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A Comparative Reclamation Field Experiment Using El-Salam Canal Water Assessing Lime/ Manure Mixture Versus Gypsum or Lime or Sulphur in Reclaiming a Saline Sodic Soil, El-Hosainiya Plain, Nile Delta

A.A. Abdel-Salam, O.H. El-Hussieny and F.A. Farag*
*Department of Soil Science, Faculty of Agriculture, Moshtohor (Benha Branch), Zagazig University; and *Agriculture Research Centre, Cairo, Egypt.*

A SILTY clay saline sodic soil was amended with a mixture of lime manure (manured lime ML) adopting the intermittent leaching technique using EL- Salam canal water in a field experiment in El- Mogtaribeen village, south of El- Hosainiya Plain, with EC (saturation extract) 17.7 dS/m; ESP: 38.0 and pH:8.1. in the top soil (0-15cm). Following two cycles of leaching (each cycle comprised two water applications: 1^{st} : 600m^3/fed, 2^{nd} : 900m^3/ fed with a 2 weeks interval between each, and one- month interval between the cycles) was considerably positive. Final EC, and ESP in top soil decreased markedly reaching 3.0 dS/m, and 21.8, respectively by (ML). For the others, final EC and ESP were , 3.4 and 24.1 for lime (L), 4.6 and 13.5 for gypsum (G); 3.6 and 9.6 for sulphur (S). Final pH values were. 8.13 (ML), 8.29 (L), 8.06 (G) and 8.28 (S). Indigenous contents of $CaCO_3$ in soil were 3.5%; and El-Salam canal water had an EC of 1.4 - 1.6 dS/m and SAR of 6-9; final soil EC, ESP, and pH of soil subjected to leaching with noamendments reached 4.1 dS/m, 24.7 and 8.33, respectively . The underlying sub soil layer (15 – 30 cm) of initial EC, ESP and pH of 12.8 dS/m,40.0 and 8.0, respectively ended up after leaching with respective values as follows: 3.7 dS/m,25.4 and 8.23 (ML); 5.0 dS/m, 30.8 and 8.27 (L); 4.4 dS/m , 29.4 and 8.50 (S); 5.0 , 26.8 and 8.25 (G); 5.5 dS/m, 28.0 and 8.20 (non-amemded).

Practical implications show that lime could be used efficiently by mixing it with organic manure to make it a credible for reclaiming amendment for sodic soils; El-Salam water proved to be, of practical use in reclaiming such soils.

Reclamation of saline sodic soils requires leaching of the soil in order to get rid of excess soluble salts; it also requires applying soil amendments to replace adsorbed sodium by calcium (and some times by calcium and magnsium) cotions so as to render the soil non- sodic. The most common reclamation amendment for this purpose is gypsum "$CaSo_4$. $2H_2O$, because of its low cost, commercial availability and ease of handling. Miyamoto & Enriquez (1990) and Singh & Bajwa (1991) found that application of gypsum for the reclamation of sodic soils enhanced the removal of soluble Na^+ and decreased ESP and pH of the reclaimed soil. Khalifa *et al.* (1994) and Koriem *et al.* (1994) reported that application of gypsum decreased soil salinity, soluble ions and exchangeable Na and Mg and increased exchangeable Ca. Similar results were found by many workers such as Anter *et al.* (1972); EL- Kobbia *et al.* (1969) and Sumner *et al.* (1986). Local conditions in some regions may call for using other calcium material such as lime. However, although lime contains more calcium (40%Ca) than gypsum(24,4%Ca), its low solubility and its alkaline reaction makes its less suitable for reclamation of sodic soils. Adding acidic materials to lime may render such reclamation practical. Organic manures, particularly when they are well decomposed, may be suitable acidic materials for such purposes (Avinelech *et al.*, 1990) According to FAO (1973) lime was used for reclamation of sodic soils having ESP of 50 –57 and resulted in a final ESP of 7-8 following 4 years.

The current study aims at assessing the practical use of lime mixed with farmyard manure as a reclamation material for saline sodic soils, in comparison with agricultural gypsum and elemental sulphur using field experiments in a saline sodic soil in the region of north Delta, Egypt.

Material and Methods

The study was undertaken on a silty caly saline sodic soil (Table1) south El-Hosainiya plain, north east of Delta, Sharqueya Governorate to assess the efficiency of four reclamation materials of gypsum, sulphur, lime and manured lime. The soil was a saline sodic since its EC of the paste extract is >4 dS/m (13- 17 dS/m) and its exchangeable sodium percent "ESP is > 15 (38-40).

TABLE 1. Chemical analysis of El- Salam Canal water used for reclamation leaching.

Property	Sample No			Mean
	1	2	3	
	El-Salam canal	Main canal	Field canal	
PH	7.5	7.7	7.6	7.6
EC (dS/m)	1.4	1.5	1.6	1.5
Soluble cations (mmol$_c$/L):				
Ca^{++}	3.3	3.4	3.6	3.4
Mg^{++}	3.5	4.2	4.4	4.0
Na^{+}	10.8	17.0	13.4	13.7
K^{+}	0.31	0.37	0.16	0.28
Soluble cations (mmol$_c$/L):				
$CO_3^{=}$	0.0	0.0	0.0	0.0
HCO_3^{-}	4.4	4.2	4.4	4.3
Cl^{-}	10.5	15.0	15.5	13.7
$SO_4^{=}$	3.01	5.77	1.66	3.4
SAR	5.9	8.7	6.7	7.1
SCAR	8.4	13.1	10.0	10.5
Adj. SAR	13.0	19.3	15.4	16.0
RSC	np	np	np	np
SSP	60	68	62	63.0
Mg ratio(%)	51.5	55.3	55.0	54.0

SAR: Sodium adsorption ratio, SCAR: Sodium to calcium activity ratio (= Na+ Ca in mmol$_c$/L), Adj SAR: adjusted sodium adsorption ratio. SSP: Soluble sodium percent. RSC: residual sodium carbonates (np: no positive values for RSC).

The top (0-15 cm) soil, *i.e.*, the plough layer had a cation exchange capacity (CEC in $cmol_c\ kg^{-1}$) of 33.1 and an initial exchangeable sodium percent ESP. (ESP_i) of 38.4 the gypsum requirement (G.R) was calculated on the basis of a required final, ESP (ESP_F) of 10.0.

On such a basis G.R. was calculated according to the following equation: based on reclaiming the top soil (0-15cm)

$$G.R = \frac{ESP_i - ESP_f}{100} \times CEC \times 0.86$$

Taking the data of the top 15-cm of the soil, GR would be as follows:

$$G.R. = \frac{38.4-10.00}{100} \times 33.14 \times 0.86 = 8.25\ Mg\ fed^{-1}$$ (1megagram = 10^6g) " for top soil".

This equation is on the assumption that the weight of the 0-15cm of one feddan is one million kg (*i.e* 1000 Mg) on a basis of bulk density = 1.5 Also, on the assumption of material with no impurities. The material used was powdered lime. On the same basis, GR for the underlying sub soil layer of initial ESP of 40.0 was calculated at 9.08 Mg/ fed. Purity of lime 89.1%.

Experimental

The experimental design of the field experiment was a randomized complete block (factorial) with 3 factors and 3 replicates. The 3 factors were: -

Form of amendment

There were 4 forms: Gypsum., sulphur, lime and manured lime (lime with farmyard cattle manure at 25 m^3 /fed).

Rate of application of amendment

There were 2 rates of each amendment. The first rate was an equivalent of 1 GR (*i.e.*, 100% Gypsum requirement). The second rate was 1.25 GR (*i.e.*, 125% Gypsum requirement). Rates of equivalent GR are as follows:

1Mg (megagram) of gypsum is equivalent to 0.186 Mg of S or 0.58 Mg of lime ($CaCO_3$).

Method of application of amendment

There were two methods:

(1) "Non-mix" application, *i.e.*, broadcasting the amendment without mixing within the upper 15-cm soil surface.

(2) " Mix" application, *i.e.*, broadcasting the amendment with through mixing within the upper 15cm soil surface.

Chemical analysis of the irrigation water used for reclamation

Water used for leaching and irrigation was from El- Salam canal. Three samples were taken as follows, sample (1): from El- Salam main canal at a spot south El- Hosainiya plain. Sample (2): from the first branch of El- Salam canal at Mogtarbeen area. Sample (3) from the branch at the bead of the experimental field. Data of analysis are in Table 1.

Physical and chemical properties of the soil of the experiment

A representative composite sample of the field of the experiment was collected to represent its top soil (0-15cm) and subsoil (15-30cm). Table 2 shows that the soil was silty clay, saline sodic; alkaline in reaction. According to USDA (1954) it would be classified as " a highly saline sodic soil". It is 17.71 dS/m^{-1} in topsoil, 12.81dS/m^{-1} in subsoil; with ESP exceeding 15; being 39 in topsoil, 40 in subsoil. The pH was 8.1 in topsoil and 8.0 in subsoil.

TABLE 2. Initial status of physical and chemical properties of the saline - sodic soil of the experiment.

Property	Soil depth (cm)	
	0-15	15-30
$CaCO_3$ (%)	3.46	1.26
Organic matter (%)	0.70	0.50
Clay (%)	46.4	50.7
Silt (%)	36.8	34.2
Coarse sand (%)	1.9	1.5
Fine sand (%)	14.9	13.6
Textural class	Silty clay	Silty clay
PH	8.10	8.00
EC (dS m^{-1}) of saturation extract	17.71	12.81
Soluble ions of saturation extract (in m L -1)		
Ca^{++}	12.20	5.20
Mg^{++}	32.90	14.30
Na^{+}	146.10	127.30
K^{+}	1.90	1.40
$CO_3^{=}$	0.00	0.00
HCO_3^{-}	0.60	0.70
Cl^{-}	178.60	116.40
$SO_4^{=}$	13.90	31.10
Sodium Adsorption Ratio (SAR)	30.80	40.80
Exchangeable cations (cmol kg^{-1}):		
Ca^{++}	6.2	7.3
Mg^{++}	9.8	11.5
Na^{+}	12.9	14.1
K^{+}	4.2	2.3
Cation exchange capacity (CEC, cmol kg^{-1}):	33.1	35.2
Exchangeable sodium percentage (ESP)	38.4	40.0

Reclamation procedure

Reclamation was carried out using the intermittent leaching process as follows:

After broadcast of amendment, 600m^3 of water /fed were added to the soil and allowed for equilibrium for 2 weeks. This dose is the equilibrium dose which acts on the added amendment and soil during this period. Thenafter, 900 m^3 water/fed were added in order to flush excess salts and sodium ions and leach them out of the practical soil root zone. This dose is the " leaching dose". One month was allowed after applying this leaching dose. Such cycle of applying water in such two doses was repeated twice and the rate of amendment was applied in two equal portions one for each cycle. The first cycle was in January and the second was in March. 1999. After completion of the 2nd cycle, a representative composite soil sample of each plot was taken to represent the topsoil, (0-15cm) and the sub soil (15-30cm) for analysis.

Soil physical and chemical analysis

Mechanical analysis (Piper,1950), organic matter, total soluble salts, soil pH, soluble ions, cation exchange capacity and exchangeable sodium percentage were determined in soil samples according to Jackson (1967).

Results and Disussion

Reclamation and soil improvement,effect on soil salinity

Salinity in top soil (0-15cm).

The EC before leaching was high; it was 17.71 dSm^{-1}. After leaching, it decreased to between 2.31 and 5.64 dSm^{-1}. Treatments where soil was not amended (NA) had a mean EC value of 4.06 dSm^{-1}. Those where soil was amended showed mean values of 2.95 (manured lime "ML"), 3.60 (sulphur "S"), 3.79 (lime "L") and 4.62 dSm^{-1} (gypsum "G"). The "non-mix" application method (surface application) was more effective (EC 3.53 dSm^{-1}) than "the mix" application when amendments were mixed into the soil surface (3.95 dSm^{-1}). The rates were equally effective giving EC between 3.72 (rate 1) and 3.76 dSm^{-1} (rate 2). The superior efficient effect of manured lime over the other materials was particularly evident with rate 1(Table 3).

Salinity in sub soil (15-30 cm)

The EC before leaching was high; it was 12.81 dS/m^{-1}. After leaching, it decreased to between 2.04 and 7.43 dSm^{-1}. Treatments where soil was not amended (NA) had a mean EC value of 5.48 dSm^{-1}. Those where soil was amended showed mean values of 3.74 "ML" 4.36 "S" 4.96 "G" and 4.99 dSm^{-1} "L".

The two methods of application were equally effective giving EC between 4.17 (non–mix) and 4.86 dSm^{-1}. (mix). The two rates were equally effective giving EC between 4.18 (rate 1) and 4.84 dSm^{-1} (rate 2). Under conditions of rate 1, the three treatments of G,S and L were equal in effect, but the "ML" treatment gave EC lower than "G" and this was particularly with the non-mix method. Rate 2 was particularly superior to rate 1 when S was used. The surface application was particularly superior to the mixing application in the case of "ML" and "G" amendments.

Overall assessment of effect on soil salinity

Leaching reclamation especially with amendments resulted in a marked decrease in soil salinity. The EC decreased from being about 12.8 to 17.7 to between a range of 2.0-5.6 dSm^{-1}. Taking into consideration the salinity of the water used for reclamation, (1.4 to 1.6 dSm^{-1}), the outcome of leaching reclamation using manured lime was nearly in accordance with the empirical equation. This equation is as follows $EC_e = 3/2\ EC_i$ where EC_e is the EC of the soil saturation extract and EC_i is the EC of the irrigation water. Applying the equation on the current case gives EC of 2.1 to 2.4 dsm^{-1}. Results show that the lowest EC obtained was in the case of leaching with "ML"; being 2.31 in the topsoil and 2.04 dSm^{-1} in subsoil; and both values are near enough to the theoretical values by the aforementied equation. Presence of manure must have improved the physical conditions of the soil (Singh and Singh 1989). Besides, decomposition of the manure's organic matter with the production of organic acids may have accelerated the desalination of the soil. Also, applying manure involves organic colloids which would adsorb more salt ions from soil solution, thus decreasing salinity of soil water. Physical improvement of soil structure and improved infiltration rate may have occurred in soils receiving the manured lime (ML) treatment and thus contributing to accelerated removal of soluble salts in the ML-treatments.

TABLE 3. Salinity (EC dSm^{-1}) in the soil after reclamation by leaching a saline sodic soil using different amendments.

Material (T)	Rate (R)	Topsiol Method (S)		Mean	Subsoil Method (S)		mean
		Non- mix	Mix		Non- mix	Mix	
Gypsum	Rate 1	3.90	4.55	4.23	3.07	4.92	3.99
	Rate 2	4.40	5.64	5.02	4.47	7.43	5.93
	Mean	4.15	5.10	4.62	3.75	6.17	4.96
Sulphur	Rate 1	3.89	4.21	4.05	5.73	4.34	5.03
	Rate 2	2.70	3.59	3.15	3.37	3.98	3.68
	Mean	3.30	3.90	3.60	4.55	4.16	4.36
Lime	Rate 1	3.70	3.99	3.84	4.50	5.23	4.87
	Rate 2	3.42	4.06	3.74	5.62	4.62	5.12
	Mean	3.56	4.02	3.79	5.06	4.93	4.99
Manured lime	Rate 1	3.18	2.31	2.75	2.04	3.62	2.83
	Rate 2	3.01	3.28	3.15	4.57	4.71	4.64
	Mean	3.10	2.80	2.95	3.31	4.17	3.74
		Mean of rates			Mean of rates		
	Rate 1	3.67	3.76	3.72	3.83	4.53	4.18
	Rate 2	3.38	4.14	3.76	4.50	5.19	4.84
G. Mean		3.53	3.95		4.17	4.86	
Non- amended soil (Leached with no amendments)		4.06			5.48		
LSD 0.05		T= 0.54 R= ns S= 0.38 RS= ns TR= 0.76 TS= ns TRS= ns			T= ns R= ns S = ns RS=ns TR=1.56 TS=1.56 TRS= ns		

Effect on soil pH

Soil pH in top soil (0-15 cm).

The pH before leaching was 8.10; after leaching it ranged between 7.87 and 8.43. Treatments where soil was not amended "NA" had a mean pH of 8.33. Those where soil was amended showed mean values of 8.06 "G", 8.13 "ML", 8.28 "S" and 8.29 "L" (Table 4).

The two methods of application were generally equally effective giving pH between 8.16 (mix) and 8.21 (non- mix). Although the former was superior to the latter in the case of the high rate of application, rate 2 was more effective (pH 8.14) than rate 1 (8.24). The two materials of "G" and "ML" were superior to the "S" and "L" materials.

TABLE 4. Soil pH in the soil after reclamation by leaching a soil using different amendments.

Material (T)	Rate (R)	Topsoil Method (S) Non-mix	Topsoil Method (S) Mix	Mean	Subsoil Method (S) Non- mix	Subsoil Method (S) Mix	Mean
Gypsum	Rate 1	8.03	8.27	8.15	8.37	8.33	8.35
	Rate 2	8.07	7.87	7.97	8.27	8.03	8.15
	Mean	8.05	8.07	8.06	8.32	8.18	8.25
Sulphur	Rate 1	8.30	8.30	8.30	8.53	8.43	8.48
	Rate 2	8.43	8.07	8.25	8.67	8.37	8.52
	Mean	8.37	8.18	8.28	8.60	8.40	8.50
Lime	Rate 1	8.33	8.33	8.33	8.40	8.33	8.37
	Rate 2	8.33	8.17	8.25	8.27	8.07	8.17
	Mean	8.33	8.25	8.29	8.33	8.20	8.27
Manured lime	Rate 1	8.13	8.20	8.17	8.37	8.33	8.35
	Rate 2	8.07	8.10	8.08	8.10	8.13	8.12
	Mean	8.10	8.15	8.13	8.23	8.23	8.23
		Mean of rates			Mean of rates		
	Rate 1	8.20	8.28	8.24	8.42	8.36	8.30
	Rate 2	8.23	8.05	8.14	8.33	8.15	8.23
G. Mean		8.21	8.16		8.37	8.25	
Non-amended soil		8.33			8.20		
LSD 0.05	T=0.09 R=0.06 S=ns TR=ns TS=ns RS=0.09 TRS=ns			T=0.17 R=0.12 S=0.12 TR=ns TS=ns RS=ns TRS=0.33			

Soil pH in subsoil (15-30cm)

The pH before leaching was 8.00; after leaching it ranged between 8.03 and 8.67. Treatments where the soil was not amended "NA" had a mean pH of 8.20. Those where the soil was amended showed mean values of 8.23 "ML", 8.25 "G", 8.27 "L", and 8.50 "S". The mix method was more effective (pH 8.25) than non-mix one (pH 8.37). Rate 2 showed a mean pH of 8.23, and rate 1 showed 8.39. The amendments "ML" , "G" and "L" were equally similar in effect and showed values lower than given by the "S" amendment.

Overall assessment of effect on soil pH

The decrease in soil pH upon leaching was most apparent in the topsoil particularly in treatments of gypsum and manured lime. This illustrates the indirect effect of Na removal and the direct effect of organic acids (which must have been formed during decomposition of manure). The addition with non-mix of materials was less efficient in lowering soil pH than with mix. The indication may be that in this case greater concentration of Ca ions due to the amendments would be in direct contact with soil colloids. Obtained decrease in soil pH upon application of gypsum. Anter *et al.* (1972) found that gypsum was more effective than sulphur in decreasing pH of a sodic soil, EL- Tal El- Kabeer, Egypt. Gypsum and sulphuric acid were shown equally effective by Milapchand *et al.* (1977) and Starkey (1966) reported that some of the important micro-organisms which oxidize sulphur perform their highest activity with a pH range of 2 to 4.7; therefore with a rather high soil pH sulphur oxidation would not be marked.

Effect on sodium adsorption ration (SAR) of soil water

SAR in top soil (0-15cm)

SAR before leaching was high, being 30.80. After leaching, it decreased to become between 8.58 and 23.01. Treatments where soil was not amended "SAR" had a mean value of 22.21. Those where soil was amended showed mean values of 10.69 "G", 16.49 "S", 18.83 "ML" and 21.39 "L" . Gypsum was the most effective in reducing SAR followed by sulphur, then by manured lime and lastly by lime. (Table 5).

The two methods of application were equally effective on average giving SAR between 16.73 (non-mix) and 16.97 (mix). The "S" with mixing reduced SAR to a greater extent than without- mixing mean SAR values being 15.0 1 and 17.97 for each technique, respectively. Both rates showed very close values (mean value of 16.71 for rate 1 and 16.99 for rate 2).

The greater efficiency of gypsum over the other materials regarding SAR was marked whether mixed or not mixed in soil. On the other hand, when S, L and ML were not mixed in the soil, they were equally effective, but when mixed into the soil surface, sulphur was superior to ML which in turn showed superiority over L.

SAR in subsoil (15-30cm)

SAR before leaching was high, it was 40.80. After leaching it decreased to be between 18.78 and 34.01. Treatments where soil was not amended "NA" had a mean SAR of 26.11. Those where soil was amended showed mean values of 23.34 "ML", 25.19"G", 28.06"S" and 29.98"L". The manured lime and gypsum were rather similar. Such a pattern was particularly true with non- mix application since under mix condition, all materials were rather similar. Mean SAR values were 25.95 for the non-mix and 27.33 for the mix application. The mean values for the two rates were 25-61 for rate 1 and 27.67 for rate 2 when the material was ML or Gypsum and mixed with the soil, rate 2 showed significantly lower SAR than rate 1.

TABLE 5. Sodium adsorption ratio (SAR) in the soils after reclamation by leaching a soil using different amendments.

Material (T)	Rate (R)	Topsoil Method (S) Non- mix	Topsoil Method (S) Mix	Mean	Subsoil Method (S) Non- mix	Subsoil Method (S) Mix	Mean
Gypsum	Rate 1	10.43	10.30	10.37	24.23	22.46	23.35
	Rate 2	8.58	13.44	11.01	19.27	34.78	27.03
	Mean	9.51	11.87	10.69	21.75	28.62	25.19
Sulphur	Rate 1	19.90	14.77	17.34	27.30	25.43	26.37
	Rate 2	16.03	15.25	15.64	34.01	25.49	29.75
	Mean	17.97	15.01	16.49	30.66	25.46	28.06
Lime	Rate 1	19.00	22.13	20.57	33.51	28.38	30.95
	Rate 2	21.43	23.01	22.22	29.77	28.26	29.02
	Mean	20.22	22.57	21.39	31.64	28.32	29.98
Manured lime	Rate 1	18.68	18.47	18.58	20.70	22.90	21.80
	Rate 2	19.77	18.39	19.08	18.78	30.98	24.88
	Mean	19.23	18.43	18.83	19.74	26.94	23.34
		Mean of rates			Mean of rates		
	Rate 1	17.00	16.42	16.71	26.44	24.79	25.61
	Rate 2	16.46	17.52	16.99	25.45	29.88	27.67
G. Mean		16.73	16.97		25.95	27.33	
Non-amended soil (Leached with no amendments)		22.21			26.11		
LSD 0.05		T= 2.05 R= ns S = ns TR= ns TS= 2.90 RS= ns TRS= ns			T= 4.48 P= ns S = ns TR= ns TS= 6.32 RS = 4.48 TRS= 8.94		

Overall assessment of effect on SAR

Leaching of the soil even without amendments reduced SAR since most of the soluble salts were sodium salts and were subjected to removal by leaching. Amendments, in most cases reduced SAR; gypsum and sulphur showed the most marked effect and lime showed the least effect in the top soil. Mixing sulphur within the soil increased its efficiency and this confirms the importance of contact between sulphur and soil particles in order to obtain its full reclamation benefit. Murakami (1968) reported that high moisture is important for sulphur to show its maximum effect and Kowalenko & Lowe (1975) noted that Sulphur is oxidized in soil within 14 weeks of its addition. In the current experiment, sulphur was allowed 12 weeks for the first applied half and 6 weeks for the second half. Regarding the subsoil (15-30cm), manured lime along with gypsum showed more efficiency than sulphur indicating a slow liberation of calcium ions, most probably under effect of decomposing organic materials. The higher efficiency of sulphur was exerted more in the topsoil than in the subsoil reflecting the greater biological activity of soil in its plough layer and oxidation of sulphur depends mainly on such biological activities. (Kowalenks & Lowe, 1975). The mean SAR values in the subsoil for the two methods of application were not significantly different: 25.95 for non -mix and 27.33 for the mix methods.

Effect on exchangeable sodium percentage (ESP).

ESP in top soil (0-15cm)

ESP before leaching was high; being 38.93; but after leaching it decreased drastically to between 10.61 and 25.53. Treatments where soil was not amended "NA" had a mean ESP of 24.70. Those where soil was amended showed mean values of 13.52 "G", 19.6 "S", 21.86 "ML" and 24.10"L". As occurred with SAR, the most effective amendment was gypsum followed by sulphur, then manured lime; and the least effective was lime which showed an effect resembling that of the non- amended soil. Such pattern occurred under both methods of application (non-mix or mix), also at both rates, *i.e.* no significant interaction occurred; neither with the method of application, nor with the rate of application, nor with both (Table 6) .

TABLE 6. Exchangeable sodium percentage (ESP) in the soils after reclamation by leaching a soil using different amend.

Material (T)	Rate (R)	Topsoil Method (S) Non- mix	Topsoil Method (S) Mix	Mean	Subsoil Method (S) Non-mix	Subsoil Method (S) Mix	Mean
Gypsum	Rate 1	13.27	10.61	11.94	26.52	21.44	23.98
	Rate 2	13.51	16.68	15.09	24.40	34.72	29.56
	Mean	13.39	13.55	13.52	25.46	28.08	26.77
Sulphur	Rate 1	22.75	17.97	20.36	28.92	27.50	28.21
	Rate 2	19.22	18.74	18.84	33.75	27.30	30.52
	Mean	20.99	18.21	19.60	31.34	27.40	29.37
Lime	Rate 1	21.95	24.76	23.36	33.33	29.59	31.46
	Rate 2	24.15	25.53	24.84	30.80	29.46	30.13
	Mean	23.05	25.15	24.10	32.06	29.53	30.79
Manured lime	Rate 1	21.64	21.51	21.58	23.18	25.20	24.19
	Rate 2	22.71	21.44	22.08	21.81	31.57	26.69
	Mean	22.18	21.48	21.83	22.50	28.38	25.44
		Mean of rates			Mean of rates		
	Rate 1	19.91	18.72	19.31	27.99	25.93	26.96
	Rate 2	19.90	20.52	20.21	27.69	30.76	29.23
G. Mean		19.90	19.62		27.84	28.35	
Non- amended soil (Leached with no amendments)		24.70			27.98		
LSD 0.05		T= 2.07 R= ns S = ns TR= ns TS= ns RS= ns TRS= ns			T= 3.19 R= 2.26 S = ns TR= ns TS= 4.51 RS= 3.19 TRS= 6.37		

The two methods of application were equally effective giving ESP between 19.62 (mix) and 19.90 (non-mix). The two rates were also equally effective giving ESP of 19.31 (rate 1) and 20.21 (rate 2).

ESP in subsoil (15-30cm)

ESP before leaching was high; being 40.09. After leaching, it ranged between 21.44 and 34.72. Treatments where soil was not amended "NA" had a mean ESP of 27.98. Those where soil was amended showed mean values of 25.44 "ML", 26.77 "G", 29.37 "S" and 30.79"L". Gypsum and manured lime were equally effective and superior to sulphur and lime which were also equally effective. This pattern was particularly true when amendments were surface applied (non- mix) and at the high rather than the low rate. When application was by mixing the amendments, all materials were rather similar indicating permission of contacting soluble Ca^{++} ions to soil colloids to replace their adsorbed Na.

The mix and non-mix methods were equally effective giving mean ESP values of 27.84 and 28.35, respectively. Rate 1 showed mean ESP of 26.96 and rate 2 showed 29.23.

Overall assessment of effect on soil ESP

The process of leaching was effective in presence as well as in absence of amendments. The ESP of the soil was very high to start with, amounting to around 39 within the 0 to 30 cm of the soil surface. Reclamation leaching caused a reduction in ESP reaching the non-sodic level of below 15. The use of the El-Salam irrigation water seems adequate for reclamation, and reducing ESP. This is most probably due to its rather adequate contents of Ca+ Mg and its low SAR (Table 1) and its marked contents of soluble cations (14 -16 $mmol_cL^{-1}$). However the ESP decrease by leaching without using amendments was not considerable and the soil remained sodic with ESP around 25 to 28 (*i.e.*, exceeding 15). The use of the calcium sources of easily released Ca^{++} ions (*i.e.*, gypsum in particular and manured lime in general) proved to be more effective than either, the non-Ca-acid producing material (*i.e.*, Sulphur), or the alkaline " lime" material (which has extreme slow release of Ca^{++} ions in comparison with gypsum or manured lime).

The effect was most pronounced in the topsoil in particular. Surface applied water (which was used in the experiment) would pass through the surface-applied amendment and infiltrate the top layers allowing exchange process between Ca^{++} and Na. Gupta *et al.* (1985) prefer surface application of easily soluble calcium salts in sodic soils reclamation.

However, the final ESP obtained after leaching with amendments was in the majority of case greater than the calculated value of 10 upon which the gypsum requirement (GR) used in the study was computed. The nearest values to 10 were obtained with gypsum (ESP of 11 to 17). The other three materials showed greater ESP values raneging between 18 to 25. Such differences between the theoretically calculated final ESP and the practically obtained ESP showing unattainability of the required ESP may be due to a number of reasons :

(1) the possibility of exsitance of high contents of free sodium carbonates in soil solution; (2) a probable insufficiency of time for equilibrium between amendments and soil, since gypsum was the only amendment which gave the nearest ESP value to the required ESP target; and lime gave the farthest; therefore, indicating that allowing enough time for equilibrium is of great importance. (3) the actual abtainable ESP may not necessarily be exactly identical to the theoretically calculated ESP. The equation is based on the topsoil, (*i.e.*, the plough layer of 0-15cm) but the subsoil layer benefitted from the materials, so their action was not restricted to the topsoil only. Therefore, when considering the two layers, results show that the gypsum material was more than satisfied the quantity of cmol. kg^{-1} to be substituted with divalent cations. The mean of final ESP in the gypsum- treated topsoil (about 14) is less than its original ESP (about 39) by 25; the corresponding difference for the subsoil is 13. Therefore combining the action for the two layers, applied gypsum requirement seemed sufficient since the GR equation was based on a difference of about 29. Ca- ions in the soluble phase were very high in the gypsum- treated soils particularly in the topsoil (average of about 11 me L^{-1}) in comparison with soils treated with any of the other amendments or the non-amended soil (from about 1 to 2 me L^{-1})

Effect on soluble sodium

Soluble Na^+ in top soil (0-15cm)

Soluble Na^+ before leaching was very high. It was 146.10 $mmol_c$ L^{-1}. After leaching it decreased considerably to between 21.67 and 40.37 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Na^+ of 36.43 me L^{-1}. Those where soil was amended showed mean values of 27.28 "ML", 27.56 "S", 31.48 "G" and 32.18 me L^{-1}"L".

The "mix" application method gave more soluble Na^+ (31.73 $mmol_c$ L^{-1}) than surface application of amendments (27.52 $mmol_c$ L^{-1}); this was particularly true when gypsum or lime was used. Mixing of Ca- materials may have enhanced displacement of Na ions adsorbed on soil colliod thus leading to more Na^+ ions in the soil solution. The two rates gave rather similar souble Na^+ of 29.30 (rate 1) and 29.95 m L^{-1} (rate 2). There was an interaction with the method of application; when amendments were mixed, rate 2 showed more soluble Na^+ than rate 1. Intensive exchange reaction causing more release of adsorbed Na^+ to the soluble phase was probably more active at the high than at the low rate with mixing than with non- mixing (Table7) .

Soluble Na^+ in subsoil (15-30cm)

Soluble Na^+ before leaching was high; it was 127.30 $mmol_c$ L^{-1}. After leaching it decreased to between 20.57 and 72.13 $mmol_c$ L^{-1} . Treatments where soil was not amended "NA" had a mean value of 46.97 $mmol_c$ L^{-1}. Those where soil was amended showed mean values of 32.79 "ML", 36.52 "S", 43.97 "G" and 44.78 me L^{-1}"L". Soluble Na^+ in the two treatments of gypsum and lime were rather similar but higher than in the two treatment of sulphur and manured lime which were also rather simlar. Such a pattern occurred under conditions of mixing amendments with soil.

The "non-mix" application method showed 35.00 mmol$_c$ L^{-1} whereas the mixing method gave a greater value of 44.03 mmol$_c$ L^{-1}. Such pattern of greater values for the (mix) method was particularly true in the case of gypsum. Both rates were effective giving averages of 36.28 (rate1) and 42.74 mmol$_c$ L^{-1} (rate 2).

TABLE 7. Soluble sodium (Na, mmol$_c$ L^{-1}) in the soil after reclamation by using different amendments.

Material (T)	Rate (R)	Topsoil Method (S) Non-mix	Topsoil Method (S) Mix	Mean	Subsoil Method (S) Non-mix	Subsoil Method (S) Mix	Mean
Gypsum	Rate 1	27.10	31.57	29.33	27.43	41.43	34.43
	Rate 2	27.73	39.50	33.62	34.87	72.13	53.50
	Mean	27.42	32.53	31.48	31.15	56.78	43.97
Sulphur	Rate 1	32.50	29.00	30.75	43.70	36.80	40.25
	Rate 2	21.67	27.07	24.37	30.03	35.53	32.78
	Mean	27.08	28.03	27.56	36.87	36.17	36.52
Lime	Rate 1	28.40	33.50	30.95	41.20	49.93	45.57
	Rate 2	26.47	40.37	33.42	45.73	42.57	44.00
	Mean	27.43	36.93	32.18	43.32	46.25	44.78
Manured lime	Rate 1	29.43	22.87	26.15	20.57	29.20	24.88
	Rate 2	26.87	29.97	28.42	36.73	44.67	40.70
	Mean	28.15	26.42	27.28	28.65	36.93	32.79
		Mean of rates			Mean of rates		
	Rate 1	29.36	29.23	29.30	33.23	39.34	36.28
	Rate 2	25.68	34.23	29.95	36.77	48.73	42.74
G. Mean		27.52	31.73		35.00	44.03	
Non- amended soil (Leached with no amendments)		36.43			46.97		
LSD 0.05		T= ns R= ns S = 2.61 TR= ns TS= 5.21 RS= 3.70 TRS= ns			T= 9.24 R= ns S = 6.54 TR= 13.03 TS= 13.03 RS= ns TRS= ns		

Overall assessment of effect of soluble Na$^+$

The very high soluble Na$^+$ of this saline sodic soil before its reclamation decreased considerably upon its reclamation by leaching (with or without amendments) to become one sixth to half of its original level. Soils amended with lime or gypsum showed more soluble Na$^+$ than those amended with manured lime or sulphur. Exchange reaction in the case of gypsum-treated soils or lime- treated soils may have been responsible for releasing more Na$^+$ to the soil solution in comparison with the sulphur treated or the manured lime- treated soils. Gypsum caused the most effective replacement of Na$^+$ by Ca^{++} ions as shown earlier in discussing ESP. The manure material provides colloidal surface for adsorption of soluble Na$^+$. Mixing of gypsum or lime with the soil must have enhanced displacement of adsorbed Na$^+$ on soil colloids.

Effect on soluble chloride

Soluble Cl^- in top soil (0-15cm)

Soluble Cl^- before leaching was high, it was 178.60 $mmol_c L^{-1}$. After leaching it decreased to between 11.00 and 34.00 $mmol_c L^{-1}$. Treatments where soil was not amended "NA" had a mean soluble Cl of 28.00 $mmol_c L^{-1}$. Those where soil was amended showed mean values of 17.13 "ML", 20.57 "S", 21.57 "G" and 24.65 $mmol_c L^{-1}$ "L". Manured lime showed lower soluble Cl^- particularly in relation to gypsum and at the high rate of application. The two methods of application were generally equally effective giving soluble Cl^- of 21.60 (for mix - method) and 20.36 $mmol_c L^{-1}$. Non– mix and the two rates were generally equally effective giving soluble Cl^- between 20.38 (rate 1) and 21.58 $mmol_c L^{-1}$. (rate 2): There was an interaction between the method and rate. The non- mix method showed lower Cl^- than the mix method when both methods concern the high rate; at the low rate both methods showed no difference between each other (Table 8).

TABLE 8. Soluble chloride (Cl; $mmol_c L^{-1}$) in the soil after reclamation by using different amendments.

Material (T)	Rate (R)	Topsoil Method (S)		Mean	Subsoil Method (S)		Mean
		Non- mix	Mix		Non- mix	Mix	
Gypsum	Rate 1	16.60	13.20	14.40	9.73	19.10	14.42
	Rate 2	23.47	34.00	28.23	31.70	51.27	41.49
	Mean	19.53	23.60	21.57	20.72	35.18	27.95
Sulphur	Rate 1	26.00	23.50	24.75	38.77	24.77	31.77
	Rate 2	15.27	17.50	16.38	16.27	16.27	16.27
	Mean	20.63	20.50	20.57	27.52	20.52	24.02
Lime	Rate 1	24.50	29.00	26.75	29.77	37.27	33.52
	Rate 2	20.00	25.10	22.55	41.00	38.90	39.95
	Mean	22.25	27.05	24.65	35.38	38.08	36.73
Manured lime	Rate 1	19.27	11.00	15.13	5.90	17.43	11.67
	Rate 2	18.77	19.50	19.13	20.50	30.10	25.30
	Mean	19.02	15.25	17.13	13.20	23.77	18.48
	Mean of rates				Mean of rates		
	Rate 1	21.59	19.18	20.38	21.04	24.64	22.84
	Rate 2	19.13	24.03	21.58	27.37	34.13	30.75
G. Mean		20.36	21.60		24.20	29.39	
Non- amended soil (Leached with no amendments)		28.00			34.00		
LSD 0.05		T= 4.81 R= ns S = ns RS= 4.81 TS= ns RS= 4.81 TRS= ns			T= 9.33 R= 6.60 S = ns TR= 13.16 TS= ns RS= ns TRS= ns		

Soluble Cl^- in subsoil (15-30 cm)

Soluble Cl before leaching was 116.40 $mmol_c L^{-1}$. After leaching it decreased to between 5.90 and 41.00 $mmol_c L^{-1}$. Treatments where soil was not amended "NA" had a mean soluble Cl^- of 34.00 me L^{-1}. Those where soil was amended showed mean values of 18.48 "ML", 24.02 "S", 27.95 "G" and 36.73 me L^{-1} "L". Therefore gypsum showed a general trend of greater Cl than manured lime but similar to sulphur and lower than lime. There was an interaction with the rate of application: at the low rate gypsum showed lower Cl^- than lime or sulphur; at the high rate it showed the greatest Cl^- of all amendments.

Rate I showed average contents of 22.84 as compared with 30.75mmol$_c$ L^{-1} shown by rate 2 and the non- mix method showed average Cl^- content of 24.20 as compared with 29.39 mmol$_c$ L^{-1} given the mix method.

Overall assessment of effect on soluble Cl^-

To start with, this saline sodic soil contained very high contents of chlorides which were drastically reduced to as much as, one sixth or less of their original concentration, upon leaching of the soil. Manured lime must have caused more improvement to soil structure compared with other treatments. This would lead to increased infiltration of water, thus, more removal of chlorides as well as other soluble ions. Manured lime also showed the lowest EC compared with soils treated with other amendments.

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دراسة حقلية مقارنة باستخدام مياه ترعة السلام وتقييم الجير المخلوط بسماد بلدى ازاء الجبس أو الجير أو الكبريت فى استصلاح أرض مالحة صودية بسهل الحسينية – دلتا النيل

على احمد عبد السلام ، عمر حسينى محمد الحسينى و فكرى عبد المنعم فرج*
قسم الأراضى – كلية الزراعة – بمشتهر (فرع بنها) جامعة الزقازيق و* مركز البحوث الزراعية – القاهرة – مصر.

أجريت تجربة حقلية بقرية المفتربين- سهل الحسينية- دلتا النيل وهى أراضى ملحية صودية ذات قوام سلتى طينى ولها EC= ١٧,٧دس/م ، ESP= ٣٨,٩، pH= ٨,١ مع إضافة الجير، الجبس ،الكبريت، الجير المخلوط بسماد بلدى أو بدون إضافة.

واستخدمت مياه ترعة السلام فى غسيل هذه الأراضى بنظام الغسيل المتقطع بدورتين كل دورة تشمل عطائين من المياه الأول ٦٠٠م^{٣}/ فدان ويترك لمدة اسبوعين يليه الثانى وهى ٩٠٠ م^{٣} /فدان ثم يترك شهر لتبدأ بعدها الدورة الثانية والنتائج المتحصل عليها هى:-

انخفاض الـ EC، ESP انخفاضا ملحوظا وصل إلى ٣ دس/م و٢١,٨ على التوالى عند إضافة الجير المخلوط بالسماد البلدى. ووصلت لباقى الاضافات إلى ٣,٤دس/م ، ٢٤,١ (بالنسبة للجير) ، ٤,٦ دس/م، ١٣,٥ (بالنسبة للجبس)، ٣,٦ دس/م، ٩,٦ (بالنسبة للكبريت).

أما قيم الـ pH بعد الاضافة فأصبحت ٨,٣ (للجير المخلوط بالسماد البلدى)، ٨,٢٩(للجير) ، ٨,٠٦ (بالنصبة للجبس)، ٨,٢٨ (بالنسبة للكبريت).

أما الأراضى التى غسلت بدون إضافة فانخفضت قيمة الـ EC لتصل إلى ٤,١ دس/م، ESP إلى ٢٤,٧ ، pH وصل إلى ٨,٣٣ والتجربة تظهر أن الجير ازدادت كفاءته فى استصلاح الأراضى الملحية الصودية وذلك بخلطه بالمادة العضوية.