The Effect of Differential Sugarcane Fertilizer Treatments on a Coloso Silty Clay

George Samuels and Pablo Landrau, Jr.[1]

INTRODUCTION

There are many factors to be considered in relation to soil properties and fertility, such as climate, parent material, and vegetative cover. However, one of the important factors normally denied due consideration is man. For man can modify many of the properties of the soil by his management. By improper management he can accelerate erosion or lower soil fertility. Using proper agronomic practices, he can prevent erosion and increase crop yields.

In many agricultural areas one crop is grown continuously on the same soil using the same fertilizer practices year after year. This is true of many of the sugarcane lands of Puerto Rico. Over 150,000 tons of fertilizer are being applied yearly to the sugarcane grown in Puerto Rico. Typical applications are equivalent to 1,200 pounds of a 12-4-10 mixed commercial fertilizer per acre per year placed on the fields (7)[2]; meanwhile, 40 to 50 tons of cane per acre per year are removed from these fields. The sugarcane soil is not a static condition here, but rather in one of constant change involving large fertilizer additions and the removal of plant nutrients by the cane. Depending on the type and quantity of fertilizer he uses, man can readily modify the fertility of the soil.

OBJECTIVES

It is the purpose of this study to show in what manner the use of certain differential fertilizer treatments has influenced certain chemical properties of the soil to which the fertilizer was applied.

The study covers 9 years of differential fertilizer treatments on a Coloso silty clay, and their effects on soil pH, organic matter, and nitrogen, and on the "available" phosphorus and potassium supply. A detailed study of the cane yields and their response to the fertilizer treatments has been made by Samuels and Landrau (8). A balance sheet will be presented of the quantities of plant nutrients added to the soil by the fertilizer and

[1] Plant Physiologist and Assistant Agronomist, respectively, of the Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The authors wish to acknowledge and thank for their cooperation F. A. Abruña, Soil Scientist, S. Silva, Soil Scientist Aid, and J. Figarella, Soil Scientist, all of the cooperative ARS. Project of the Agricultural Experiment Station, for their help in taking the soil profile and making the physical and chemical analyses of the profile.

[2] Numbers in parentheses refer to Literature Cited, p. 187.

the cane trash, and of the materials removed by the harvested cane stalks, to demonstrate the dynamic flow of materials in the soil which influence soil properties.

PROCEDURES

The experimental field was located on a Coloso silty clay soil of field 9, San Francisco Farm, of the Cambalache Area of the Land Authority of Puerto Rico. The site of the experiment is 8 km. from the city of Arecibo on the Arecibo-to-Utuado road.

This was a sugarcane fertilizer-variety experiment begun on September 18, 1944, with a plant cane aged 17 months, and continued for five ratoons averaging 12 months each, and another plant cane of 18 months. Four sugarcane varieties (P.O.J. 2878, P.R. 903, M. 275, and M. 317) and seven different fertilizer levels of nitrogen, phosphorus, and potassium were utilized (see table 1). The design of the experiment was a split-plot one, in which varieties were considered as the whole-plot effect and the various fertilizer levels were regarded as the sub- or split-plot effect. The plot size was approximately 1/72 of an acre, and the fertilizer treatments were replicated nine times for each variety.

In March 1953, following the harvesting of the second plant cane, soil samples were taken from each plot of the various fertilizer treatments for one variety (P.O.J. 2878), using a soil-sampling tube to a depth of 12 inches. The samples were removed from the side of the cane stool, in the furrow, three samples per row of cane (at the beginning, middle, and end of each row) and for the four rows in the plot. Thus a total of 12 samples per plot was taken. These samples were composited for each plot. The soil samples were air-dried, passed through a 2-mm. sieve to remove stones and organic debris, and then analyzed.

TABLE 1.—*Fertilizer applied per acre for the sugarcane experiment on a Coloso silty clay at Arecibo*

Treatment No.	Fertilizer applied per acre as—		
	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

Nitrogen was determined by the standard Kjeldahl method; pH was determined electrometrically by means of a Macbeth pH-meter; and organic matter by the Schollenberger colorimetric method. A 1 N ammonium-acetate extract of the soil was used for determining available phosphorus and potassium. The phosphorus was determined colorimetrically, and the potassium by means of a flame photometer.

The values obtained from the chemical analyses were all analyzed statistically to determine whether differences obtained between treatments were significant.

An undisturbed soil core was taken of the Coloso silty clay at the margin of the field in order to evaluate the general characteristics of this soil type as it appeared in this area. The sample was taken to a depth of 72 inches by using a Kelly soil-sampling machine (3). The soil core was differentiated into horizons, and certain morphological, physical, and chemical tests were made on these horizon samples. The methods and procedures used for permeability measurements, quick drainage, pF, and volume weight were given in detal in another publication(4).

THE SOIL

The Coloso silty clay of which there are 14,976 acres in Puerto Rico (6) is a poorly drained soil of the river flood plain which occurs in the humid and subhumid sections along the western, northern, and eastern coasts of Puerto Rico. The soil is normally only a few feet above sea level, the water table averages less than 24 inches from the surface, and most of the areas are subjected to frequent inundations and sedimentations. The soils are heavy-textured, having been formed from the slow accumulations of sediments derived from neutral fine-textured materials washed from soils derived from fine-grained volcanic rock and limestone. The subsoil is a heavy plastic clay, mottled and poorly drained.

On March 11, 1952, a profile of a Coloso silty clay was examined at the border of the sugarcane experiment at the San Francisco Farm near Arecibo. The land was flat with no apparent signs of erosion and some signs of deposition, and the vegetative cover was sugarcane. The root development was very good down to a depth of 20 inches. All horizons had a fine-sized internal porosity and a moisture content above field capacity.

0–14″ Plow layer of dark grayish-brown dense silty clay with grayish mottling spots near surface. Moderate blocky structure with some horizontal overlap. pH 6.0 for the 0–6″ layer and 6.8 for the 6–12″ layer.

14–26″ Dark-brown dense clay with dark grayish-brown mottling spots. Moderate to weak fine blocky structure with vertical overlap. pH 6.8.

TABLE 2.—*Permeability and other soil-moisture data on soil cores from a Coloso silty clay*

Depth (inches)	Permea-bility	Water drained at 60 cm. in 15 minutes	Maximum saturation	Water remaining at pF of—			Available water (water held between pF. 1.9 and pF 4.2)	Volume-weight
				1.9	2.7	4.2		
	In./hr.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Cm./c.c.*
0–7	1.96	0.6	54.7	51.0	34.7	21.2	29.8	1.20
7–14	.78	1.7	50.9	44.7	36.3	23.0	21.7	1.30
14–26	7.00	2.3	52.1	47.7	34.8	25.3	22.4	1.27
26–33	1.98	1.0	51.3	48.3	35.5	27.5	20.8	1.29
33–40	2.80	1.3	51.3	48.5	35.9	28.1	20.4	1.29
40–56	1.58	1.0	52.1	49.9	39.2	29.7	20.2	1.27

26–40″ Dark grayish-brown heavy clay quite similar in color to surface horizon, and suggestive of deposition. Moderate blocky structure with horizontal overlap. pH 7.0.

40–56″ Gray and yellow mixed heavy dense clay with some iron concretions. Moderate to weak large blocky structure with both horizontal and vertical overlap. pH 6.9.

The physical properties of the profile are given in table 2. The percolation rate was slow throughout the profile except for the 14–26-inch layer which had high values caused by worm and root holes. The quick drainage (water drained at 60 cm. in 15 minutes) was low, indicating the poor drainage obtained in this soil. The maximum saturation values were high (above 50 percent) and changed very little throughout the profile. The water remaining at pF 1.9 averaged 48.4 percent and showed a high field capacity. The values were high at pF 4.2 (considered the permanent wilting point) indicating that the soil retained large amounts of water unavailable for the use of the plant.

If the available water for the crop is regarded as the difference between water remaining in the soil when tensions equivalent to pF 1.9 are applied and that remaining when permanent wilting occurs (pF 4.2), this soil does have a moderately high water-supplying power, despite its high values at the permanent wilting point. In general, the physical values show that this soil, Coloso silty clay, is one where drainage and excess water are problems to be contended with in growing crops.

EXPERIMENTAL RESULTS

Unfortunately, soil samples were not taken at the initiation of this experiment in 1944, so that comparisons could not be made with original soil values. However, the influence of nitrogen, phosphorus, or potassium fertilizers on the soil can readily be determined by comparing those treatments

TABLE 3.—*The influence of fertilizer levels for sugarcane on certain chemical soil properties of a Coloso silty clay*

Treatments (pounds per acre)			Organic matter	Soil pH	Soil N	Available soil P	Available soil K
N	P_2O_5	K_2O					
Nitrogen treatments							
			Percent		*Percent*	*P.p.m.*	*P.p.m.*
0	300	300	2.0	5.9	0.14	40	110
125	300	300	2.1	5.8	.14	37	86
250	300	300	2.1	5.7	.13	36	81
Phosphorus treatments							
250	0	300	2.2	5.6	0.14	32	83
250	150	300	2.0	5.7	.14	32	84
250	300	300	2.1	5.7	.13	36	81
Potassium treatments							
250	300	0	2.1	5.6	0.14	31	61
250	300	150	2.2	5.7	.14	36	79
250	300	300	2.1	5.7	.13	36	81
Least significant difference needed between treatments at:							
5-percent level			—	—	—	8	12
1-percent level			—	—	—	11	16

where a particular fertilizer element was varied from none to high applications. A summary of the values obtained for certain chemical soil properties at different fertilizer levels is given in table 3.

SOIL ORGANIC MATTER

The organic-matter content of the soil was not significantly influenced by variations in nitrogen, phosphorus, or potassium fertilizers. Although the no-nitrogen treatment averaged 26 tons of cane less per acre than the 250-pound-N-per-acre treatment (table 4, treatment 1 minus treatment 7), there was still sufficient organic material produced by roots, stubble, and cane trash of the 40 tons per acre to maintain the organic-matter content of the soil.

SOIL NITROGEN

The nitrogen content of the soil showed no significant variation with any of the fertilizer treatments used. The no-nitrogen treatments revealed no lower soil-nitrogen content, although no nitrogen fertilizer had been applied

TABLE 4.—*Mean yields of 4 sugarcane varieties grown at different fertilizer levels for 7 crops*

Treatment No.	Treatments in pounds per acre of—			Cane per acre	Available 96° sugar per acre	Sucrose in cane
	N	P_2O_5	K_2O			
				Tons	*Cwt.*	*Percent*
1	0	300	300	40.0	91	11.84
2	125	300	300	58.5	133	12.09
3	250	0	300	65.0	144	11.90
4	250	150	300	65.7	145	11.87
5	250	300	0	61.3	133	11.57
6	250	300	150	65.2	141	11.69
7	250	300	300	65.2	147	11.94
Mean for all treatments				60.1	134	11.84

for 9 years. Nor did increasing increments of nitrogen (125 and 250 pounds of N per acre respectively) increase the soil nitrogen over the level of the no-nitrogen plots.

SOIL pH

The use of various fertilizer levels did not significantly influence soil pH. During the 9 years of the experiment a total of 8,750 pounds of sulfate of ammonia were applied to the 250-pound-N-per-acre plots. This represents an equivalent acidity that would require 9,630 pounds of calcium carbonate to neutralize. No lime was applied in this experiment but, as can be seen from table 3, the pH of the soil was not decreased significantly when ammonium sulfate treatments are compared with the no-nitrogen treatment.

When used over long periods ammonium sulfate has been found to lower the pH of the soil. Cooper (1) stated that the use of 250 pounds of ammonium sulfate yearly for 21 years on an Orangeburg fine sandy loam lowered the pH from 5.9 to 4.9 in South Carolina. Chardón and Méndez (5) found that the use of 625 pounds of ammonium sulfate annually for 6 years did not lower the pH of a Vega Baja silty clay with a pH of 5.9. The use of ammonium sulfate for 9 years failed to lower the pH of the Coloso silty clay.

However, there are certain compensating factors which tend to nullify the acidity of the sulfate of ammonia in this experiment. One is the heavy texture of the silty clay with its high buffer capacity as compared with the light texture of the sandy loams of the eastern United States. Another aid in counteracting the acidity of the ammonium sulfate is the large quantity of base returned by the cane trash. A 50-ton crop of cane will return bases to the soil equivalent to approximately 1,750 pounds of $CaCO_3$[3].

[3] Based on a 4:1 cane-to-trash ratio with a 1.8 percent CaO and 1.6 percent MgO content (2) of the cane trash on a dry-weight basis.

AVAILABLE SOIL PHOSPHORUS

There was no significant difference in available soil phosphorus for any of the treatments (table 3). Soil phosphorus showed no significantly lower value when no phosphorus was applied than when 300 pounds of P_2O_5 per acre were applied. There was no increase in cane tonnage or sugar that could be attributed to the use of the phosphate fertilizers (table 4). It appears, therefore, that values of over 30 p.p.m. available soil phosphorus are adequate for the Coloso silt loam to produce optimum yields.

AVAILABLE SOIL POTASSIUM

Significantly lower available soil-potassium values were obtained when no potash had been applied for 9 years as compared with the potash-treated plots (table 3). There were also significant differences in yield attributable to the use of potash (table 4). It appears from these results that, for this experiment, values of available soil potassium of 60 p.p.m. or less, indicated a definite deficiency of potassium. Soil-potassium values were not significantly changed when 300 pounds of K_2O were applied in lieu of 150 pounds per acre.

The available potassium increased significantly where no nitrogen was used (table 3). In fact, the available potassium increased with decreasing nitrogen applications. This may be attributed, in part, to the fact that yields were 20 tons lower when no nitrogen was applied to the soil, hence the crop removed less potassium from it.

DISCUSSION

Cropping of sugarcane for over 9 years at various fertilizer levels had no significant influence on the level of organic matter, nitrogen, pH, and available phosphorus in a Coloso silty clay soil.

It would perhaps seem logical that removing an average of 50 tons of cane per acre yearly from the soil would produce some measurable changes in soil fertility. The omission of nitrogen and potassium fertilizers did not significantly reduce cane tonnage or sugar content. From a soil-chemical standpoint we could detect only a reduction in "available" soil potassium. Soil organic matter and nitrogen were of no value as guides to the nitrogen-fertility status of this soil.

One possible reason for the lack of large changes in certain chemical soil indices is the cane crop itself. For even when 50 tons of cane per acre are taken away yearly, a high percentage of organic matter and mineral elements remains behind as cane trash (dried cane leaves, tops, and stubble). In table 5 a summary of the quantity of materials removed from the field and that left behind is given. On harvesting 50 tons of cane per acre there are removed from the field 43 pounds of N, 43 pounds of P_2O_5, and 59 pounds of K_2O per acre. Left behind in the trash to decompose and enter

TABLE 5.—*Quantities of plant nutrients and fertilizer materials involved in harvesting a 50-ton crop of P.O.J. 2878 growing on a Coloso silty clay at Arecibo*

Item	Nutrient content per acre as—			Fertilizer equivalent per acre as—		
	N	P_2O_5	K_2O	Ammonium sulfate (20-percent N)	Superphosphate (20-percent P_2O_5	Potassium chloride (60-percent K_2O)
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Millable cane stalks[1]	43	43	59	215	215	100
Cane trash[2]	150	97	285	750	485	475
Total	193	140	344	965	700	575
Fertilizer added	250	300	300	1,250	1,500	500

[1] Based on a 73-percent cane-stalk moisture and a nutrient content of 0.16 N, 0.07 percent P, and 0.18 percent K, on a dry-weight basis.

[2] Based on a 4:1 cane stalk-to-dry-trash ratio with an average nutrient content of 0.6 percent N, 0.17 percent P, and 0.93 percent K, on a dry-weight basis.

the soil are approximately 150 pounds of N, 97 pounds of P_2O_5, and 285 pounds of K_2O per acre. The trash also contributes 2,000 pounds of humus (C:N ratio 10:1) to the soil in return for the 50 tons of cane harvested.

It is apparent from table 5 that large quantities of plant nutrients are in transit in the soil. There is the material added by man, in this case as inorganic fertilizers, the nutrients removed by the harvested cane, and those materials in organic form returned to by the trash. This large interchange of plant nutrients has buffered some of the expected changes in chemical soil properties which might be associated with constant cropping at different fertilizer levels. At least for the Coloso silty clay cropped for over 9 years to sugarcane at various fertilizer levels, the influence of these fertilizer levels on certain chemical soil properties was not as appreciable as was the fertilizer influence on cane yield.

SUMMARY

The findings in this study of the influence of different fertilizer levels on a Coloso silty clay for over 9 years of sugarcane cropping were:

(1) A morphological description of a Coloso silty clay profile is given together with data on certain physical properties of the soil.

(2) There were no significant differences in soil organic matter, nitrogen, or available phosphorus attributable to any of the fertilizer levels used.

(3) The available soil-potassium values were significantly lower where no potash was applied than where potash treatments were used.

(4) There were no differences in soil pH where sulfate of ammonia was used as compared with the no-nitrogen treatment.

(5) A discussion is presented of the amounts of plant nutrients removed from the soil by the cane and added to it in the cane trash. This indicates that when sugarcane is grown, large quantities of plant nutrients are in transit in the soil, and this interchange of plant nutrients buffers some anticipated changes in chemical soil properties that might otherwise be associated with constant cropping.

RESUMEN

La influencia de distintos niveles de abonamiento sobre un suelo Coloso limoarcilloso sometido durante 9 años al cultivo de la caña de azúcar, se reveló como sigue:

(1) No hubo diferencias significativas en cuanto a materia orgánica, nitrógeno o fósforo asimilable que pudieran atribuirse a alguno de los niveles de abonamiento usados.

(2) Los valores del potasio asimilable en el suelo fueron significativamente menores donde no se aplicó potasa que donde se aplicó.

(3) No hubo diferencias en el pH del suelo cuando se usó sulfato amónico en comparación con el tratamiento donde no se usó este elemento fertilizante.

En este trabajo se incluye una descripción morfológica del perfil Coloso limoarcilloso, como también datos sobre ciertas propiedades físicas del suelo. Se discute, a la vez, sobre la cantidad de nutrimentos que la caña remueve del suelo y que luego pasa, en parte, a la paja.

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