Reclamation of a Saline-Sodic Soil by Use of Molasses and Distillery Slops

Raúl Pérez Escolar[1]

INTRODUCTION

Reclamation of saline, and saline-sodic soils low in organic matter constitutes a potential major problem in many areas of the world. Removal of soluble salts by leaching from a soil high in free salts and low in exchangeable sodium may result in the formation of solonetzic horizons at lower depths by a mass-action effect. Similarly, the removal of free salts from a soil with a relatively high content of exchangeable sodium may result in the formation of sodic layers in the entire profile. The increase in the electrokinetic potential by the enhanced dissociation of the hydrated sodium ions results in the dispersion of the soil colloids with the corresponding clogging up of soil pores which creates poor air: water relations.

REVIEW OF LITERATURE

An intensive search of the literature revealed that not a single attempt had been made to use rum distillery slops as a soil ammendment to improve structural conditions in saline-sodic and sodic soils. This may be because most distilleries discharge this waste-product directly into the oceans and rivers.

Dhar and Mukerji (*2*)[2] appear to be the only investigators who conducted experimental work using blackstrap molasses to help reclaim solonetzic soils. They claim to have brought these soils back to "normal conditions" in a period of 6 months when molasses was applied at the rates of 30 to 40 tons to the acre. They believed that their results were produced by the acidity of molasses and the organic acids such as acetic, propionic, butyric, and lactic, produced upon decomposition of the molasses. These acted to neutralize the bases and carbonates present in soil rich in alkali. It was also proposed that, in the process, the evolution of CO_2 from the molasses-treated soil rendered it porous and improved its tilth. It was observed that microbial activity, which is normally low at the prevailing pH of sodic soils, was considerably increased. Soil nitrogen content was increased from 0.0025 to 0.05 percent. This increase in soil nitrogen was caused by greater fixation of atmospheric nitrogen by micro-organisms.

[1] Associate Soil Scientist, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[2] Italic numbers in parentheses refer to Literature Cited, p. 217.

MATERIALS AND METHODS

The soil used in this experiment was a saline-sodic Fe clay of southwestern Puerto Rico. It is associated with other soils of the alluvial fans in the semi-arid sections from Boqueron to Guayama. The surface soil in a cultivated field is a grayish-brown granular calcareous clay, very plastic when wet and either granular or cloddy when dry, depending on the moisture condition

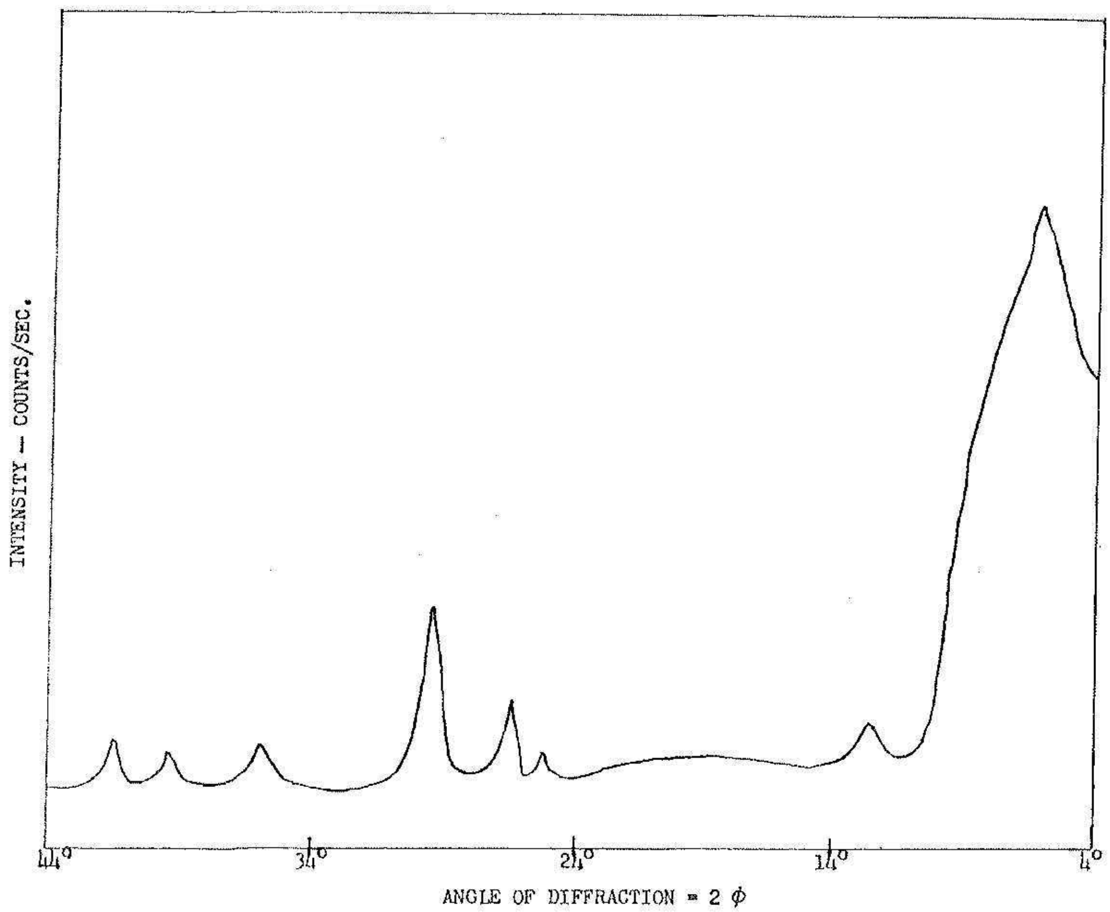

FIG. 1.—X-ray diffractogram of clay fraction of Fe soil.

of the soil when plowed. The subsoil, to a depth of approximately 20 inches, is light pinkish-brown or purplish-brown plastic calcareous medium-compact columnar clay. Montmorillonite, as shown in fig. 1, is the predominant clay mineral in the soil colloidal fraction. Kaolinite and quartz are found in traces.

This soil was 43-percent sodium-saturated and the conductivity of the saturation extract of the soil was 67 mmhos per centimeter. The soil was broken up with a wooden rolling-pin and aggregates of 2- to 1-mm. size were separated. Seven hundred and fifty grams of these aggregates were placed in glass tubes of 1¾-inch interior diameter and 24 inches long. To insure uniform soil-packing, the columns were subjected to a vibrating machine for 1 minute. The following treatments, in duplicate, were established:

1. Control.
2. A third of soil column wetted with slops.
3. Two-thirds of soil column wetted with slops.
4. The whole soil column wetted with slops.
5. A third of the soil column wetted with 25 percent by volume of blackstrap molasses.
6. The whole soil column wetted with 25 percent by volume of blackstrap molasses.

Exactly 1 day after the treatments were applied 3.4 inches of tapwater were added to the soil columns. Thereafter, the columns were watered every other day at this rate. After each foot of water had been passed through the column, the leachate was collected and the following measurements were made: 1, Volume of leachate; 2, pH; 3, specific conductance; and 4, sodium, calcium, and magnesium contents.

When 6 feet of water had been passed through the columns, the soil tubes did not receive any additional water for 1 month. This was done to determine whether a drying period would alter the effects produced by use of blackstrap molasses and of distillery slops. When this period was ended watering was resumed as before.

After a total of 12 feet of water had been passed through the columns, the soils were taken out undisturbed and cut into sections 5 inches long. The following measurements were made on these sections: 1, pH; 2, saturation percentage; 3, specific conductance of the saturation extract; and 4, content of exchangeable sodium and calcium and magnesium in the saturation extract.

The pH of the leachates and of the soil was determined electrometrically, employing a Beckman pH-meter. Calcium and magnesium contents of leachates were determined by the E.D.T.A. method (*1*). Specific resistance of the saturation extracts and of the leachates was determined with a Wheatstone bridge using a cell with a constant of 1. Electrical conductivity was calculated by multiplying the measured negative resistance by the cell constant. Exchangeable sodium was determined by plotting the values of soluble Ca, Mg, and Na into a nomogram.

Soil organic matter was determined by the chromic acid reduction method (*6*). Cation-exchange capacity of the soil was determined by the barium acetate method (*4*).

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

The minerals present in the soil colloidal fraction were determined using an RCA-Leiments Crystalloflex IV X-ray diffractometer with an automatic recording device.

RESULTS AND DISCUSSION

This reclamation experiment in the laboratory was a complete success and the results of these studies and the characteristics of the Fe clay soil

TABLE 1.—*Sodium content of leachates collected during the percolation of 12 feet of water through soil columns treated with distillery slops or molasses (meq. per leachate) at different levels*

Foot No.	Check	Low slops	Medium slops	High slops	Low molasses	High molasses
1	169.53	291.35	259.98	276.26	224.28	275.27
2	55.98	65.10	42.49	42.02	73.09	47.72
3	15.89	18.97	15.08	13.91	15.91	10.78
4	11.35	14.42	14.02	10.66	12.52	8.28
5	7.65	10.35	8.74	8.18	8.73	3.49
6	5.89	8.76	7.50	6.58	6.06	4.47
7	8.33	8.77	6.79	4.10	4.79	1.64
8	7.98	6.40	3.99	2.36	4.02	1.66
9	6.78	4.42	2.13	1.24	2.27	1.04
10	3.24	3.59	.63	.45	.91	.92
11	2.17	2.87	.31	.32	.33	.38
12	1.88	2.02	.23	.23	.23	.36

are presented in tables 1 through 5, and in the following tabulation, showing some chemical and physical data on the Fe clay soil:

pH	*Organic-matter, Percent*	*Cation-exchange capacity, Meq./100 gm.*	*Saturation, Percent*	*Conductivity, C.C. × 10³ Mmhos*	*Exchange Na, Percent*	*Sand, Percent*	*Silt, Percent*	*Clay, Percent*
8.2	3.00	47.7	75	66.7	43	16.8	20.6	62.6

All soil columns treated with slops or molasses at the end of the test exhibited excellent drainage characteristics. The first 3 acre-feet of water passed through the treated soil columns removed approximately 92 percent of the exchangeable, or free sodium salts present. Complete wetting of the soil columns with either slops or molasses, followed by irrigation, yielded leachates that contained more calcium and magnesium than those under all of the other treatments. As was the case with sodium, the bulk of the Ca and Mg was also removed by the first 3 acre-feet of irrigation water passed through these columns.

That most Ca and Mg was found in leachates of columns treated with the highest level of the slops or molasses may have occurred because of the production of organic acids during the decomposition of both slops and molasses. These organic acids rendered soluble the $CaCO_3$ and $MgCO_3$ present in the soil. The recovery of applied water varied with the treat-

TABLE 2.—*Calcium content of leachates collected during the percolation of 12 feet of water through soil columns treated with distillery slops or molasses (meq. per leachate) at different levels*

Foot No.	Check	Low slops	Medium slops	High slops	Low molasses	High molasses
1	14.61	15.17	29.63	49.96	26.53	47.82
2	2.03	2.59	1.13	2.29	3.16	11.25
3	.81	.89	.50	.53	.70	1.32
4	.79	.88	.88	.64	.99	1.74
5	.37	.29	.27	.42	.46	1.61
6	.18	.23	.32	.65	.43	1.28
7	.19	.25	.24	.56	.38	1.54
8	.16	.21	.37	.35	.45	1.12
9	.17	.16	.37	.43	.62	.96
10	.11	.08	.46	.48	.58	1.12
11	.12	.17	.46	.44	.59	1.11
12	.11	.53	.64	.46	.62	1.05

TABLE 3.—*Magnesium content of leachates collected during the percolation of 12 feet of water through soil columns treated with distillery slops or molasses (meq. per leachate) at different levels*

Foot No.	Check	Low slops	Medium slops	High slops	Low molasses	High molasses
1	29.22	35.77	64.27	84.55	46.07	95.64
2	7.31	8.23	4.86	7.65	12.31	18.20
3	.80	.65	.77	.92	.94	3.43
4	.75	.58	.96	.96	1.26	2.12
5	.83	.98	.60	.89	.70	.97
6	.64	.32	.34	.93	.86	1.17
7	.55	.32	.42	1.49	.46	1.56
8	.24	.19	.30	1.07	.49	1.25
9	.17	.08	.75	1.25	.71	1.27
10	.13	.07	1.56	1.36	.94	1.12
11	.13	.15	1.33	1.40	1.15	1.48
12	.29	.68	1.30	1.34	1.20	1.23

ments, and ranged from 84 to 92 percent with the slops and molasses treatments, respectively. The water recovered from the control treatment amounted to only 51 percent of that applied.

During the course of the experiment the infiltration rates of water on the slops and molasses treatments were very satisfactory. Although infiltration rates were not determined, observations indicated that the rate for the poorest treatment was about 1 inch per hour, even after 12 feet of water had been applied. This estimate would have been higher if a constant head of water had been maintained in the soil column.

The average pH values of the leachates of all treatments after the passage of the 12 feet of water ranged from 8 to 9. These high pH values indicate the removal of alkaline salts such as Na_2CO_3, $CaCO_3$, and $MgCO_3$.

As will be shown in a forthcoming publication, the active soil-aggregating fraction of the slops dissolves at high pH values, and it would not seem logical that its effects would be so long-lasting in these soils, when the relatively high pH values of the percolating waters are considered. However, it is possible that the presence of high quantities of free Na salts may have reduced its solubility. Further dehydration of the active material may be involved. It should be pointed out that dehydration is not only attained by using heat to drive off moisture, but it can also be achieved when salts are present in large quantities. This reaction is like the "salting-out" phenomenon associated with chemical precipitation of proteins. Dehydration phenomena have been considered for a long time to be an integral factor involved in the stabilization of soil aggregates.

TABLE 4.—*Leachate volume, total Na, Ca, and Mg contents, and pH values of leachates collected during percolation of 12 feet of water through soil columns treated with distillery slops or molasses at different levels*[1]

Treatment	Average H_2O delivered per acre-foot	Water recovered in leachates	Na	Ca	Mg	pH of leachates
	Cc.	*Percent*	*Meq.*	*Meq.*	*Meq.*	
Check	239.33	51.03	296.67	19.65	41.06	9.0
Low slops	400.00	85.46	362.64	21.43	47.51	8.9
Medium slops	416.29	88.76	361.88	35.26	77.42	8.5
High slops	426.00	90.84	366.29	57.48	103.77	8.3
Low molasses	411.38	87.72	353.14	35.59	67.07	8.3
High molasses	430.25	91.74	356.31	71.89	129.41	8.0

[1] A foot of H_2O equalled 469 cc.

The untreated soil columns underwent some reclamation in the upper part, but the lower layers, although losing some exchangeable sodium, still contained enough markedly to retard water movement. It should also be pointed out that, when water was applied to the control columns, it required around 10 days to collect 3.4 inches of percolate, amounting to a recovery of about one-half. Apparently water loss by evaporation was high from the top of the column, since only 51 percent of the applied water was recovered. Water infiltration was observed to decrease with time in the check treatments, which can be explained by the dispersive action of sodium adsorbed by the soil.

The fact that the adsorbed sodium was partly removed from the top

TABLE 5.—*Chemical properties at various soil depths after treatment with distillery slops or molasses, and the percolation of 12 feet of water*

Treatment	Saturation extract					Soil		
	Depth	Saturation	Electrical conductivity × 10^3	Ca + Mg	Na	pH	Exchangeable sodium	
	In.	*Percent*	*Mmhos/cm.*	*Meq./l.*	*Meq./l.*		*Meq./100 gr.*	*Percent*
Check	0-5	82	1.00	6.70	3.30	8.4	0.72	1.51
	5-10	82	1.33	6.70	6.60	8.4	1.92	4.00
	10-15	102	3.00	3.67	26.33	8.9	15.42	32.13
	15-20	114	2.00	1.94	18.06	9.1	14.88	31.00
Low slops	0-5	78	1.25	9.51	2.95	8.2	.29	.60
	5-10	82	.79	5.98	1.91	8.2	.23	.48
	10-15	89	.72	5.00	2.21	8.2	.27	.57
	15-20	88	.76	5.30	2.31	8.4	.31	1.02
Medium slops	0-5	81	1.13	8.35	2.91	8.1	.25	.53
	5-10	92	.65	4.43	2.08	8.2	.22	.45
	10-15	85	1.02	7.70	2.46	8.2	.20	.41
	15-20	85	.75	6.08	1.43	8.2	.24	.50
High slops	0-5	81	1.58	12.10	3.66	8.0	.29	.61
	5-10	80	.81	5.72	2.38	8.0	.22	.47
	10-15	86	.82	4.92	3.29	8.1	.23	.49
	15-20	83	1.11	7.56	3.54	8.1	.33	.69
Low molasses	0-5	81	1.62	12.48	3.73	8.0	.35	.72
	5-10	86	.71	5.02	2.08	8.0	.26	.55
	10-15	86	.96	7.29	2.26	8.1	.27	.57
	15-20	81	1.14	8.70	2.71	8.0	.29	.61
High molasses	0-5	83	1.89	14.15	4.75	8.0	.29	.61
	5-10	82	1.26	7.78	4.83	8.0	.26	.55
	10-15	85	1.21	7.51	4.60	7.9	.35	.74
	15-20	87	1.17	6.64	5.01	8.0	.33	.69

layers of the check treatment, can be explained by the effects of soluble NaCl on the solubility of Ca and $MgCO_3$. It is known that the solubility of these salts is greatly increased in the presence of NaCl. The addition of ocean water, high in NaCl, has proved to be a beneficial practice in the reclamation of sodic soils, so long as the soils contain free $CaCO_3$ (*5*). This practice, however, presupposes the additions of this water with decreasing NaCl as reclamation progresses.

After the sixth acre-foot of water had been passed through the columns, a whole month was allowed to pass before any more water was applied. This did not exert any apparent effect on the infiltration rates of water which had been previously noted.

When the cores were sectioned for analyses, an excellent stable soil structure was found in all molasses and slops treatments when compared with the highly dispersed controls.

SUMMARY

Data are presented on a laboratory study conducted to determine the effects of the use of blackstrap molasses and rum distillery slops on the reclamation of a highly saline-alkali heavy clay soil of southwestern Puerto Rico.

The study revealed that even the lowest levels of distillery slops and diluted molasses, around 2.3 acre-inch, were sufficient to lower the conductivity of the soil-saturation extract from 67 mmhos/cm. to less than 3, and the exchangeable sodium percentage from 43 to less than 1 percent.

It is believed that most of the Ca and Mg found in leachates of columns treated with the most slops or molasses may be attributed to the production of organic acids during the decomposition of slops and molasses. These organic acids rendered soluble the soil-free $CaCO_3$ and $MgCO_3$, widening the Ca and Mg:Na ratio to substitute the sodium by a mass action effect.

Subjecting the soil to a dry period in between the 6 and 7 acre-feet of water did not alter the movement of water and resulted in a complete soil reclamation.[3]

RESUMEN

Se presentan los datos de un estudio de laboratorio para determinar la acción de las mieles finales y los mostos de destilerías sobre la restauración de un suelo arcilloso con un alto contenido de sales y sodio intercambiables.

El estudio reveló que aún los niveles más bajos de mosto y miel diluída, en la proximidad de 2.3 acre-pulgadas, bastaron para bajar la conductividad del extracto de saturación del suelo, de 67 mmhos/cm. a menos de 3 mmhos/cm, y el sodio intercambiable de 43 por ciento a menos de 1 por ciento.

Se cree que el hecho de que las cantidades más altas de Ca y Mg apare-

[3] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee, warranty, or endorsement by the Agricultural Experiment Station indicating or implying superiority to other similar products not mentioned.

cieran en las aguas de filtración de las columnas que contenían altos niveles de mosto y miel, se deba a la acción disolvente de los ácidos orgánicos que se formaron de la descomposición del mosto y de la miel. De esta manera se aumentó la proporción de Ca y Mg/Na para sustituir el sodio mediante una acción en masa.

Cuando el suelo se sometió a un período seco entre el sexto y el séptimo acre-pie de agua, no hubo alteración en el movimiento del agua, resultando así en una completa restauración del suelo.

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