SODIC SOILS RECLAMATION USING VINASSES [1]

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417.

ABSTRACT

To evaluate the effect of vinasses on sodic soils reclamation two experiments were performed in a Typic Pellustert characterized by a very high ESP, massive structure and total missing of the capacity to conduce water (HC = 0 mm/day). High electrolytic concentration waters (like vinasses) applied to soil columns promoted soil aggregation, improved soil structure and, in consecuence, a better hydraulic conductivity was gotten. As the soil physical properties get better Na is leached and replaced by Ca resulting in soil reclamation success. Amount of replacement was related to the solution concentration and to the volume of solution added. Results concluded that the reclamation of a sodic soil depended critically on the maintenance of a hydraulic conductivity high enough to assure Ca ions to move in the soil to remove exchangeable Na and the consequent leaching of deep soil layers. Under field conditions it was confirmed that vinasses can be used on the reclamation process because they cause changes in the soil permeability like those promoted by high electrolytic concentration waters. Application of 2.000 t/ha of vinasses diluted in water made it possible to recover the hydraulic properties of the studied soil in a short period of time on the leaching of a great amount of the exchangeable Na initially present in the soil.

Keywords: Vinasses, Hydraulic conductivity, Electrolytic concentration, sodic soil reclamation.

COMPENDIO

USO DE VINAZAS EN LA RECUPERACION DE SUELOS SODICOS

Para evaluar el efecto de vinazas en la recuperación de suelos sódicos se realizaron dos experimentos en un suelo Typic Pellustert caracterizado por un altísimo PSI, estructura masiva y pérdida total de la capacidad para conducir el agua (HC=0 mm/día). La aplicación de aguas con alta concentración de electrólitos (como las vinazas) a columnas conteniendo dicho suelo promovieron la agregación de suelo, mejoraron la estructura del suelo y, en consecuencia, se consiguió una mejor conductividad hidráulica. A medida que las condiciones físicas mejoran el sodio se lava y es reemplazado por Ca dando como resultado la recuperación del suelo. La cantidad de Na reemplazado depende de la concentración y del volumen de la solución añadida. Los resultados permiten concluir que la recuperación de un suelo sódico depende críticamente del mantenimiento de una conductividad hidráulica lo suficientemente alta para permitir que los iones de Ca se muevan en el suelo para remover el Na intercambiable y que este sea lavado a capas más profundas del suelo. En condiciones de campo se confirmó que las vinazas se pueden usar en el proceso de recuperación porque ellas causan cambios en la permeabilidad del suelo semejantes a los promovidos por las aguas con alta concentración de electrólitos. La aplicación de 2.000 t/ha de vinazas diluidas en agua hicieron posible la recuperación de las propiedades hidráulicas del suelo en un corto período de tiempo y el lavado de una gran cantidad del Na intercambiable inicialmente presente en el suelo.

Palabras claves: Vinazas, Conductividad hidráulica, Recuperación de suelos sódicos, Concentración de electrólitos.

INTRODUCTION

Vinasses resulting from alcohol factories are highly contaminated because they have high chemical proportion of Oxygen (COD_5 = 70.000 mg/L) and a high biological proportion of Oxygen (BOD_5 = 26.450 mg/L); this makes these waste products difficult to handle. Legal regulations demand the investment of enormous amounts of money to design treatment systems to process them. Each ton of sugarcane produces 45 kg of

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molasses, and this can produce 156 liters of vinasses. Vinasses from molasses have a high concentration of organics (58.9 g/L), are highly acid (pH between 3.5 and 4.3) and have a very high salinity (EC = 11 dS/m) and are rich in K_2O (6.0 kg/m^3), NO_3 (4.42 g/m^3), P_2O_5 (73.28 g/m^3), SO_4 (9.58 kg/m^3), CaO (1.5 kg/m^3), MgO (1.34 kg/m^3) and micronutrients (*Table 1*).

The reclamation of sodic soils can be achieved by processing them with waters of high electrolytic concentration to improve the soils physical condition and, after that, through the application of low solubility amendments, like gypsum, or lowering the electrolytic concentration of the water to be applied.

Adsorbed sodium causes a low infiltration rate, low permeability to water penetration and loss of structure. The degradation of the soils physical properties by sodium depends on the sodium saturation percentage (ESP), the kind and amount of clay materials and on the electrolytic concentration of the soil solution. The basic phenomena involved in this process is the dispersion and swelling of clays. Swelling is a continual process which gradually increases as the electrolytic concentration of the solution decreases, and dispersion is only possible when the solution concentration is lower than the flocculation value or the lowest electrolityc concentration necessary to aggregate a colloidal dispersion in a given amount of time.

Therefore the high electrolytic concentration make vinasses potentially usefull in sodic soils reclamation.

Table 1. Chemical composition of vinasse

PROPERTIES	UNITS	AMOUNT
COD_T	mg/L	70.000
COD_S	mg/L	58.000
BOD_5	mg/L	26.450
TSS	mg/L	13.000
VSS	mg/L	10.000
Sugar	% p/v	0.8
Alcohol	% p/v	0.2
Density	g/ml	1.0
pH	---	3.5-4.3
EC	dSm^{-1}	11.33
N	g/m^3	633
P_2O_5	g/m^3	73.28
NO_3	g/m^3	6.42
K_2O	kg/m^3	6.0
CaO	kg/m^3	1.05
MgO	kg/m^3	1.34
SO_4	kg/m^3	9.58
Na	kg/m^3	0.156
Pb	kg/m^3	0.007
Cl	kg/m^3	1.31
HCO_3	me/L	16.0
CO_3	me/L	0.00
B	mg/kg	0.02
Cu	mg/kg	1.04
Zn	mg/kg	8.32
Fe	mg/kg	21.84
Co	mg/kg	0.07
Solids	g/L	58.90
Temp	°C	96

MATERIALS AND METHODS

Experiment 1

A soil of EL RINCON (Typic Pellustert) with 22.2% sand and 33.8% clays, plastic, with no water conductivity, high EC (8.3 dSm^{-1}) high exchangeable sodium (19.95 me/100g) and low in organic matter content (0.57%) was used.

Twenty eight soil columns were prepared to a dry soil bulk density of 1.5 Mg/m^3 and solutions with electrolytic concentrations of 0, 10, 50, 100, 200, 400 and 600 me/L, based on $CaCl_2$ and $MgCl_2$, were applied considering amounts of solutions equivalents to twice the pore volume of the dry soil. The effluents were collected and pH, EC and cations and anions in the solution were determined. This procedure was done until the Na concentration in the effluent was low and constant.

Experiment 2

On the same soil under field conditions, 2.000 t/ha of vinasses diluted in water (1:1) were applied, and two sucessive washings were done with water to eliminate excessive salts and ions. The soil was prepared to plant sugarcane after a year of the iniciated reclamations process.

RESULTS AND DISCUSSION

Experiment 1

No percolation of water through the soil was observed when free electrolyte water was used.

There was not enough salt dissolution on the soil to maintain a solution concentration high enough to be higher than the flocculation value of the soil clays, to promote particle aggregation and to improve soil permeability and a better soil hydraulic conductivity. According to Shainberg et al (1981 a,b) the soil potential to release salts, when distilled water is use to leach it, is a dominant factor to determine how easy the soil will disperse and the corresponding decrease in the hydraulic conductivity.

High electrolyte concentration waters promoted soil aggregation, better structure and better hydraulic conductivity. Calcium replaced exchangeable sodium which was leached. Amount of replacement was related to the solution concentration and to the volume of solution added (*Table 2*).

The reclamation of a sodic soil depends fundamentally on the maintenance of a hydraulic conductivity to assure the Ca transport in the soil to replace exchangeable sodium. Application of destilled water did not cause changes on the chemical characteristics of the soil because it didn't cause changes on the physical conditions to permit leaching of sodium in the solution. Increasing the water electrolytic concentration caused a decrease in the time necessary to get a reduction of sodium concentration on the column effluent due to a greater rate of Na replacement on the exchange complex and to improve soil physical conditions mainly hydraulic conductivity. According to Miyamoto and Stroehlin (1986), the management of a sodic soil requires a strong, steady infiltration rate to permit the reclamations in a reasonable time.

The salt concentration of the column effluent (EC) diminished gradually approaching assintotally the salt concentration of the applied water suggesting an initial high leaching of soluble salts which decrease slowly

Table 2. Chemical properties and clay content of the "EL RINCON" soil (Typic Pellustert), after reclamation using high electrolytic waters.

TREATMENT	ELECTROLYTIC CONCENTRATION (me L^{-1})	pH	E.C. (dS m^{-1})	CIC	Ca	Mg	Na	K
				(me /100g of soil)				
1	0	9.2	7.41	18.7	10.65	2.52	35.45	0.51
2	10	9.3	1.13	20.6	14.05	4.90	16.43	0.47
3	50	8.2	1.81	19.1	16.47	8.99	1.70	0.42
4	100	7.9	2.67	23.4	12.12	7.18	8.19	0.40
5	200	7.8	5.01	22.2	12.59	7.53	8.18	0.35
6	400	7.8	8.06	21.1	16.08	7.23	8.21	0.30
7	600	7.8	8.80	20.2	17.30	7.48	8.21	0.30

Table 2. Cont. ...

TREATMENT	ELECTROLYTIC CONCENTRATION (me L^{-1})	Ca	Mg	Na	K	CO_2	HCO_3	SAR	ESP** (%)
		(me L^{-1})							
1	0	6.27	2.45	95.4	0.36	0.0	3.8	45.68	189.57
2	10	2.76	1.79	10.32	0.42	0.0	4.2	6.84	79.75
3	50	5.53	4.20	9.51	0.25	0.0	2.2	4.31	8.90
4	100	7.81	11.90	1.28	0.38	0.0	2.2	0.41	0.81
5	200	8.48	35.90	0.82	0.35	0.0	1.6	0.17	0.81
6	400	8.68	61.90	1.32	0.43	0.0	1.8	0.22	1.00
7	600	8.40	68.20	1.45	0.41	0.0	1.8	0.23	1.03

* CEC: OAcNa, 1M pH 8.2 ** ESP = Ex. $\frac{Na}{CIC}$ * 100

to reach equilibrium with the salt concentration of the water applied. Column effluent salt concentration depends on the electrolytic concentrations of the applied water and on the dissolution and hydrolisis of solid and exchangeable salts during the leaching (Alfaro, 1971).

Field Experiment

Vinasse application under field conditions caused a decrease of exchangeable Na from the upper soil horizons. The effects of vinasse were observed inmediately: first, there was an apparent change in the physical conditions especially concerning soil aggregation which advanced gradually to deeper horizons. The infiltration rate improved at the same time as observed on vinasse penetration on the soil after application and on water penetration during the rainy season. After few days vinasses reached a 12m water table as checked in a well located near the working area.

The soil was sampled each 50m apart through 120 cm depth as presented in *Table 3*. In most cases a decrease in the exchangeable Na concentration was evident accompained of an increase of the same ion in the deeper horizons. Some points (C2, C5, D2, etc.) were not well leached with vinasse due to soil topography.

The electrical conductivity remanent on the soil is not hih and it is expected that will be controlled through the application of leaching fractions during the irrigation of sugarcane. Also, the soil K content was not as high as expected from the high K concentration of vinasse, suggesting that this element is easily leached in the soil.

The infiltration rate and the permeability changes observed in this soil are due to the electrolytic concentration of vinasse which promoted soil particle aggregation when the salt concentration of the soil solution increased over the critical concentration level of the soil clays. Also, the decrease in the concentration gradient existing between the diluted solutions in the macropores and the more concentration solution in the micropores favored the permeability enhancing throughthe promotion of the aggregationof disperse particles which is the main cause of hydraulic conductivity alteration (Frenkel et al, 1978).

Table 3. Chemical properties of the EL RINCÓN soil (Typic Pellustert) after 2.000 t/ha. application of vinasses

PLACE	DEPTH	pH	Ca	Mg	Na	K	EC	ESP
			me/100g				ds/m	(%)
A1	0-30	8.0	20.0	10.0	3.3	1.3	1.28	9.3
	30-60	8.8	18.0	13.8	6.6	0.6	1.58	18.9
	60-90	9.0	15.6	10.8	9.0	0.4	1.51	26.1
	90-120	8.9	13.8	7.8	8.1	0.7	2.26	26.1
A2	0-40	8.0	22.3	10.3	2.9	3.4	3.17	8.46
	40-80	8.7	19.0	10.0	6.5		2.11	6.52
	80-120	8.9	15.8	10.0	8.4		1.96	8.35
A3	0-30	7.9	25.0	15.0	2.7	3.5	1.66	6.81
	30-60	8.1	10.5	7.0	1.3	2.2	1.43	3.35
	60-90	8.5	20.0	12.3	6.9		1.13	23.03
	90-120	9.0	15.0	12.5	12.0	0.4	0.90	33.74
A4	0-40	8.1	21.8	12.0	2.5	3.9	3.17	8.21
	40-80	8.6	14.8	10.2	10.1	1.9	1.73	32.90
	80-120	8.6	16.3	8.5	9.7	0.9	1.73	32.38
A5	0-30	8.3	25.0	12.5	3.4	0.7	0.90	8.22
	30-60	8.9	20.0	12.5	8.8	0.6	0.68	22.35
	60-90	8.8	17.5	13.8	9.4	0.7	0.98	25.64
	90-120	8.7	18.8	12.5	9.2	0.4	1.20	28.72

Table 3. Cont. ...

PLACE	DEPTH	pH	Ca	Mg	Na	K	EC ds/m	ESP (%)
			me/100g					
A6	0-40	8.4	27.8	11.8	4.2	0.6	1.51	10.58
	40-80	8.8	17.0	14.0	8.4	0.3	0.98	25.03
	80-120	9.2	12.5	10.0	9.9	0.2	0.75	41.82
A7	0-40	7.9	20.0	11.3	2.6	2.3	1.88	10.4
	40-80	8.7	15.8	13.0	6 5	1.4	1.35	22.8
	80-120	8.9	12.0	9.5	5.8	0.5	1.35	24.9
A8	0-40	8.3	13.3	8.0	2.2	4.3	1.81	9.5
	40-80	8.9	12.5	12.0	5.3	1.7	1.58	21.2
	80-120	8.9	11.3	11.3	4.2	1.0	1.60	19.6
B6	0-30	8.0	20.5	20.0	2.7	1.8	1.96	7.4
	30-60	8.6	15.0	12.5	8.2	1.2	1.35	21.0
	60-90	8.9	8.0	9.8	7.0	0.7	1.73	26.1
	90-120	9.2	8.0	17.3	14.8	0.7	1.05	41.8
C2	0-40	9.0	10.0	8.81	0.5	0.3	1.58	34.0
	40-80	8.7	13.3	10.0	5.3	1.1	1.58	16.7
	80-120	9.2	10.0	9.8	10.4	0.5	1.28	36.8
C5	0-40	9.3	19.0	16.8	15.1	0.4	1.81	40.0
	40-80	9.4	15.8	12.8	18.7	0.7	1.86	51.3
	80-120	9.4	17.5	12.8	17.2	0.5	1.35	45.8
C7	0-40	8.6	18.5	11.3	6.5	5.3	2.49	18.7
	40-80	9.3	15.5	12.8	10.5	4.0	2.11	32.9
	80-120	9.3	10.0	8.5	8.3	0.5	1.59	30.0
C9	0-40	8.1	27.5	10.0	2.1	1.1	2.64	4.8
	40-80	9.3	12.5	20.5	10.9	0.3	0.83	37.9
	80-120	8.8	17.3	13.5	5.9	0.6	1.21	15.9
D2	0-40	8.9	12.5	17.5	8.6	0.7	1.21	24.9
	40-80	8.3	20.0	15.0	1.8	1.2	0.98	6.1
	80-120	9.3	14.0	15.0	7.3	0.4	1.06	22.7
D10	0-40	8.3	30.0	12.8	1.7	1.0	1.51	4.8
	40-80	8.9	25.0	16.0	5.4	0.8	1.13	17.9
	80-120	9.1	15.0	9.5	4.8	0.3	1.06	20.9
E2	0-40	8.2	17.5	8.3	5.3	5.3	3.47	19.6
	40-80	9.0	15.0	10.0	6.6	1.7	1.36	24.1
	80-120	8.3	13.8	8.3	1.4	2.8	1.96	6.6
E7	0-40	7.9	30.0	8.3	2.6	2.6	3.85	9.0
	40-80	9.5	17.5	14.8	13.0	0.4	1.81	60.5
	80-120	9.4	7.5	5.3	6.3	0.3	2.87	35.5
F2	0-40	8.2	25.0	13.5	3.7	1.1	1.66	10.4
	40-80	9.3	20.0	19.5	19.5	0.4	0.98	49.9
	80-120	9.3	17.5	16.5	16.4	0.3	0.57	50.7

Table 3. Cont. ...

PLACE	DEPTH	pH	Ca	Mg	Na	K	EC ds/m	ESP (%)
			me/100g					
E5	0-40	8.8	12.5	7.5	7.2	3.8	3.17	22.8
	40-80	9.6	10.0	3.8	10.3	1.0	1.66	30.7
	80-120	9.7	7.5	5.8	7.1	1.7	2.49	37.5
G1	0-40	7.2	17.5	13.8	0.4	2.1	1.35	0.9
	40-80	7.8	15.5	15.5	2.3	1.9	1.28	8.6
	80-120	8.8	12.5	8.8	4.7	0.3	0.90	16.2
G4	0-40	7.7	37.5	9.3	2.1	0.8	3.02	2.8
	40-80	9.0	18.8	12.5	9.7	0.6	1.35	8.6
	80-120	9.2	5.0	4.3	3.5	0.1	1.43	6.2
G5	0-40	8.3	12.5	8.8	2.9	1.3	2.26	11.3
	40-80	9.3	9.3	8.0	8.6	1.1	1.88	29.0
	80-120	9.6	7.5	6.3	6.2	0.7	2.64	30.3
I2	0-40	8.0	17.3	5.0	0.5	1.1	1.13	2.1
	40-80	8.2	15.0	4.3	0.7	1.0	0.83	4.3
	80-120	8.1	13.8	4.8	0.4	0.8	0.61	2.7

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