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Effect of Lime and Phosphate-bearing Materials on Sugarcane Yields

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INTRODUCTION

May (*6*)[2], in 1910, obtained yield responses for a plant and a first-ratoon crop of sugarcane when lime and fertilizer were applied to a heavy clay soil in the Mayagüez area. Similar responses were reported in 1914 by Gile and Ageton (*4*) in a Catalina clay in the Añasco area. Pietri and Gómez-Montoya (*8*) obtained increases of sugarcane yields when lime was applied to a Coloso clay up to an amount equivalent to 80 percent of the soil base saturation. No additional responses were obtained by saturating with lime up to 100 percent.

The use of phosphatic fertilizers for sugarcane grown in coastal plain soils has been seriously questioned (*1*). In many instances their application has not exerted any effect, either beneficial or detrimental, on the yields of several successive sugarcane crops. The question has been raised as to whether the same situation would hold on other acid humid-region soils where sugarcane is grown in Puerto Rico, outside of the coastal plain area.

This paper reports data obtained from a field experiment designed to determine both the effect on sugarcane yields of lime and of two sources of phosphorus added to an acid soil of Puerto Rico.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 6.

MATERIALS AND METHODS

The experiment was located at the Corozal Agricultural Experiment Substation Farm in the interior, humid region of Puerto Rico. The soil is a nearly level Lares clay, an acid, medium-friable, Red and Yellow Podzolic (*9*) soil, occurring in terrace formations and derived from materials washed from the Lower Tertiary clays and shales. Feldspars are absent in the soil and kaolinite is the predominant clay mineral (*5*).

The experiment consisted of a split-plot design with a total of 16 treatments. The main treatments were the two sources of phosphorus: superphosphate and hyperphosphate,[3] and the lime application. The subtreatments were the different rates of phosphorus applied. The subtreatments consisted of four different rates of application: 0, 50, 125, and 200 pounds of P_2O_5 to the acre. Both the main treatments and subtreatments were completely randomized and the subtreatments were replicated six times for a total of 96 plots, each 24 x 16 feet. On August 22, 1952 half of the plots received lime at the rate of 4 tons to the acre. The original pH of the topsoil was 5.6 while that of the reddish subsoil was 4.0. The field was planted on July 30–31, 1952, to sugarcane variety P.R. 1000. Six rows, 16 feet long, were planted at a 4-foot interval. One unplanted row was left between the sugarcane rows to separate the plots. On September 5 all plots received ammonium sulfate and muriate of potash at rates of 1,000 and 125 pounds to the acre, respectively. The plant crop was harvested February 1–2, 1954. The two succeeding ratoon crops were fertilized in a similar way to the plant crop, including the differential phosphorus treatments, but the lime application was not repeated. The first ratoon was harvested February 14–16, 1955, and the second March 5–6, 1956.

Soil samples were taken on April 10, 1956, 44 months after the lime was applied. Soil pH was determined with a Macbeth pH-meter. In a selected number of samples available phosphorus was determined by the Olsen sodium bicarbonate method (*7*), cation-exchange capacity by the ammonium acetate method, and exchangeable calcium by the versenate titration method (*10*).

RESULTS AND DISCUSSION

Table 1 presents data on the sugarcane yields obtained for each and for the total of three crops harvested. Table 2 summarizes the effect of lime on sugarcane yields.

[3] Hyperphosphate is obtained from the North African sedimentary deposits of phosphate of lime. It has an average content of 26 percent of total P_2O_5 while the commonly used superphosphate has only 19 percent. The available P_2O_5 however, was only 5.9 percent in the hyperphosphate, while almost all is available in the superphosphate.

There was a significant sugarcane yield response in the first crop and in the total of the three crops (table 1) when lime was added with 200 pounds

TABLE 1.—*Effect of superphosphate and hyperphosphate in the absence or presence of lime, upon yields of each of 3 crops, and the total yield of sugarcane variety PR-1000 grown in acid Lares clay*

Crop	Materials applied	Yield per acre of sugarcane at indicated P_2O_5 level				Mean-yields per acre for materials applied
		0	50 lb. per A.	125 lb. per A.	200 lb. per A.	
		Tons	*Tons*	*Tons*	*Tons*	*Tons*
First	Superphosphate	82.0	86.8	85.1	82.0	84.0
	Hyperphosphate	75.2	84.0	85.8	83.9	82.2
	Superphosphate plus lime	85.8	87.3	90.8	94.9	89.7
	Hyperphosphate plus lime	85.9	83.8	85.2	82.4	84.3
Second	Superphosphate	47.2	51.0	47.4	48.0	48.4
	Hyperphosphate	46.0	48.2	44.8	47.0	46.5
	Superphosphate plus lime	48.8	48.6	54.6	55.2	51.8
	Hyperphosphate plus lime	50.2	46.9	52.9	53.5	50.9
Third	Superphosphate	40.1	41.3	42.8	41.9	41.5
	Hyperphosphate	38.6	41.3	41.9	40.4	40.6
	Superphosphate plus lime	41.2	44.8	45.4	45.5	44.2
	Hyperphosphate plus lime	44.1	42.5	46.7	44.8	44.5
Total	Superphosphate	169.3	179.1	175.3	171.9	173.9
	Hyperphosphate	159.8	173.5	172.5	171.3	169.3
	Superphosphate plus lime	175.8	180.7	190.8	195.6	185.7
	Hyperphosphate plus lime	180.2	173.2	184.8	180.7	179.7

Item	L.S.D. for indicated means at the—							
	5-percent level for crops				1-percent level for crops			
	First	Second	Third	Total	First	Second	Third	Total
Materials applied	8.1	5.3	3.0	13.7	11.2	7.4	4.1	19.0
Different rates of P_2O_5 application for same material	8.5	6.5	4.6	16.0	11.4	8.6	6.2	21.3
Different materials for same rate of P_2O_5 application	10.9	7.7	5.0	19.5	14.9	10.5	6.7	26.4

of P_2O_5 as superphosphate to the soil. The significant yield response obtained in the third crop when lime and 200 pounds of hyperphosphate were added to the soil was not effective in causing a significant response in the total yield of the three crops.

There was a significant sugarcane yield response due to lime (table 2) in the second and third and in the total of three sugarcane crops.

Long-time field experiments under way at two other locations in Puerto Rico indicate that sugarcane yields can be maintained at practically maximum levels for a long period with an annual application of only 20 pounds of P_2O_5 per acre (*2*). One location was at the acid Vega Alta clay, a Red and Yellow Podzolic soil similar to Lares clay. Previous work (*3*) with tagged superphosphate added at the rate of 50 pounds of P_2O_5 per acre to acid Vega Alta clay, indicated that sugarcane absorbs most of the phosphorus from the soil. The mean amount derived from the soil was 99 percent 17 days after the application of the tagged superphosphate, and about 90 percent after 80 days. In limed plots the phosphorus absorbed from the soil was 99.5 percent 17 days after the application, and 87 percent 51 days afterwards (*3*). Liming the acid Vega Alta clay at the rate of 7 tons of limestone per acre was not effective in changing the amount of phosphorus absorption.

TABLE 2.—*Effect of lime on acid Lares clay upon yields of each, and of total yield, of 3 crops of sugarcane*

Crop	Mean yields		Least significant differences	
	Unlimed	Limed	5 percent	1 percent
	Tons/A.	*Tons/A.*		
First	83.1	87.0	5.7	7.9
Second	47.5	51.4	3.8	5.2
Third	41.0	44.5	2.1	2.9
Total	171.6	182.9	9.7	13.4

No sugarcane yield response was obtained in the experiment herein reported when different rates of P_2O_5 as superphosphate or hyperphosphate, up to 200 pounds P_2O_5 per acre, were added. Laboratory analyses indicate that the acid Lares clay supplies from 35 to 72 pounds of available P_2O_5 per acre. These results confirm those previously reported (*1*) from a number of field experiments in which possible needs of phosphorus fertilizers for sugarcane grown in coastal plain soils were provided though no responses were obtained. On the other hand, the use of lime in acid soils where sugarcane is grown has not yet been fully acknowledged. The beneficial effects of liming herein reported confirm those reported at earlier dates by several investigators (*4, 6*), as well as those obtained at a more recent date by Pietri and Gómez-Montoya (*8*), after applying lime up to 80-percent base saturation to a soil where sugarcane was grown.

The data reported here (table 1) point to an interaction between lime and superphosphate. When a high level up to 200 pounds of P_2O_5 to the acre was added to the soil, significant increases of sugarcane yields were obtained in the first crop and in the total of the three crops. The combined action of lime and P_2O_5 was not effective at the lower rates of 50 and 125 pounds of P_2O_5 to the acre.

The soil reaction of Lares clay 44 months after the 4 tons of limestone were applied, was still acid (pH 5.7–6.2), but the mean exchangeable calcium (table 3) increased to 8.2 m.e. per 100 g. of dry soil, 4.8 m.e. above the mean value for the unlimed soil, equivalent to 2.4 tons of residual limestone per acre. The exchangeable calcium of the unlimed soil was 25.0 percent of the total exchange capacity and that of the limed soil was 59.4 percent.

With the beginning of the fourth consecutive crop (third ratoon) on these plots, phosphorus applications were discontinued in an effort to measure any possible response that might become apparent with continuous phosphorus extraction from the soil.

TABLE 3.—*Range in pH, total exchange capacity, and exchangeable calcium of unlimed and limed plots in Lares clay*[1]

Treatment	Range in pH	Total exchange capacity per 100 g. of dry soil	Exchangeable calcium, Ca per 100 g. of dry soil	Percentage exchangeable Ca of total exchange
		M.e.	*M.e.*	
Unlimed	5.5–5.6	13.6	3.4	25.0
Limed	5.7–6.2	13.8	8.2	59.4

[1] Each value represents the mean of 12 samples taken at 0–8-inch depths 44 months after liming at the rate of 4 tons of $CaCO_3$ per acre.

SUMMARY

Data are reported here from a field experiment with sugarcane on acid Lares clay located in the humid area of Puerto Rico, at the Corozal Agricultural Experiment Substation. The effect of lime and of two sources of phosphorus fertilizers was tested. The experiment included superphosphate and hyperphosphate, each with or without lime, at four rates: 0, 50, 125, and 200 pounds P_2O_5 to the acre. Lime was used at the rate of 4 tons to the acre. Yield data are reported for a plant crop of sugarcane and for two succeeding ratoon crops. No significant differences were obtained attributable to either type or rate of phosphorus fertilizer when added to the acid soil. Liming caused significant increases in sugarcane yields in both ratoon crops and in the total of the three crops, amounting to 11.3 tons of sugarcane per acre. The highest significant increase of 24.3 tons of sugarcane per acre was obtained when lime was added with 200 pounds P_2O_5 per acre as superphosphate.

RESUMEN

Se presentan aquí los datos obtenidos de un experimento de campo con caña de azúcar en el suelo ácido Lares arcilloso, de la zona húmeda de Puerto Rico, en la Subestación de Corozal. Se estudió el efecto de la cal y de 2 abonos fosfáticos. Los tratamientos estudiados incluyeron superfosfato e hiperfosfato, con y sin cal, a razón de 0, 50, 125 y 200 libras P_2O_5 por acre. La cal se aplicó a razón de 4 toneladas por acre. Se informan los datos de rendimientos de una plantilla y 2 retoños de caña de azúcar. No se observaron diferencias significativas atribuíbles al tipo o a la cantidad de fósforo aplicada al suelo ácido. El uso de cal causó aumentos significativos en el tonelaje de ambos retoños y en las 3 cosechas aumentó el rendimiento total en 11.3 toneladas de caña por acre. El aumento significativo más alto, de 24.3 toneladas de caña por acre, se obtuvo cuando se aplicó cal y 200 libras de P_2O_5 por acre, como superfosfato.

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