.591	.187	10.977	.177	6.278	.101	10.161	.164	10.458	.169	5.830	.094	.174
No. 4 (Oct. 28 to Dec. 28)	11.259	.182	10.110	.163	6.810	.110	11.714	.189	8.819	.142	7.249	.117	.169
No. 5 (Dec. 29 to Feb. 24)	9.089	.157	7.761	.134	6.580	.113	7.354	.127	6.373	.110	6.375	.110	.132
No. 6 (Feb. 25 to Apr. 24)	12.466	.208	9.570	.160	6.021	.100	10.827	.180	9.158	.153	5.563	.093	.175
No. 7 (Apr. 25 to June 26)	13.789	.219	13.182	.209	5.233	.084	12.136	.193	11.190	.178	5.865	.093	.200
Total	69.986		62.062		36.627		64.403		57.711		36.853		
Average per day	.192		.170		.101		.177		.158		.101		

[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-plot data were not included in this average.

TABLE 8.—*Effect of irrigation and nitrogen fertilization on the yield (pounds of dry matter per acre) of forage harvested at different periods over a 1-year period, at Lajas, P.R., 1959–60*

Harvest and irrigation treatment[1]	Effect of indicated pounds of nitrogen applied per acre per year to forage[2]												Mean
	Guinea grass			Para grass			Guinea-kudzu			Para-kudzu			
	0	400	800	0	400	800	0	400	800	0	400	800	
Harvest No. 1[3] (June 29–30, 1959)													
Frequent irrigation	13,646	13,746	13,847	6,789	6,184	6,588	8,503	8,705	10,049	4,806	4,806	5,680	8,612
Intermediate irrigation	13,982	13,276	13,410	5,949	6,487	7,529	9,142	8,974	10,016	4,604	4,436	4,638	8,537
No irrigation	9,881	9,579	11,528	6,218	5,411	6,991	6,554	6,151	8,470	3,462	3,058	3,932	6,770
Mean	12,503	12,200	12,928	6,318	6,027	7,036	8,066	7,943	9,511	4,282	4,100	4,750	7,973
Harvest No. 2 (Aug. 27–28, 1959)													
Frequent irrigation	3,294	5,915	6,453	4,235	6,184	7,260	3,294	5,344	5,042	3,697	5,277	6,251	5,187
Intermediate Irrigation	3,899	6,184	7,260	4,336	5,848	7,159	3,193	5,310	4,806	3,126	5,478	5,781	5,198
No irrigation	3,260	3,596	5,008	3,294	3,966	4,638	3,126	2,790	3,193	2,521	3,294	3,361	3,504
Mean	3,484	5,232	6,240	3,955	5,333	6,352	3,204	4,481	4,347	3,115	4,683	5,131	4,630
Harvest No. 3 (Oct. 28–29, 1959)													
Frequent irrigation	4,450	5,162	6,493	4,575	6,749	7,701	3,708	4,712	5,035	4,430	6,614	6,729	5,530
Intermediate irrigation	4,837	5,906	6,269	4,830	6,742	8,564	4,094	4,911	5,140	3,849	6,827	7,129	5,758
No irrigation	4,229	5,149	5,835	3,883	5,835	7,112	3,883	3,768	5,261	3,751	4,474	4,907	4,840
Mean	4,505	5,406	6,199	4,429	6,442	7,792	3,895	4,464	5,145	4,010	5,972	6,255	5,376
Harvest No. 4 (Dec. 29–30, 1959)													
Frequent irrigation	2,454	4,477	4,564	3,717	6,249	6,950	2,097	3,264	3,838	3,489	5,677	6,749	4,460
Intermediate irrigation	2,548	4,481	5,469	3,663	5,711	6,534	2,323	3,788	3,852	2,843	5,747	6,211	4,431
No irrigation	2,514	4,911	5,812	2,991	5,452	5,966	2,700	3,903	3,795	3,015	5,317	5,281	4,305
Mean	2,505	4,623	5,282	3,457	5,804	6,483	2,373	3,652	3,828	3,116	5,580	6,080	4,399

Harvest No. 5 (Feb. 25–26, 1960)													
Frequent irrigation	1,801	4,349	4,531	3,401	6,157	6,860	1,637	3,439	3,764	3,818	6,531	7,072	4,447
Intermediate irrigation	1,949	4,432	5,015	3,103	5,694	7,320	1,926	3,325	4,548	2,222	6,003	7,421	4,413
No irrigation	1,691	3,278	4,040	3,251	5,828	6,890	1,718	2,841	2,780	2,433	5,498	5,751	3,833
Mean	1,814	4,020	4,529	3,252	5,893	7,023	1,760	3,202	3,697	2,824	6,011	6,748	4,231
Harvest No. 6 (Apr. 25–26, 1960)													
Frequent irrigation	2,155	5,478	6,762	2,330	6,641	7,277	1,922	4,531	5,113	2,942	5,704	7,885	4,895
Intermediate Irrigation	2,427	5,610	7,217	2,944	5,677	8,044	2,454	5,653	6,276	1,889	6,733	7,360	5,190
No irrigation	1,398	2,769	3,862	1,409	3,661	4,786	1,261	2,256	2,810	1,600	3,428	4,853	2,841
Mean	1,993	4,619	5,945	2,228	5,326	6,702	1,879	4,147	4,733	2,144	5,288	6,699	4,309
Harvest No. 7 (June 27–28, 1960)													
Frequent irrigation	3,381	7,082	7,936	3,331	8,167	9,592	3,405	6,390	7,365	2,857	7,428	9,227	6,347
Intermediate Irrigation	3,116	7,125	7,966	3,123	6,769	10,022	3,226	6,605	6,484	2,245	7,468	9,247	6,116
No irrigation	1,580	2,538	4,367	1,573	3,226	5,227	1,624	2,413	3,092	2,007	3,163	3,650	2,872
Mean	2,692	5,582	6,756	2,676	6,054	8,280	2,752	5,136	5,647	2,370	6,020	7,375	5,112

[1] Irrigation applied to the plots with the nonirrigation treatment to establish the crop—first harvest only.
[2] Fertilizer applied to the plots with the no-fertilization treatment to establish the crop—first harvest only.
[3] First harvest after planting (Mar. 9, 1959). Subsequent harvests occurred every 2 months, approximately.

TABLE 9.—*Effect of irrigation and nitrogen fertilization on the total yield (pounds of dry matter per acre) of forage over a 1-year period at Lajas, P.R., 1959-60*[1]

Irrigation treatment	Effects of indicated pounds of nitrogen applied per acre per year in forage—												Mean
	Guinea grass			Para grass			Guinea-kudzu			Para-kudzu			
	0	400	800	0	400	800	0	400	800	0	400	800	
Frequent	17,530	32,458	36,722	21,557	40,122	45,622	15,992	27,678	30,159	21,235	37,233	43,878	30,849
Intermediate	18,778	33,701	39,209	22,364	36,440	47,652	17,232	29,567	31,049	16,133	38,248	43,175	31,129
No irrigation	14,748	22,216	28,909	16,359	27,957	34,629	14,268	17,952	20,903	15,346	25,178	27,752	22,185
Mean	17,019	29,458	34,946	20,093	34,840	42,634	15,830	25,066	27,369	17,571	33,554	38,268	28,054

[1] The yields of the first harvest were not included in this table because all plots were irrigated and fertilized to establish the crop.

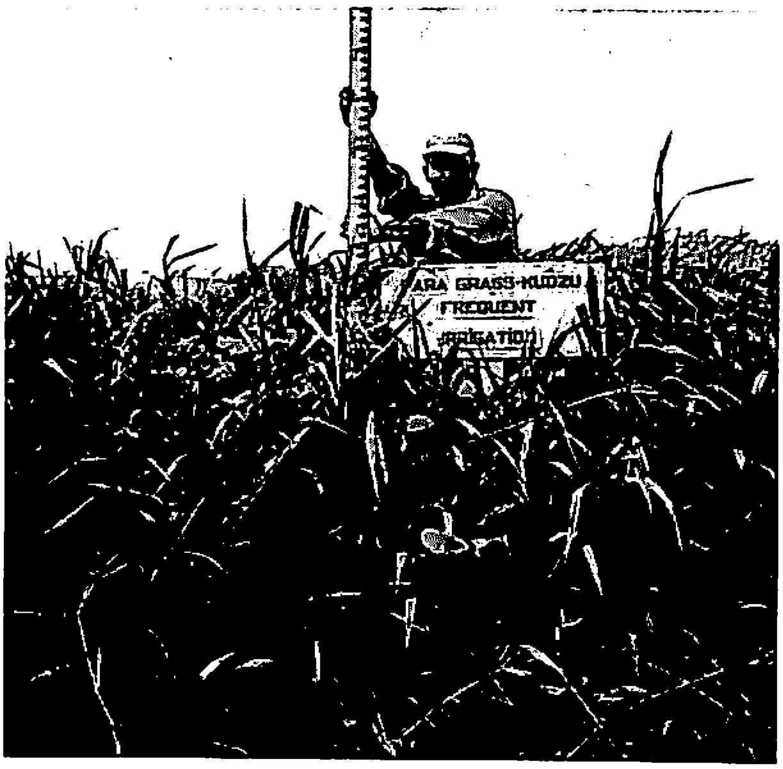

FIG. 2.—Para grass-kudzu mixture grown under frequent irrigation during the first growing period at Lajas.

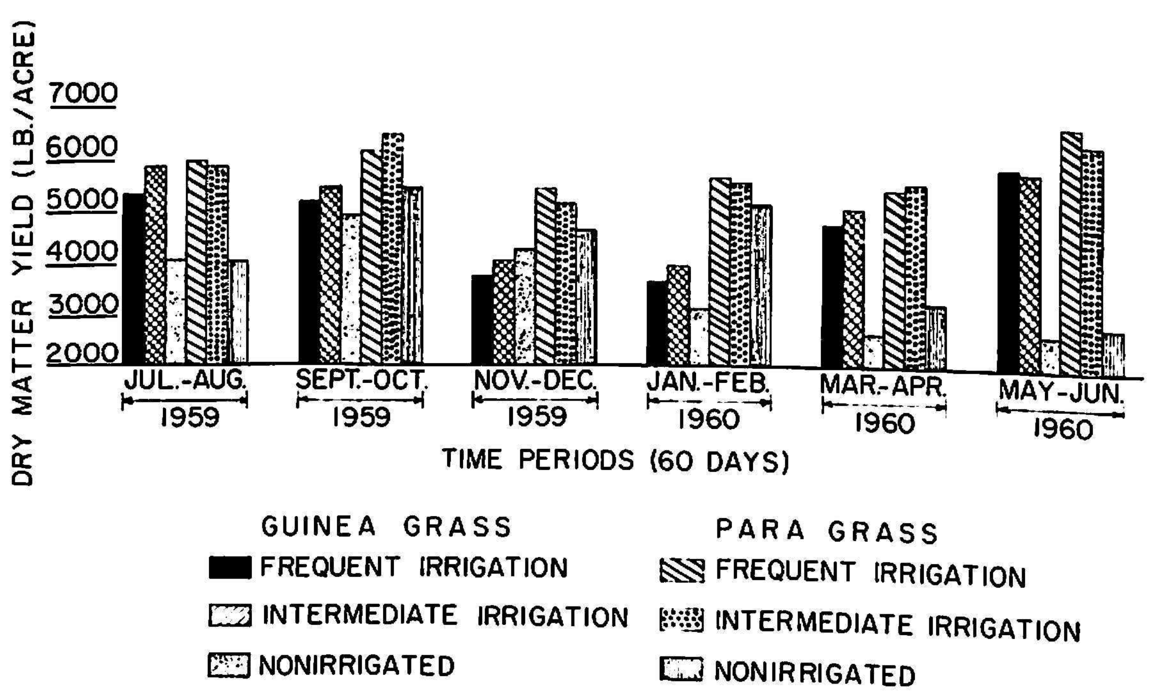

FIG. 3.—Yearly fluctuation in dry-matter yields of Guinea grass and Para grass under different irrigation treatments.

As can be observed in table 8 and figure 3 there is a seasonal effect on forage yields. In general, the highest yields occurred during the period from May to June on the irrigated plots. The lowest yields on the irrigated Para grass plots occurred during the period from November to December. In the irrigated Guinea grass plots the lowest yields occurred during the period from January to February. On the nonirrigated plots the highest yields were observed during the period from September to October for Guinea grass and January to February for Para grass. Para grass outyielded Guinea grass by 1,742 pounds of dry matter per acre during the period from January to February.

The difference in production between these grasses decreased during spring and summer, the least difference being 336 pounds of dry matter per acre by which Para grass outyielded Guinea grass during the period of July to August (derived from table 8). Each grass outyielded its mixture with kudzu except Para grass in the last four harvests. This can be explained by the fact that Para grass extended rapidly, covering the whole plot once the kudzu was eliminated.

TABLE 10—*Average protein content (percent) of forage at different irrigation and nitrogen levels in experiment at Lajas, P.R., 1959-60*

Irrigation treatment	Effects of indicated pounds of nitrogen applied per acre per year on the protein content of—												Mean
	Guinea grass			Para grass			Guinea-kudzu			Para-kudzu			
	0	400	800	0	400	800	0	400	800	0	400	800	
Frequent	4.66	5.53	6.62	3.82	6.66	7.90	5.22	5.94	6.97	5.25	6.38	8.06	6.08
Intermediate	4.94	5.62	6.94	4.25	6.78	7.88	4.82	5.82	7.56	4.94	5.44	8.28	6.10
No irrigation	5.22	7.02	9.68	5.97	7.50	9.47	6.04	7.16	8.16	7.32	8.66	10.25	7.70
Mean	4.94	6.06	7.75	4.68	6.98	8.42	5.36	6.31	7.56	5.84	6.83	8.86	—

The protein content of the forage at different irrigation and nitrogen levels is presented in table 10. As can be observed in this table nitrogen fertilizer increased the protein content of the forage while irrigation decreased it.

DISCUSSION

The data clearly show that there is a seasonal effect on the consumptive use of water and forage yields of Guinea grass and Para grass. The highest water use and yields were observed during the spring and summer, the lowest occurring during the winter (see figure 3). Table 7 shows an average daily water use of 0.189 inch during the growth period of October 28 to December 28 in the frequently irrigated plots of Para grass, which is too high as compared with the consumptive-use values for the period in the other irrigation treatments. This was probably caused by sampling error. As can be observed in figure 1, the water used in the nonirrigated plots was highest during the winter, *i.e.*, during the period of November to December and January to February. This occurred because of the heavy rainfall during November and January (see table 2). The water used during the first growing period was not calculated because it took a long time to establish the crop, all plots having been irrigated with the same frequency for that time.

During the period from November to December the nonirrigated Guinea grass plots outyielded the irrigated ones, although the difference was not statistically significant (see fig. 3 and table 8). However, the frequently irrigated Para grass plots outyielded the nonirrigated ones, the difference being significant at the 5-percent level. For the growth period of January to February there was no significant difference in yields between the irrigated and nonirrigated Para grass plots, but the intermediately irrigated Guinea grass outyielded the nonirrigated plots at the 5-percent level of significance. In all harvests there was no significant difference in production between the frequently and the intermediately irrigated plots under each respective grass. In general we can conclude that the representative yearly consumptive use of Guinea grass would be that of the intermediately irrigated plots, except for the growth period of November to December when the water used in the nonirrigated plots is representative. For Para grass the consumptive use in the intermediately irrigated plots is the representative one also, but the period of January to February is represented by the nonirrigated plots.

Table 8 shows that nitrogen increased yields in a significant way, the increase in yields due to the application of 400 pounds of nitrogen treatment as compared with the nonfertilized plots, being higher than the 800-pound nitrogen treatment over the 400-pound. The interaction between nitrogen fertilizer and irrigation was highly significant, except in harvests Nos. 1, 3, and 4. In other words, although nitrogen and irrigation alone increased forage yields, the highest yields were observed when the crop was irrigated in the presence of nitrogen fertilizer. Similar results were found by the author (*6*) working with corn in the same area. In harvest No. 1 the irrigation and nitrogen interaction was not significant, probably because all plots were fertilized with nitrogen, there being only two treatments *i.e.*, 400 and 800 pounds of nitrogen per acre per year, and the difference between these was not too high, as shown in the other harvests (see table 8). In harvests Nos. 3 and 4 the rainfall masked the irrigation effects. As derived from table 9, an extra 400 pounds of nitrogen per acre per year increased Guinea grass dry-matter yields by 4,886 pounds yearly, while the increase in yields of Para grass was 8,356 pounds. This evidently shows that Para grass makes better use of nitrogen fertilizer.

Nitrogen application increased the protein content of the forage while irrigation decreased it. That means that, under irrigation, forage crops must be fertilized with nitrogen to maintain their quality.

Finally, we can conclude that both irrigation and nitrogen application are necessary to obtain high productions of good-quality forage under Lajas Valley conditions. Frequent applications of irrigation water are not necessary to obtain maxium yields. Further research is needed especially on soil-moisture treatments within the range of 2 to 15 atm. of suction, and of grass-legume mixtures under grazing conditions.

SUMMARY

A field experiment was conducted at Lajas Substation in order to study the effects of three irrigation and three nitrogen levels on dry-matter yields of Para grass, Guinea grass, and the mixtures of these grasses with tropical kudzu. Some plots were frequently irrigated when the average soil-moisture suction in the active root-zone reached 0.7 atm. and intermediately irrigated when the average soil-moisture suction in the active root-zone reached 2.0 atm. Nonirrigated plots were used as a check. The nitrogen levels tested were 0, 400, and 800 pounds of nitrogen per acre per year.

In general the data show that:

1. There was a response to irrigation throughout the whole year, with the exception of the growing period from November to December when Guinea grass was not affected by irrigation, and from January to February when Para grass did not respond. The average increase in total annual yields from irrigation was 8,804 pounds of dry matter per acre.

2. There was no significant difference in production between the frequently and the intermediately irrigated plots.

3. The representative consumptive use of water in inches by Guinea grass was as follows: 10.462 during the period from June 29 to August 26, 10.977 from August 27 to October 27, 6.810 from October 28 to December 28, 7.761 from December 29 to February 24, 9.570 from February 25 to April 24, and 13.182 from April 25 to June 26, with a total of 58.762 inches in 364 days. For Para grass the consumptive use of water was 11.713, 10.458, 8.819, 6.375, 9.158, and 11.190 inches for the growth periods from June 29 to August 26, August 27 to October 27, October 28 to December 28, December 29 to February 24, February 25 to April 24, and April 25 to June 26, respectively. The total water used in 364 days was of 57.713 inches.

4. Nitrogen fertilization increased forage yields in a highly significant way. The increase in yields from using 400 pounds of nitrogen per acre per year over the no-nitrogen treatment was greater than that from 800 pounds of nitrogen as compared with 400 pounds.

5. There was a highly significant interaction between nitrogen fertilizer and irrigation, with the exception of harvests Nos. 1, 3, and 4.

6. Para grass outyielded Guinea grass in a highly significant way in the last six crops, the greatest difference being observed during the winter months.

7. There was a seasonal effect on forage yields, the highest yields being observed from May to June, and the lowest from November to January.

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

9. Tropical kudzu grows fairly well in this area under irrigation, but it does not resist cutting well.

RESUMEN

En la Subestación de Lajas se llevó a cabo un experimento de campo para estudiar el efecto de tres distintos niveles de riego y tres de nitrógeno sobre la producción de materia seca de las yerbas Guinea y malojillo, y las mezclas de éstas con Kudzú tropical. Se regaron con frecuencia algunas parcelas cuando su promedio de succión (tensión) en el área en torno a las raíces alcanzó 0.7 de atmósfera, y se regaron con frecuencia intermedia cuando alcanzaron 2.0 atmósferas. Sirvieron de testigos las parcelas sin riego. Los niveles de nitrógeno fueron 400 y 800 libras por acre por año. Como testigos, se usaron parcelas sin aplicárseles nitrógeno.

En términos generales, los datos obtenidos demostraron lo siguiente:

1. La aplicación de riego aumentó la producción de forraje durante todo el año, excepto en el caso de la yerba Guinea en los meses de noviembre a diciembre y en el del malojillo, de enero a febrero, en que el efecto no fue significativo.

El aumento promedio en la producción de materia seca total durante el año fue 8,804 libras por acre.

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

3. La yerba Guinea requirió las siguientes cantidades de agua: 10.462 pulgadas en el período de junio 29 a agosto 26; 10.977 de agosto 27 a octubre 27; 6.810 de octubre 28 a diciembre 28; 7.761 de diciembre 29 a febrero 24; 9.750 de febrero 25 a abril 24; y 13.182 de abril 25 a junio 26, o sea, un total de 58.762 pulgadas durante 364 días. La yerba malojillo requirió 11.713, 10.458, 8.819, 6.375, 9.158 y 11.190 pulgadas durante los períodos de crecimiento de junio 29 a agosto 26, agosto 27 a octubre 27, octubre 28 a diciembre 28, diciembre 29 a febrero 24, ferbrero 25 a abril 24 y abril 25 a junio 26, respectivamente. El total de agua usada fue 57.713 pulgadas durante 364 días.

4. El nitrógeno produjo un aumento de materia seca, altamente significativo. El aumento en la producción de las parcelas que recibieron 400 libras de nitrógeno por acre, por año, sobre las que no recibieron nitrógeno fue mayor que el de las parcelas que recibieron 800 libras de nitrógeno al compararse con el aumento de las que sólo recibieron 400 libras.

5. Hubo una interacción altamente significativa entre la aplicación de

nitrógeno y riego, salvo en el caso de las cosechas número uno, tres y cuatro (cuadro 8).

6. La producción de la yerba malojillo excedió significativamente la de la yerba Guinea durante las últimas seis cosechas, particularmente durante los meses de invierno.

7. La estación del año también afectó la producción de forraje. Los rendimientos más altos fueron de mayo a junio y los más bajos de noviembre a enero.

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

9. El Kudzú tropical se desarrolló bastante bien bajo riego en esta zona, pero no se prestó para el corte.

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