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RESPONSE OF FOUR SUGARCANE VARIETIES TO FERTILIZERS DURING THE FIRST ISABELA CYCLE, 1946–51

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INTRODUCTION

Fertilizer imports into Puerto Rico rose from 43,260 tons, in 1922–23, to 247,995, in 1951–52. Over five times as much fertilizer material is now being applied to crops in the field, especially to sugarcane, as was 30 years ago. About 70 percent of this imported fertilizer is used for sugarcane, which clearly indicates the importance placed by the growers on fertilizing this crop.

OBJECTIVES

The experiment described herein was designed to test the effect of various levels of nitrogen, phosphorus, and potassium on leading cane varieties in the Isabela section. The soil chosen was the Coto clay at Isabela which represents a cane-growing area situated between the high rainfall and the irrigated regions. Cane usually makes better growth here when irrigated. In many aspects this may be treated as a humid cane-growing section; however, it possesses certain characteristics of the irrigated cane areas. It was thought, therefore, that a study of it would be of value not only to the farmers living there, but to others interested in cane growing under similar environmental conditions.

This paper reports on the first cycle of a plant cane and three ratoons of the Isabela experiment on Coto clay.

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The Area and Site

The Isabela area is located on the northwestern corner of the coast of Puerto Rico. The site of the experiment was approximately 275 feet above sea level and about 3 to 4 miles from the town of Isabella on the road to Aguadilla. The soil here is mainly a Coto clay which occurs in a nearly level area. The parent material from which the soil was derived belongs to the limestone of the Tertiary formation.

The land is devoted mainly to sugarcane and it is seldom profitable to grow more than two ratoons on this soil. Other crops, if irrigated, such as pineapple, peppers, tomatoes, tobacco, cotton, and corn, return a good profit. Tobacco and minor crops are the principal ones grown without irrigation. The land is owned mainly by farmers with small acreages. The sugarcane grown here is mainly ground at Central Coloso, located in the outskirts of Aguadilla and a few miles from Isabela.

The site selected for sampling was located on No. 2 road (North Coast), Km. 122.6, to Km. 122.7, with a slope of about 5 percent. The vegetative cover was mainly carpet grass and St. Augustine grass along the roadbank.

Soil Horizons

(1) 0 to 8 inches: Medium brown. Medium-sized fragmental to rounded structural aggregates; clay texture. Roots mostly confined to the surface 8 inches, and denser at the immediate surface.

(2) 8 to 18 inches: Well-defined fragments tending to cubical or nutlike shape. Transitional to next horizon.

(3) 18 to 26 inches: Gradual color change from brown to light yellow. Softer and lighter in color with depth. Very few roots. Nutlike tendency with some fragmental units. Highly variable structure. High visible porosity. Structure very weak.

(4) 26 to 42 inches: Light yellow. High visible porosity. Low volume-weight apparent. Poorly defined nutlike and fragmental structure. Permeability probably high through visible pores rather than through structural cleavage. Very few roots. Four-inch transition to next horizon.

(5) 46 to 60 inches[2]: Bright brown with khaki mottling. Fine fragments with considerable horizontal overlap. Very definite colloidal film over all cleavage faces giving a glazed appearance. Soil somewhat resistant, then quickly and completely collapses to fine, glazed fragments.

[2] This horizon was not seen at any other location and is, therefore, considered unusual. The soft, light-weight layer described from 26 to 42 inches is apparently more typical of what usually overlies the limestone parent rock. Limestone rock occurs at variable depths in this soil, from near the surface to 15 feet or more below. The stone is light-colored, cavernous, variable in hardness, and of Tertiary age.

TABLE 1.—*Fertilizer treatments used in this experiment and rates of application per acre*

Treatment No.	N	P_2O_5	K_2O
	Pounds	*Pounds*	*Pounds*
1	0	300	300
2	125	300	300
3	250	0	300
4	250	150	300
5	250	300	0
6	250	300	150
7	250	300	300

PROCEDURES

A sugarcane-fertilizer experiment was initiated on October 21, 1946, at the Isabela Substation of the Agricultural Experiment Station. The experiment consisted of growing four sugarcane varieties, P.R. 905, P.R. 902, P.O.J. 2878, and M. 28, at seven different levels of nitrogen, phosphorus, and potassium used to fertilize a Coto clay soil.

A split-plot experimental design was used, one in which varieties were considered as the whole-plot effect and the various levels of the fertilizer were regarded as the sub-split-plot effect. The plots were 32 feet long, 20 feet wide, or 640 square feet. In other words, each plot of the four varieties tested was subdivided into seven parts to which different levels of fertilizer were applied as shown in table 1. There were five cane furrows per plot. The actual field design of the experiment is shown in figure 1. The analysis of variance was calculated as described by Cochran and Cox (2)[3].

The crop was planted September 18–20, 1944, using 32 three-eye seed pieces to the furrow, or approximately 10,325 to the acre. The harvesting dates and age of the cane at harvest are shown in table 2. Table 3 gives the pH and organic-matter content of the Coto clay used, and table 4 the rainfall data for Isabela, 1946–51.

The fertilizer for each treatment was compounded from ammonium sulfate (20-percent N), superphosphate (20-percent P_2O_5), and potassium chloride (60-percent K_2O). The mixed fertilizer for each plot was applied by hand at the base of the stools for the plant and the successive ratoon crops.

Only one fertilizer application was made for each crop, as soon after cutting the ratoon as conditions would permit.

The cane was cut as in commercial practice. The cane from each plot

[3] Numbers in parentheses refer to Literature Cited p. 95.

A 3	D 1	C 2	B 7
A 6	D 5	C 3	B 1
A 4	D 7	C 5	B 4
A 7	D 3	C 1	B 5
A 5	D 2	C 7	B 6
A 1	D 4	C 6	B 2
A 2	D 6	C 4	B 3

Block 1

D 6	A 3	B 4	C 7
D 2	A 4	B 7	C 1
D 3	A 1	B 2	C 4
D 4	A 6	B 3	C 5
D 1	A 2	B 5	C 6
D 5	A 7	B 1	C 3
D 7	A 5	B 6	C 2

Block 4

B 5	D 6	C 2	A 3
B 6	D 7	C 5	A 1
B 1	D 2	C 6	A 4
B 7	D 4	C 3	A 5
B 3	D 1	C 7	A 2
B 2	D 5	C 4	A 6
B 4	D 3	C 1	A 7

Block 7

B 3	A 2	D 3	C 1
B 7	A 1	D 4	C 3
B 1	A 3	D 6	C 7
B 2	A 5	D 7	C 6
B 6	A 4	D 1	C 5
B 4	A 7	D 5	C 2
B 5	A 6	D 2	C 4

Block 2

A 5	C 4	D 6	B 3
A 2	C 6	D 5	B 7
A 4	C 2	D 3	B 4
A 1	C 3	D 4	B 1
A 3	C 7	D 2	B 6
A 6	C 1	D 7	B 2
A 7	C 5	D 1	B 5

Block 5

D 1	C 7	A 4	B 5
D 4	C 2	A 1	B 3
D 3	C 5	A 7	B 6
D 2	C 6	A 5	B 1
D 5	C 4	A 3	B 2
D 7	C 1	A 2	B 4
D 6	C 3	A 6	B 7

Block 8

D 2	C 3	B 4	A 2
D 1	C 7	B 6	A 4
D 6	C 2	B 1	A 7
D 7	C 4	B 3	A 6
D 5	C 1	B 2	A 5
D 3	C 6	B 5	A 1
D 4	C 5	B 7	A 3

Block 3

B 1	D 2	C 6	A 4
B 2	D 5	C 3	A 7
B 4	D 3	C 2	A 6
B 5	D 1	C 4	A 5
B 7	D 6	C 1	A 3
B 3	D 7	C 5	A 1
B 6	D 4	C 7	A 2

Block 6

C 7	B 6	D 2	A 5
C 2	B 3	D 4	A 2
C 1	B 4	D 3	A 6
C 4	B 7	D 5	A 3
C 5	B 2	D 6	A 1
C 6	B 5	D 1	A 7
C 3	B 1	D 7	A 4

Block 9

FIG. 1.—Field design of the experiment.

was weighed separately in the field using a portable crane and weighing baskets. Ten whole stalks of cane, minus the tops, were taken at random from different stools in each plot at the time of cutting. These canes were tagged as to origin and brought to the hydraulic mill at the Agricul-

TABLE 2.—*Harvesting dates and age of the sugarcane when harvested during this experiment*

Crop	Harvesting date	Age of cane (months)
Plant cane	Feb. 9–14, 1948	15½
First ratoon	9–15, 1949	12
Second ratoon	13–18, 1950	12
Third ratoon	12–16, 1951	12

TABLE 3.—*The pH and organic-matter content of a Coto clay profile such as was used for this experiment*

Sample depth (inches)	pH	Organic matter (percent)
0–4	7.0[1]	4.74
4–8	5.4	3.82
8–16	5.0	2.79
18–26	5.4	1.33
26–42	5.3	1.04
46–60	5.3	.52

[1] Limed.

TABLE 4.—*Record of rainfall for Isabela during the period of this experiment, 1946–51*[1]

Year	Inches of rain for month of —												Annual total (inches)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1946	2.82	1.89	2.46	3.41	8.41	5.80	3.68	6.09	7.50	8.34	2.25	4.55	57.20
1947	3.03	1.96	1.06	3.10	8.65	5.92	3.21	2.76	4.85	8.51	2.28	6.93	52.25
1948	3.04	3.59	1.17	3.32	7.41	4.24	2.66	5.68	4.90	5.18	5.59	2.35	49.13
1949	3.68	1.38	3.06	2.84	7.73	4.63	10.73	5.10	9.71	5.97	7.07	6.03	67.93
1950	5.13	12.65	2.52	6.97	2.51	4.25	1.53	10.12	3.78	9.58	4.97	3.25	67.26
1951	3.58	0.71	0.81	3.01	10.03	9.83	5.50	6.20	8.06	6.59	4.30	5.94	64.56
Mean of 22 yrs.	3.61	3.21	3.09	4.34	9.04	7.04	5.09	6.65	6.80	7.12	5.93	4.25	66.17
Mean	3.55	3.70	1.85	3.78	7.46	5.78	2.88	2.99	6.47	1.36	4.41	4.84	59.72

[1] Prepared from the Climatological Data, West Indies and Caribbean, Weather Bureau, U. S. Department of Commerce, 1946–51.

tural Experiment Station at Río Piedras for the determination of the sucrose content. All canes sampled were milled not later than 24 hours after cutting.

Leaf samples were taken from each plot for foliar diagnosis at a cane age of 3 months, but only for the third-ratoon crops. The leaves selected for this purpose were the 4 nearest the last emerged unopened leaf. They were obtained from 12 sugarcane shoots, 3 shoots being selected at random from each row of the 4 rows of the cane plot. Thus, from each plot, 48 elongating leaf blades were cut at the collar joint.

The leaf samples were then taken to the laboratory and cut with a knifeboard paper-trimmer so that a 1-inch section was obtained from the basal, middle, and terminal portion of each. This gave 144 approximately 1-inch-square leaf sections per plot for analysis. The cut samples were oven-dried at 70°C., ground to 60 mesh, digested with acid, and analyzed for nitrogen, phosphorus and potassium by the Soil Department. (1).

MEAN RESPONSE OF THE FOUR SUGARCANE VARIETIES TO DIFFERENT FERTILIZER LEVELS

Yield of 96° Available Sugar Per Acre

NITROGEN

The use of nitrogen produced yield increases for all crops except the plant cane (see table 5). The use of 125 pounds of nitrogen produced a striking increase in sugar per acre. An increase of 1 hundredweight was obtained for the plant cane and an average of 21 hundredweights for the ratoon crops.

Doubling the 125 pounds of nitrogen applied did not give as great an increase in yield as did the first increment over no nitrogen. For the plant

TABLE 5.—*Mean yield of the 4 sugarcane varieties, in hundredweights of available 96° sugar, when grown at different fertilizer levels*

Treatment No.	Treatments in pounds per acre			Mean yields in hundredweights of available 96° sugar per acre for —				
	N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
1	0	300	300	150	46	58	33	72
2	125	300	300	151	65	84	51	88
3	250	0	300	148	49	72	47	79
4	250	150	300	154	62	86	59	90
5	250	300	0	152	63	81	56	88
6	250	300	150	149	68	88	58	91
7	250	300	300	153	66	89	60	92
Mean for all treatments				151	60	80	52	86
Least significant difference needed between treatments of same crop at:								
5-percent level				10	6	6	6	5
1-percent level				13	8	9	7	6

cane, 250 pounds of nitrogen per acre gave 2 hundredweights more sugar per acre than 125 pounds. An average increase of 5 hundredweights of sugar was obtained for the ratoon crops. There was a tendency to an increased response to 250 pounds of nitrogen as compared with 125 pounds in a number of ratoon crops. From plant cane to third ratoon the increase in hundredweights of sugar for 250 pounds of nitrogen over 125 pounds (treatment 7 minus treatment 2, table 5) was 2, 1, 5, and 9.

PHOSPHORUS

There was a definite response in yield of sugar per acre from the use of phosphorus fertilizer (see table 5). The use of 150 pounds of phosphorus fertilizer did not increase the sugar per acre significantly in the plant-cane crop, but highly significant increases were obtained from the three consecutive ratoon crops. The use of 150 pounds of phosphorus fertilizer produced an average increase of 13 hundredweights per acre for the ratoon crops.

Doubling the 150 pounds of phosphorus applied tended to increase yields in the ratoon an average of 5 hundredweights of sugar per acre. There was a tendency for the ratoon crops to demand more than 150 pounds of phosphorus per acre. From the plant cane to the third ratoon, the increase in hundredweights of sugar per acre for 300 pounds of phosphorus as compared with 150 pounds per acre (treatment 4 minus treatment 7, table 5) was −1, 2, 6 and 7. The last two differences are statistically significant at the 5- and 1-percent levels, respectively.

Sugarcane response to phosphorus fertilizer has been observed in very few soils of Puerto Rico. The need for and response to phosphorus fertilizers were not as great as for nitrogen, but highly significant increases were realized when phosphorus was used. The responses were greater as the number of ratoons increased.

POTASSIUM

There was no general significant response in yield of sugar per acre attributable to the use of potassium fertilizers (table 5). The mean of four crops revealed a difference of only 4 hundredweights of sugar per acre between no potassium and 300 pounds of potassium per acre (treatment 5 minus treatment 7), this difference was not significant statistically. The greatest response to potassium was obtained in the second ratoon.

Sucrose-Percent-Cane Content

NITROGEN

Nitrogen had no significant influence on the sucrose content of the cane for the plant-cane and first-ratoon crops (table 6). The use of 125 pounds of nitrogen increased the sucrose content of the second- and third-ratoon

TABLE 6.—*Mean sucrose-percent-cane produced by the 4 sugarcane varieties when grown at different fertilizer levels*

Treatment No.	Treatment in pounds per acre of —			Mean yield as sucrose-percent-cane for —				
	N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
1	0	300	300	13.63	11.20	11.69	10.82	11.83
2	125	300	300	13.32	11.46	12.30	11.72	12.20
3	250	0	300	13.64	11.10	12.65	11.56	12.24
4	250	150	300	13.80	11.37	12.46	12.08	12.43
5	250	300	0	13.41	11.24	12.48	11.85	12.25
6	250	300	150	13.41	11.56	12.45	11.86	12.32
7	250	300	300	13.56	11.44	12.49	11.77	12.31
Mean for all treatments				13.54	11.34	12.36	11.67	12.23
Least significant difference needed between treatments of same crop at:								
5-percent level				0.29	0.31	0.35	0.45	0.24
1-percent level				.39	.51	.47	.60	.32

crops, this difference being statistically significant at the 1-percent level. The use of up to 250 pounds of nitrogen neither increased nor decreased the sucrose content significantly as compared with results from the first 125 pounds of nitrogen.

PHOSPHORUS

The use of phosphate fertilizer did not affect the sucrose content of the cane consistently (table 6), although the sucrose content differed from year to year and from crop to crop. These differences were significant statistically for the first ratoon when 300 pounds of phosphorus fertilizer was applied and for the third ratoon when 150 pounds of phosphorus fertilizer was used. The mean of the four crops showed no definite response to phosphorus fertilizer.

POTASSIUM

The use of potash fertilizer did not change the sucrose concentrations of the cane in any of the four crops grown (table 6).

Tons of Cane per Acre

The response in tons of cane per acre was similar to and tended to follow the same general pattern of the yield as hundredweights of sugar per acre

TABLE 7.—*Mean yield of the 4 sugarcane varieties in tons of cane per acre, when grown at different fertilizer levels*

Treatment No.	Treatment in pounds per acre of —			Mean yields in tons of cane per acre for —				
	N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
1	0	300	300	54.8	20.4	24.7	14.9	28.7
2	125	300	300	56.4	28.1	33.9	21.7	35.0
3	250	0	300	53.9	21.8	28.5	19.9	31.0
4	250	150	300	55.7	27.1	34.4	24.2	35.4
5	250	300	0	56.5	27.8	32.2	23.6	35.0
6	250	300	150	55.3	29.1	35.2	24.3	36.0
7	250	300	300	56.4	28.9	35.8	25.5	36.7
Mean for all treatments............				55.6	26.2	32.1	22.0	34.0

(compare tables 7 and 5). The greatest response was to nitrogen, then to phosphorus, and the least to potassium.

INDIVIDUAL-VARIETY RESPONSES, DISREGARDING THE EFFECTS OF FERTILIZER TREATMENTS

Yield of 96° Available Sugar per Acre

The leading two varieties, P.R. 902 and P.R. 905, had significantly greater yields of sugar per acre than the other two, P.O.J. 2878 and M. 28 (table 8). M. 28 produced significantly higher yields than P.O.J. 2878 for the plant cane and the first two ratoon crops, but failed to do so in the third-ratoon crops. The mean yields of all four crops show that the varieties P.R. 902 and P.R. 905 produced considerably more sugar per acre than did M. 28 and P.O.J. 2878. These differences are statistically significant at the 1-percent level.

Sucrose-Percent-Cane Content

Sugarcane variety P.O.J. 2878 had the lowest sucrose content of the four varieties in this experiment (table 9). M. 28, P.R. 902, and P.R. 905 produced the highest sucrose-percent-cane, there being no significant sucrose-content difference between them. P.R. 905 failed significantly to outyield P.O.J. 2878 in the second-ratoon crop. The mean of four crops shows that M. 28 had the highest sucrose-percent-cane, followed by P.R. 905, and 902 and P.O.J. 2878 the least.

Tons of Cane per Acre

Varieties P. R. 902 and 905 had the highest yields in tons of cane per acre, with means of 41.9 and 39.4 tons, respectively. Next came M. 28 and then

TABLE 8.—*Mean yields of each of the 4 varieties of sugarcane, in hundredweights of available 96° sugar per acre, disregarding the effects of different fertilizer treatments*

Variety	Mean yield in hundredweights of available 96° sugar per acre for —				
	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
M. 28	131	54	70	38	73
P.O.J. 2878	124	42	61	38	66
P.R. 902	178	74	99	67	104
P.R. 905	170	70	88	64	98
Mean	151	60	80	52	86
Least significant difference needed between varieties of same crop at:					
5-percent level	11	7	6	6	6
1-percent level	14	9	9	8	8

P.O.J. 2878 yielding a mean of 29.1 and 28.7 tons, respectively (table 10). The two P.R. sugarcane varieties produced the highest tonnage. The other two varieties yielded about alike. In this experiment yields decreased considerably from year to year. The two P.R. varieties proved to be the best adapted to this region.

INDIVIDUAL-VARIETAL RESPONSES AT DIFFERENT FERTILIZER LEVELS

Available 96° Sugar per Acre

NITROGEN

All four varieties failed to respond significantly to nitrogen applications in the plant-cane crop. For the ratoon crops, however, the response to 125 pounds of nitrogen per acre was significant (table 11). Varieties M. 28 and P.O.J. 2878, which had the lowest yields, increased in yield 100 percent and over when 125 pounds of nitrogen was used in the third ratoon. The higher yielding varieties P.R. 902 and P.R. 905 showed no such large increases from nitrogen applications. However, it should be remembered that the yields of these varieties were equal to or greater than the highest yields of the poorer yielding varieties when grown without nitrogen. It appears that nitrogen is urgently needed to maintain yields of low-yielding varieties such as M. 28 and P.O.J. 2878 in the older ratoon crops.

Under the conditions of this experiment the use of more nitrogen for the ratoons was of greater benefit than for the plant cane, whereas, normal practice is to favor the plant cane with higher nitrogen applications. None

TABLE 9.—*Mean surcose-percent-cane produced by each of the 4 varieties of sugarcane, disregarding the effects of different fertilizer treatments*

Variety	Mean yield in sucrose-percent-cane for —				
	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
M. 28	13.63	11.68	12.87	12.02	12.55
P.O.J. 2878	13.01	10.67	11.81	10.52	11.50
P.R. 902	13.74	11.46	12.50	11.94	12.41
P.R. 905	13.78	11.55	12.27	12.18	12.45
Mean	13.54	11.34	12.36	11.67	12.23
Least significant difference needed between treatments of same crop at:					
5-percent level	0.35	0.47	0.52	0.41	0.28
1-percent level	.48	.65	.71	.57	.36

TABLE 10.—*Mean yields of each of the 4 varieties of sugarcane, in tons of cane per acre, disregarding the effects of different fertilizer treatments*

Variety	Mean yields in tons of cane per acre for —				
	Plant cane	First ratoon	Second ratoon	Third ratoon	All 4 crops
M. 28	49.4	23.1	27.2	15.8	29.1
P.O.J. 2878	47.7	19.7	25.8	18.1	28.7
P.R. 902	64.8	31.8	39.6	28.1	41.9
P.R. 905	61.7	30.3	35.9	26.3	39.4
Mean	55.9	26.2	32.1	22.1	34.8

of the varieties made a significant yield increase when 250 pounds of nitrogen per acre were used in lieu of 125 pounds.

PHOSPHORUS

None of the varieties responded significantly to phosphorus in the plant cane. In the ratoon crops, the yields of the lower yielding varieties, M. 28 and P.O.J. 2878, increased highly significantly when 150 pounds of P_2O_5 per acre were applied. The highest yielding variety, P.R. 902, did not produce so significant an increase. However, P.R. 905, the second highest yielder, did respond sharply to P_2O_5 in the ratoon crops. In general, the need for P_2O_5 increased with an increasing number of ratoons.

The use of 300 pounds of P_2O_5 per acre did not produce significant yield increases for any of the varieties when compared with the 150-pound P_2O_5 application (table 11 and fig. 2). It is altogether probable that even the first increment of 150 pounds of P_2O_5 per acre was excessive, and that rates up to 100 pounds of P_2O_5 per acre are sufficient for this soil.

Of those tested, variety P.R. 902 showed the best capacity for utilizing

TABLE 11.—*Yields of each of the 4 varieties of sugarcane, in hundredweights of available 96° sugar per acre, when grown at different fertilizer levels*

Treatments in pounds per acre of —			Mean yield in hundredweights of available 96° sugar per acre for —				
N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	Mean of 4 crops
			M. 28				
0	300	300	135	39	45	18	59
125	300	300	124	60	73	39	74
250	0	300	120	42	64	35	65
250	150	300	132	53	86	41	78
250	300	0	140	63	70	46	80
250	300	150	130	61	75	42	77
250	300	300	133	60	80	47	80
Mean for all treatments.........			131	54	70	38	73
Significant difference needed between treatments of same crops:							
5-percent level................			19	13	13	11	10
1-percent level................			25	17	17	15	13
			P.O.J. 2878				
0	300	300	112	31	40	20	51
125	300	300	124	43	64	40	68
250	0	300	125	29	53	29	59
250	150	300	127	45	67	45	71
250	300	0	126	40	60	40	67
250	300	150	131	54	72	45	76
250	300	300	124	50	71	46	73
Mean for all treatments.........			124	42	61	38	66
Significant difference needed between treatments of same crops:							
5-percent level................			19	13	13	11	10
1-percent level................			25	17	17	15	13

TABLE 11.—*Continued*

Treatments in pounds per acre of —			Mean yield in hundredweights of available 96° sugar per acre for —				
N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	Mean of 4 crops
P.R. 902							
0	300	300	185	62	85	52	96
125	300	300	177	76	102	57	103
250	0	300	179	70	92	67	102
250	150	300	187	77	99	80	111
250	300	0	171	74	102	68	104
250	300	150	167	80	107	76	106
250	300	300	182	75	103	72	108
Mean for all treatments.........			178	73	99	67	104
Significant difference needed between treatments of same crops:							
5-percent level................			19	13	13	11	10
1-percent level................			25	17	17	15	13
P.R. 905							
0	300	300	167	51	62	40	80
125	300	300	178	79	95	68	105
250	0	300	166	55	79	55	89
250	150	300	170	73	91	68	101
250	300	0	170	74	91	71	102
250	300	150	166	75	96	70	102
250	300	300	174	80	103	75	108
Mean for all treatments.........			170	70	88	64	98
Significant difference needed between treatments of same crops:							
5-percent level................			19	13	13	11	10
1-percent level................			25	17	17	15	13

the available phosphorus in the soil. Not only did it give the highest yields, but it did so with smaller fertilizer applications.

POTASSIUM

None of the varieties responded significantly to potash in plant cane or ratoons (table 11 and fig. 2). There was no response to potassium in the high- or low-yielding varieties, not even with the increasing number of ratoons.

Sucrose-Percent-Cane Content

The use of nitrogen did not produce any decrease in sucrose for the mean of four crops of the four varieties (table 12). In general, the response was similar for all varieties in that the plant cane showed a reduction in sucrose with nitrogen, whereas the ratoons showed increases in sucrose with nitrogen applications.

When phosphorus was applied to P.O.J. 2878 it produced a severe reduction in sucrose content; compare the no-phosphorus and the 150-pound-P_2O_5 treatment per acre for the third ratoon (table 12). When P_2O_5 was omitted the mean sucrose content decreased significantly in all four crops.

There were no significant differences in yield at the various potassium fertility levels.

Tons of Cane per Acre

Table 13 shows a variety response at different fertilizer levels similar to that observed for yields in hundredweights of sugar per acre.

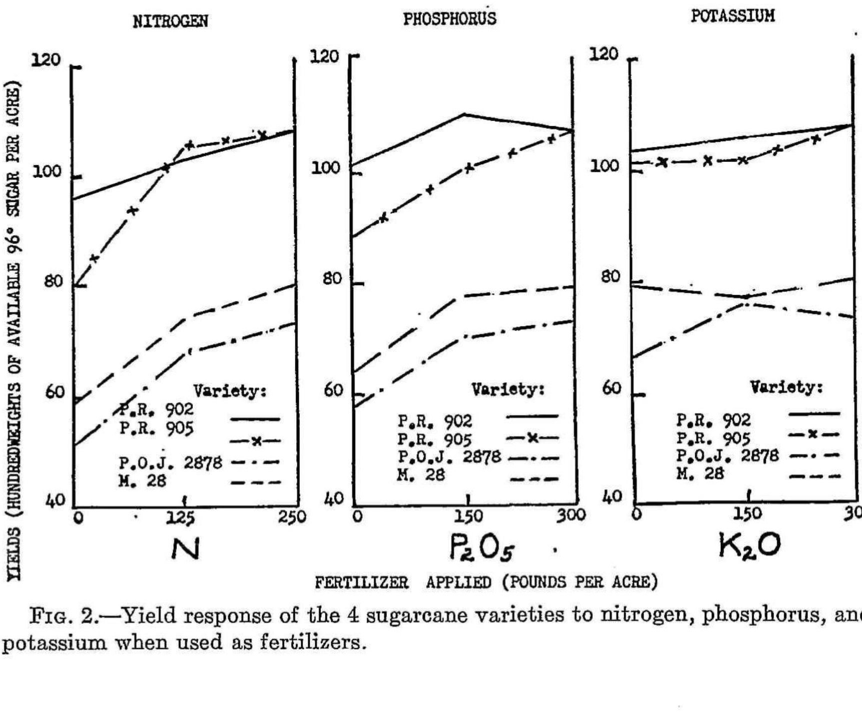

FIG. 2.—Yield response of the 4 sugarcane varieties to nitrogen, phosphorus, and potassium when used as fertilizers.

Reduction in Yields of Individual Varieties from Omission of Specific Fertilizer Elements

As a guide to the fertility status of the soil in relation to the available nutrients it could supply to the cane crop, reductions in yield from the

TABLE 12.—*Sucrose-percent-cane produced by each of the 4 varieties of sugarcane when grown at different fertilizer levels*

Treatments in pounds per acre of —			Mean sucrose-percent-cane content of —				
N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	Mean of 4 crops
			M. 28				
0	300	300	13.59	11.69	12.39	11.38	12.26
125	300	300	13.13	12.19	12.80	12.24	12.59
250	0	300	13.43	11.58	13.58	12.07	12.67
250	150	300	13.83	11.50	12.81	12.43	12.64
250	300	0	13.77	11.58	12.21	12.11	12.42
250	300	150	13.40	11.53	13.03	11.70	12.42
250	300	300	14.21	11.65	13.26	12.22	12.84
Mean for all treatments.......			13.26	11.67	12.86	12.02	12.55
Significant difference needed between treatments of same crops at:							
5-percent level..............			0.31	0.84	0.72	0.91	0.43
1-percent level..............			.41	1.10	.94	1.19	.63
			P.O.J. 2878				
0	300	300	13.30	10.71	10.51	9.44	10.99
125	300	300	12.98	10.73	11.71	10.41	11.46
250	0	300	13.23	9.95	12.08	9.75	11.25
250	150	300	13.19	10.44	12.08	11.24	11.74
250	300	0	12.93	10.69	12.22	10.99	11.71
250	300	150	12.99	11.20	11.96	10.85	11.75
250	300	300	12.44	11.00	12.10	10.96	11.63
Mean for all treatments.......			13.01	10.67	11.81	10.52	11.50
Significant difference needed between treatments of same crops at:							
5-percent level..............			0.31	0.84	0.72	0.91	0.43
1-percent level..............			.41	1.10	.94	1.19	.63

TABLE 12.—*Continued*

Treatments in pounds per acre of —			Mean sucrose-percent-cane content of —				
N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	Mean of 4 crops
			P.R. 902				
0	300	300	13.90	11.22	12.05	11.09	12.07
125	300	300	13.68	11.15	12.60	12.00	12.36
250	0	300	13.85	11.50	12.50	11.86	12.43
250	150	300	13.77	11.48	12.17	12.21	12.41
250	300	0	13.65	11.62	13.19	12.12	12.65
250	300	150	13.37	11.79	12.48	12.23	12.47
250	300	300	13.99	11.44	12.48	12.07	12.50
Mean for all treatments			13.74	11.46	12.50	11.94	12.41
Significant difference needed between treatments of same crops at:							
5-percent level			0.31	0.84	0.72	0.91	0.43
1-percent level			.41	1.10	.94	1.19	.63
			P.R. 905				
0	300	300	13.73	11.20	11.84	11.36	12.03
125	300	300	13.49	11.76	12.11	12.24	12.40
250	0	300	14.06	11.35	12.42	12.59	12.61
250	150	300	14.41	12.05	12.77	12.45	12.92
250	300	0	13.29	11.10	12.30	12.17	12.22
250	300	150	13.87	11.74	12.32	12.66	12.65
250	300	300	13.59	11.67	12.12	11.81	12.30
Mean for all treatments			13.78	11.55	12.27	12.18	12.45
Significant difference needed between treatments of same crops at:							
5-percent level			0.31	0.84	0.72	0.91	0.43
1-percent level			.41	1.10	.94	1.19	.63

omission of specific fertilizer elements were determined. The results are presented in table 14.

The greatest reduction in yields occurred when nitrogen was omitted. P.O.J. 2878, which gave the lowest mean yields of available 96° sugar per acre (table 11), showed the greatest reduction in yields when nitrogen was omitted (table 14), whereas, P.R. 902, which gave highest yields, showed

TABLE 13.—*Yields of each of the 4 varieties of sugarcane, in tons of cane per acre, when grown at different fertilizer levels*

Treatments in pounds per acre of —			Mean yields in tons of cane per acre for —				
N	P_2O_5	K_2O	Plant cane	First ratoon	Second ratoon	Third ratoon	Mean of 4 crops
			M. 28				
0	300	300	49.7	16.7	18.2	7.9	24.1
125	300	300	47.2	24.6	28.5	15.9	29.4
250	0	300	44.7	18.1	23.6	14.5	25.7
250	150	300	47.7	23.0	33.6	16.5	30.9
250	300	0	50.8	27.2	28.7	19.0	32.2
250	300	150	48.5	26.5	28.8	17.9	31.0
250	300	300	46.8	25.8	30.2	19.2	31.2
Mean for all treatments........			49.4	23.1	27.2	15.8	29.1
			P.O.J. 2878				
0	300	300	42.1	14.5	19.0	10.6	23.2
125	300	300	47.8	20.0	27.3	19.2	29.7
250	0	300	47.2	14.6	21.9	14.9	26.2
250	150	300	48.1	21.6	27.7	20.1	30.2
250	300	0	48.7	18.7	24.5	18.2	28.6
250	300	150	50.4	24.1	30.1	20.7	32.2
250	300	300	49.8	22.7	29.3	21.0	31.4
Mean for all treatments........			47.7	19.7	25.8	18.1	28.7
			P.R. 902				
0	300	300	66.5	27.6	35.3	23.4	39.8
125	300	300	64.7	34.1	40.5	23.8	41.7
250	0	300	64.6	30.4	36.8	28.2	41.0
250	150	300	67.9	33.5	40.7	32.8	44.7
250	300	0	62.6	31.8	38.7	28.1	41.1
250	300	150	62.5	33.9	42.9	31.1	42.5
250	300	300	65.0	32.8	41.3	29.8	43.2
Mean for all treatments........			64.8	31.8	39.6	28.1	41.9
			P. R. 905				
0	300	300	60.8	22.8	26.2	17.6	33.3
125	300	300	66.0	33.6	39.2	27.8	42.3
250	0	300	59.0	24.2	31.8	21.8	35.3
250	150	300	59.0	30.3	35.6	27.3	39.1
250	300	0	64.0	33.3	37.0	29.2	41.7
250	300	150	59.8	31.9	39.0	27.6	40.3
250	300	300	64.0	34.3	42.5	31.8	43.9
Mean for all treatments........			61.7	30.3	35.9	26.3	39.4

TABLE 14.—*Percentage reductions in yield of available 96° sugar per acre for each of the 4 varieties of sugarcane attributable to the omission of nitrogen, phosphorus, and/or potassium*

Variety and crop	Percentage reduction in yield from omission of —		
	Nitrogen	Phosphorus	Potassium
M. 28:			
Plant cane	−1.48	9.77	−5.00
First ratoon	35.00	30.00	−5.00
Second ratoon	43.75	20.00	12.50
Third ratoon	61.70	25.53	2.13
Mean	26.25	18.75	0
P.O.J. 2878:			
Plant cane	9.68	−0.80	−1.59
First ratoon	38.00	42.00	20.00
Second ratoon	43.66	25.35	15.49.
Third ratoon	56.52	36.96	13.04
Mean	30.14	19.17	8.22
P.R. 902:			
Plant cane	−1.62	1.64	6.04
First ratoon	17.33	6.67	1.33
Second ratoon	17.48	10.68	.97
Third ratoon	27.78	6.94	5.55
Mean	11.11	5.55	3.70
P.R. 905:			
Plant cane	4.02	4.60	2.30
First ratoon	36.25	31.25	7.50
Second ratoon	39.80	23.30	11.65
Third ratoon	46.67	26.67	5.33
Mean	25.93	17.59	5.55
Mean of four varieties:			
Plant cane	1.96	3.27	0.65
First ratoon	30.30	25.75	4.54
Second ratoon	34.83	19.10	8.99
Third ratoon	45.00	21.66	6.67
Mean	21.73	14.13	4.35

the smallest reduction. Thus it appears that P.O.J. 2878 needs nitrogen fertilizers more than P.R. 902 to prevent yield reductions. For the mean of four crops and four varieties this reduction was 21.75 percent. The reduction in yield increased as the number of ratoons increased, and was almost negligible for the plant cane.

The omission of phosphorus produced the second highest reduction in yield. This reduction was greatest for P.O.J. 2878, M. 28, and P.R. 905, in that order. P.R. 902 showed a very small reduction as compared with the other three varieties.

The reduction from the absence of potash was the lowest with a mean of 4.35 (table 14). P.O.J. 2878 underwent the greatest yield reduction when potash was absent. M. 28 showed no mean reduction in yield for the four crops when potash was omitted.

FOLIAR DIAGNOSIS

Foliar analysis was not undertaken until the third ratoon of this experiment. However, interesting and useful data were obtained concerning the levels of the nutrient in the cane leaf and yields of cane, even for this one crop. The analyses of the leaf samples are given in table 15.

Nitrogen

Leaf nitrogen increased in all varieties when increasing applications of nitrogen fertilizer were made to the soil. When no nitrogen was added to the

TABLE 15.—*Nitrogen, phosphorus, and potassium contents of dry leaf samples taken from the 4 varieties of sugarcane when grown at different fertilizer levels, and yield per acre*

Treatment in pounds per acre of —			Fertilizer element	Content of leaf sample of —					Yield of available 96° sugar per acre
N	P_2O_5	K_2O		P. R. 902	P. R. 905	P.O.J 2878	M.28	Mean of 4 varieties	
				Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Cwt.*
0	300	300		1.41	1.42	1.37	1.36	1.39	33
125	300	300	Nitrogen	1.51	1.54	1.50	1.76	1.56	51
250	300	300		1.78	1.83	1.80	1.86	1.82	60
250	0	300		.15	.18	.15	.16	.16	47
250	150	300	Phorphorus	.20	.20	.20	.20	.20	59
250	300	300		.22	.24	.25	.26	.24	60
250	300	0		2.11	2.66	2.33	2.31	2.35	58
250	300	150	Potassium	2.42	2.58	2.30	2.14	2.36	60
250	300	300		2.08	2.76	2.80	2.59	2.46	60

soil, the mean nitrogen content of the leaf for the four varieties was 1.39 percent. When 125 pounds of nitrogen per acre was added it rose to 1.56; and when 250 pounds of nitrogen were used, the leaf nitrogen content was 1.82 percent.

Phosphorus

The concentration of phosphorus in the leaf increased with phosphate fertilizer additions. The leaves contained only 0.16 percent of phosphorus when this element was not applied to the soil, which was lower than any values elsewhere encountered for leaf phosphorus of cane in Puerto Rico. The third ratoon gave significant yield increases with phosphate application, so that these low values were associated with phosphorus deficiencies. The use of 150 pounds of P_2O_5 per acre raised the mean phosphorus content of the leaves to 0.20 percent, and 300 pounds of P_2O_5 applied per acre gave mean leaf values of 0.24 percent.

Potassium

The leaf potassium values were all above 2 percent. There was no consistent increase of potassium in the leaf when potash was applied to the soil, although the mean when 300 pounds of K_2O per acre were used was 2.46 percent, whereas the mean was only 2.35 when none was applied. The potassium values were higher for all treatments than those of the Arecibo experiment (3).

Interpretation of Foliar-Analysis Data

Nitrogen applications produced significant yield increases, and, therefore, increased leaf-nitrogen values, for the no-nitrogen treatment may be assumed to indicate nitrogen deficiency; the cane plant should then respond significantly to nitrogen applications. A leaf nitrogen content of 1.39 percent at 3 months represented nitrogen deficiency for the mean of the four varieties. This figure may be compared with the 1.41-percent leaf nitrogen for the no-nitrogen treatment of the Arecibo cycle (3). Since there was still a significant yield response when 250 instead of 125 pounds of nitrogen per acre were applied, it must be assumed that leaf-nitrogen concentrations above 1.56 percent still indicate that the cane would respond to nitrogen fertilizer. This yield response would not be so great with leaf-nitrogen values around 1.56, as at values near 1.40 percent or below. It appears that leaf nitrogen of about 1.60 percent and below indicates the possibility that ratoons sampled at 3 months would respond to nitrogen. The more the leaf-nitrogen concentrations fall below this level, the greater the response to nitrogen applications would be.

Yield responses to phosphate applications were significant in this experiment. Leaf-phosphorus values of 0.16 percent were associated with the no-phosphorus treatment, while the use of 150 pounds of P_2O_5 gave leaf values of 0.20 percent of phosphorus. As no significant yield increases were obtained when more than 150 pounds of P_2O_5 was used, it appears that leaf-phosphorus values below 0.20 and near 0.16 percent are associated with phosphorus deficiency, and that there would be positive responses to phosphate fertilizers. In the Arecibo experiment, where there was no significant yield response to phosphates, all leaf-phosphorus values were above 0.20 percent (3).

There was no significant yield response to potash applications, and leaf-potassium values were all above 2 percent. In the Arecibo experiment where responses to potassium were obtained, the leaf-potassium values were generally below 2, and they approached this value only with the use of 300 pounds of K_2O per acre. Therefore, in the Isabela experiment, the leaf-potash values above 2 percent indicated that no increased cane yields should have been expected when potash fertilizers were applied.

PRACTICAL RECOMMENDATIONS

Varieties

Of the four sugarcane varieties tested, M. 28, P.O.J. 2878, P.R. 902, and P.R. 905, varieties P.R. 902 and P.R. 905 were best and yielded the most cane per acre. There was no significant difference in sucrose content between varieties M. 28, P.R. 902, and P.R. 905. P.O.J. 2878 had a significantly lower sucrose content than the other three varieties. P.R. 902 and P.R. 905 gave the highest yields of 96° available sugar per acre and should be used in preference to the other two varieties.

Fertilizers

The response to fertilizer application was greatest for nitrogen, less for phosphorus, and least for potassium. For sugarcane growing on Coto clay and similar soils in the Isabela area, the fertilizer recommendations are:

Plant cane

Nitrogen—125 to 250 pounds of N per acre
Phosphorus—75 to 100 pounds of P_2O_5 per acre
Potassium—50 to 75 pounds of K_2O per acre

Ratoons

Nitrogen—125 to 250 pounds of N per acre
Phosphorus—100 to 150 pounds of P_2O_5 per acre
Potassium—50 to 75 pounds of K_2O per acre

SUMMARY

A variety-fertilizer experiment using four varieties of sugarcane grown at seven different fertilizer levels was carried on for a plant cane and three ratoons at the Isabela Substation on a Coto clay. The major results were:

(1) Nitrogen gave the highest yield increases in hundredweights of 96° available sugar per acre.

(2) Phosphate fertilizers gave significant increases in yields of cane for the ratoon crops.

(3) Potasium fertilizers did not increase the yield of sugar per acre.

(4) Applications of nitrogen, phosphorus, or potassium did not significantly influence sucrose concentrations in the cane.

(5) The leading two varieties, P.R., 902 and P.R. 905, gave significantly greater yields of sugar per acre than the other two varieties, P.O.J. 2878 and M. 28.

(6) All varieties maintained their relative yielding power when tested at various fertilizer levels.

(7) The reductions in yield from the omission of a fertilizer element for the mean of four crops were 22, 14, and 4 percent for nitrogen, phosphorus, and potassium, respectively.

(8) Foliar analysis was made for leaves of the third ratoon only. Nitrogen values below 1.39-percent dry matter in the leaf represented definite deficiency, and response to nitrogen applications could be expected. Values of 0.16 percent of phosphorus in the leaf represented phosphorus deficiency, while there was no response to phosphates when the percentage was 0.20 or above. The potassium leaf values were above 2 percent and no yield responses were obtained at any potash level.

RESUMEN

En la Subestación de Isabela se estableció, en un suelo arcilloso Coto, un experimento combinado de siete tratamientos de abonos y cuatro variedades de caña de azúcar. Los resultados sobresalientes para una plantilla y tres retoños son los siguientes:

(1) El uso del nitrógeno produjo los aumentos más significativos en quintales de azúcar 96° por acre.

(2) La aplicación de fósforo produjo aumentos significativos solamente en los retoños.

(3) Los rendimientos no se aumentaron significativamente por el uso de potasio.

(4) El por ciento de sacarosa en la caña no fué afectado por la aplicación de los elementos nutritivos nitrógeno, fósforo y potasio.

(5) Las variedades P.R. 902 y P.R. 905 produjeron rendimientos de azúcar por acre más altos que las variedades P.O.J. 2878 y M. 28.

(6) Los rendimientos relativos de las distintas variedades mantuvieron aumentos similares a distintos niveles de fertilidad.

(7) El por ciento de reducción debido a la ausencia de alguno de los elementos principales fueron de 22, 14 y 4 por ciento para nitrógeno, fósforo y potasio, respectivamente.

(8) El estudio de análisis foliar se inició para el tercer retoño solamente. Por cientos de nitrógeno menores de 1.39 en la hoja, a base de materia seca, representa una deficiencia de este elemento nutritivo y su aplicación representaría un aumento en los rendimientos. Valores de 0.16 por ciento de fósforo en la hoja representa una deficiencia, mientras el valor de .20 por ciento o más no responden a los fosfatos. El valor del potasio en la hoja fué de 2 por ciento o más y no se obtuvieron aumentos significativos por el uso de este elemento nutritivo.

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