Performance of Sugarcane Var. P.R. 980 Grown on a Partially Reclaimed Saline Sodic Soil of the Lajas Valley

Raúl Pérez Escolar and José S. Ortiz Vélez[1]

ABSTRACT

Sugarcane var. P.R. 980 performed very well when grown on a partially reclaimed saline sodic soil of the Lajas Valley, Puerto Rico. Varying levels of rum distillery slops and one of black strap molasses had been applied to Fe clay, a Vertisol, on the premise that these two materials stabilize soil aggregates and improve the movement of water for reclamation. After 6.1 m/ha of water had been applied to the plots, and the conductivity of the soil saturation extract was about 4 on the top 30 cm, sugarcane var. P.R. 980 was planted. The yield data for 6 crops, including two plant canes and their corresponding two ratoons, were collected and analyzed. In the combined first 3 crops, the 31 cm slops treatment was significantly better sugar yieldwise than the 6.2 cm treatment. When cane tonnage and sugar of the second plant cane and its two ratoons were combined, the 18.6 and 31 cm of slops were far superior to the check, 6.2 cm slops treatment and the molasses treatment. Salinity was reduced markedly in the top 60 cm of soil. Cane and sugar yield differences between high slops treatments and check widened with time.

INTRODUCTION

Soil salinity problems exist in a rather large area in Puerto Rico, particularly in the Lajas Valley and at Caño Tiburones between Barceloneta and Arecibo. Bonnet (1) reported around 4,100 hectares affected by salts which impair normal crop development, via osmotic and probably ion species effects.

Shen and Tung (6) have indicated that sugarcane varieties differ greatly in their tolerance to salts. Shoji and Sund (7) concluded that an electrical conductivity of 4 mmhos/cm of the soil saturation extract constituted the point above which sugarcane growth was markedly reduced.

In an attempt to satisfy the ever-increasing demands for salinity resistant varieties, Liu (4) conducted a study to evaluate this characteristic among current varieties in the Puerto Rico sugar industry. His studies concluded that the rankings of the sugarcane varieties from the most resistant to the least resistant were as follows: P.R. 1028 > P.R. 1059 > Co. 419 > M. 336 > P.R. 980 > P.R. 1017 > P.R. 1016 > P.R. 1048 > P.R. 1000.

The purpose of the present study was to determine the behavior of a

[1] Soil Scientist and Drainage Scientist, Agricultural Experimental Station, University of Puerto Rico, Mayagüez Campus, Río Piedras, P.R. The authors wish to express their gratitude to the personnel of the Sugar Corporation, formerly Land Authority of P.R., for their valuable help in the course of the experiment.

medium class salinity resistant sugarcane variety, P.R. 980, on a partially reclaimed saline sodic soil of the Lajas Valley.

MATERIALS AND METHODS

The experiment was conducted on a partially reclaimed Fe clay soil, a Vertisol from southwestern Puerto Rico. The morphological and some physical, chemical and mineralogical characteristics of the soil were determined prior to the reclamation phase. We estimated the pH electrometrically on a 2:1 distilled water to soil suspension employing a Beckman pH meter. Organic matter was determined by the chromic acid reduction method (8). Cation exchange capacity was measured by the Ba-acetate method (5). Electrical conductivity of the saturation extract was determined with a standard Solubridge. Ca + Mg were measured by the Versenate titration method (2). Soluble sodium was estimated by substracting the Ca + Mg from the value obtained by multiplying electrical conductivity by 10. We estimated exchangeable sodium percentage using a nomogram which has soluble Ca + Mg and Na as variables (9).

Particle size distribution was determined by the pipette method as modified by Kilmer and Alexander (3).

Using an RCA-Leiments crystalloflex IV X-ray diffractometer with an automatic recording device, we determined the mineralogical characterization of the clay fraction.

The reclamation experiment had begun in August 1958 on plots 3.05 × 3.05 m in a randomized block design with 3 replicates. Two tile drain lines—10 cm in diameter, 1.37 m deep and 6.1 m apart—took care of the percolating waters originating from irrigation and rainfall. The treatment differentials were as follows:

1) Control; 2) 6.2 cm of slops; 3) 18.6 cm of slops; 4) 31.0 cm of slops; and 4) 31.0 cm of 20% by vol of blackstrap molasses.

The plots received a total of 6.1 m water including irrigation and rainfall. When approximately two thirds of the salt on the top 60 cm had been leached, and the conductivity of the saturation extract was around 4 mmhos on the top 30 cm, the experiment was planted to sugarcane, var. P.R. 980. Two rows 1.37 m apart were planted per plot. The plots received fertilizer of 14-4-10 analysis at a rate of 1684 kg/ha when the cane had emerged. Water with a mean salt content of 145 p/m was applied every 2 weeks at a rate of 25 cm until about 2 months before harvest.

The experiment included a total of six crops, two plant crops and their corresponding two ratoons. Soil samples were taken immediately after each crop harvest at 15 cm intervals, down to 60 cm depth. They were analyzed for conductivity of the saturation extract and reported as mmhos/cm (E. C. $\times 10^3$).

TABLE 1.—*Chemical, physical and mineralogical characteristics of soil samples prior to slops and molasses application*

Depth	Conductivity	Exchangeable Na	pH	Organic matter	C.E.C.	Sand	Silt	Clay	Clay minerals
Cm	*Mmhos/cm*	%		%	*Meq/100 g*	%	%	%	
0–15	10.0	34	8.7	3.0	47.7	16.8	20.6	62.6	Montmorillonite, calcite and traces of quartz and kaolinite
15–30	13.3	39	8.8	—	—	—	—	—	
30–45	23.2	40	8.7	—	—	—	—	—	
45–60	28.4	42	8.7	—	—	—	—	—	

RESULTS AND DISCUSSIONS

Table 1 shows data on some chemical, physical and mineralogical characteristics of Fe clay soil. The soil is highly saline and sodic, both properties affecting adversely the development of agricultural crops. Silt and clay total above 80%, a fact that in itself reflects the high plasticity which makes the tillage operations more difficult. The cation exchange capacity is high, 47.7 meq/100 g, a property which is indicative of the capacity of the soil to retain nutrient ions in an exchangeable form. The predominant clay mineral in the clay fraction is montmorillonite, with a high coefficient of linear expansibility.

Table 2 shows the chemical composition of blackstrap molasses and rum distillery slops, the materials used mainly as soil conditioners for the reclamation phase. The materials are relatively high in nitrogen, potassium, calcium, magnesium and sulfur. The sodium content is quite low in both cases.

TABLE 2.—*Chemical analysis of blackstrap molasses and rum distillery slops*[1]

Percent	Molasses	Slops
Water	25.4	90.0
Nitrogen	1.1	0.2
Phosphorus	0.1	0.003
Potassium	2.7	0.6
Calcium	1.0	0.2
Magnesium	0.5	0.1
Sodium	0.2	0.02
Sulfates	2.4	0.3
Chlorides	1.1	0.2
Sucrose	32.0	4.0
Reducing sugars	30.0	0.6
Caramel	—	2.9

[1] Information taken from Pérez-Escolar, Raúl, "The soil conditioning properties of blackstrap molasses and rum distillery slops, Ph.D thesis, Rutgers University, 1962.

Table 3 shows the mean salt content of field plots with their indicated treatments. With the application of rum distillery slops, the initial salt content increased by about 23%. Afterwards 6.1 m of water, around two-thirds of the total salt content, was removed from the topmost 60 cm on all treatments. A high potassium content was contributed by rum distillery slops, 1.89, 5.66 and 9.44 meq/100 g of soil in treatments 2, 3 and 4, respectively.

Table 4 shows the electrical conductivity and E.S.P. values measured after the application of 6.1 m of water (rainfall and irrigation). The conductivity values from the osmotic concentration point of view were relatively normal for sugarcane growth. The exchangeable sodium percentage, a property affecting soil physical properties is relatively high.

TABLE 3.—*Mean initial salt content, salt content after 6.1 m/ha of water, percentage of salt removed per treatment on top 60 cm of soil, and potassium contributed by slops and molasses*[1]

Treatment	Salt content	Salt content after 6.1 m/ha of water	Salt removed	Potassium contributed by slops
	Kg/ha	*Kg/ha*	%	*Meq/100 g*
1. Check	73394	27731	62	0
2. 6.2 cm of slops	94579	30965	63	1.89
3. 18.6 cm of slops	80539	34434	57	5.66
4. 31.0 cm of slops	97299	39000	60	9.44
5. 31.0 cm of molasses 20% by vol.	97567	42193	57	8.50

[1] Includes soil solution salt plus that contributed by slops and molasses.

TABLE 4.—*Electrical conductivity and exchangeable sodium percentage for various treatments after the application of 6.1 m of water, prior to sugarcane planting*

Treatment	Depth	Conductivity	Exchangeable Na
	Cm	*Mmhos/cm*	%
1. Check	0–15	2.7	24
	15–30	4.4	29
	30–45	4.6	30
	45–60	12.2	34
2. 6.2 of slops	0–15	2.1	19
	15–30	2.6	30
	30–45	6.2	36
	45–60	13.0	34
3. 18.6 cm of slops	0–15	2.3	20
	15–30	3.9	31
	30–45	9.8	32
	45–60	14.0	31
4. 31.0 cm of slops	0–15	2.3	20
	15–30	2.7	29
	30–45	8.9	35
	45–60	14.4	34
5. 31 cm molasses 20% by vol.	0–15	3.1	21
	15–30	6.4	35
	30–45	13.7	37
	45–60	20.0	33

Part of this so called exchangeable sodium may be due to the K added with the slops and the molasses. The physical properties should thus be more favorable when exchange K is high.

Table 5 shows the yield values on cane and sucrose throughout six crops which included two plant canes and their corresponding two ratoons. In none of the six crops were there significant differences in cane and sucrose values among treatments when analysis of variance was run

TABLE 5.—*Cane and sucrose yields of the various slops and molasses treatments at the indicated crop number*

Treatment	Crop number												Average yield per treatment	
	1		2		3		4		5		6			
	Cane	Sucrose t/ha	Cane	Sucrose t/ha	Cane	Sucrose t/ha	Cane	Sucrose t/ha	Cane	Sucrose t/ha	Cane	Sucrose t/ha	Cane	Sucrose t/ha
1. Check	104.45	10.03	102.73	10.78	82.26	8.35	127.09	14.22	114.69	13.32	119.85	14.39	108.52	11.86
2. 6.2 cm of slops	97.40	9.15	108.21	11.13	86.26	8.38	123.86	14.22	127.34	14.80	126.08	15.12	111.56	12.14
3. 18.6 cm of slops	109.39	10.22	99.38	10.67	89.67	9.21	135.05	15.53	137.74	15.96	152.71	18.17	120.69	13.29
4. 31.0 cm of slops	106.75	10.31	116.17	12.71	94.87	9.19	131.14	15.29	129.40	15.61	143.90	17.65	120.35	13.47
5. 31.0 cm of molasses 20% by vol.	100.28	9.15	104.36	10.35	91.22	8.78	120.41	14.43	114.52	13.21	127.36	15.08	109.65	11.83

on each individual crop. However, when the first plant cane and its two ratoons and the second plant cane and its corresponding two ratoons were combined (table 6), statistically significant differences were measured. In the combined first three crops the 31.0 cm slops treatment was significantly better sugar yieldwise than the 6.2 cm slops treatment if treatment 5 is not considered in the analysis of variance. When cane tonnage of the second plant cane and its two ratoons were combined, treatment 3, 18.6 cm of slops, outyielded in a highly significant way the check and the molasses treatments. Treatment 4, 31.0 cm/ha of slops, also significantly outyielded the check and molasses. Sugar yields of treatment 3 and 4 were superior to the check and molasses treatments at the 5% level of probability.

Molasses was no better than the check treatment throughout the six

TABLE 6.—*The effect of distillery slops and molasses on cane and sugar yields of cane var. P.R. 980*

Treatment	Combined yield data for			
	1964–1965–1966		1967–1968–1969	
	Cane	Sucrose	Cane	Sucrose
	t/ha		*t/ha*	
Check	134.65 a	13.57 b	168.38 a	19.56 a
6.2 cm/ha of slops	136.05 a	13.34 a	175.72 a	20.52 a
18.6 cm/ha of slops	138.82 a	14.01 b	198.09 b	23.02 b
31.0 cm/ha of slops	147.83 a	14.98 b	188.33 b	22.67 b
31.0 of molasses[1] 20% by vol	137.62	13.15	168.64 a	19.88 a

[1] Not included in the analysis of variance for the first three years.

crops. Because of its high sugar content, microbial products forming from molasses should have but did not contribute to the development of favorable soil structure. Its mineral content, at the rate used, was similar to that of slops. The check treatment was a good sugar yielder in all crops. This fact leads us to postulate that as long as good quality water and drainage are provided on a saline sodic soil, the salt level on the top 30 cm can be brought with 6 m of water to a point where cane can be economically grown. The acid fertilizers used for the sugarcane crop dissolve to a certain extent the free calcium carbonate, bringing into circulation mobile Ca ions which displace exchangeable sodium that is drained in the percolating waters.

Table 7 shows the electrical conductivity values per treatment after each crop harvest. After the last crop, the values on the top 60 cm were between 2 and 3 mmhos/cm, indicating the movement of salts within a more porous soil resulting from root penetration, which creates the structure mechanically and is further stabilized by the microbial gums and other types of cementing agents.

RESUMEN

La variedad de caña PR 980 se comportó muy bien cuando se sembró en la arcilla Fe del Valle de Lajas, un Vertisol salino-sódico que se había restaurado parcialmente. Originalmente las parcelas habían sido tratadas con varios niveles de mosto de las destilerías y con melaza al 20% por volumen. Estos tratamientos se aplicaron a base del hecho de que el mosto y la melaza probaron ser magníficos acondionadores de los suelos de pobre estructura en el Valle de Lajas. Después que las parcelas habían recibido un total de 6.1 m/ha de riego y lluvia, y la conductividad eléctrica del extracto de saturación de los primeros 30 cm superficiales del suelo era de unos 4 mmhos/cm, se sembró caña de azúcar de la variedad mencionada. Se analizaron estadísticamente los

TABLE 7.—*Mean electrical conductivity values of the saturation extracts of top 60 cm soil samples after each cane harvest*

Treatment	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6
1. Check	5.21	5.68	5.67	3.16	3.34	3.70
2. 6.2 cm/ha of slops	3.96	4.06	4.42	3.57	3.80	3.07
3. 18.6 cm/ha of slops	6.80	5.20	3.73	3.87	4.00	3.13
4. 31.0 cm/ha of slops	5.88	3.98	4.09	3.49	2.55	2.77
5. 31.0 cm/ha of molasses 20% by vol.	5.53	6.03	7.15	2.20	4.38	2.70

datos de rendimiento de dos plantillas y sus correspondientes dos retoños en forma combinada; es decir, se estudió el efecto de los tratamientos sobre la producción de caña y azúcar producidas en dos ciclos. En el primer ciclo (años 1964–65 y 66), el tratamiento de 31 cm/ha de mosto fue significativamente mejor que el de 6.2 cm/ha, en términos de producción de azúcar. En el segundo ciclo (años 1967–68 y 69) los tratamientos de mosto de 18.6 cm/ha y 31 cm/ha fueron estadísticamente superiores al control y al de melaza. Con el tratamiento de mosto de 18.6 cm/ha se obtuvieron 32 quintales de azúcar por acre sobre el control. Con todos los tratamientos la salinidad de los 60 cm superficiales de suelo bajo notablemente. Con los de mosto los rendimientos de caña y azúcar aumentaron con el tiempo.

LITERATURE CITED

1. Bonnet, J. A., 1953. Soil salinity studies as related to sugarcane growing in southwestern P. R., J. Agri. Univ. P. R., 37 (2): 103–13.
2. Cheng, K. and Bray, R. H., 1951. Determination of calcium and magnesium in soil and plant material, Soil Sci. 72: pp. 449–458.

3. Kilmer, V. J. and Alexander, J. T., 1949. Methods of making mechanical analysis of soils, Soil Sci. 68: 15–24.
4. Liu, Lii-Jang, 1967. Salinity effects on sugarcane germination, growth and root development, J. Agri. Univ. P. R., 51 (3): 201–209.
5. Parker, F. W., 1929. The determination of exchangeable hydrogen in soils, J. Am. Soc. Agron., Vol. 21, pp. 1030–1039.
6. Shen, I. S. and Tung, H. L., 1964. Study on salt tolerance in sugarcane, Rep. Taiwan Sugar Exp. Stn. 35: 1–24.
7. Shoji, K. and Sund, K. A., 1965. Drainage and salinity investigation at the Halft Tapeh sugarcane project, Iran, Proc 12th Congr. I.S.S.C.T.
8. Walkley, A. and Blake, T. A., 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chomic acid titration method, Soil Sci. 37: 29–38.
9. The United States Salinity Laboratory Staff, 1954. Diagnosis and Improvement of Saline and Alkali Soils, USDA. Agri. Handbook No. 60, p. 103.