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4- RESULTS AND DISCUSSION

Results will be dealt within the context of two aspects. The first is the response after execution of leaching operation for the objective of removing excess sodicity and salinity. The second is the subsequent response in terms of growth and yield of rice cultivated in the reclaimed experimental plots.

4.1. Reclamation leaching of soil and improvement in soil salinity, sodicity, and other chemical properties.

The aim of this experiment with regard to both salinity and sodicity reclamation is to evaluate four different sodicity – reclamation materials (gypsum, sulphur, lime, and manured lime) in removing excess sodicity from a saline sodic silty clay soil using the intermittent - leaching technique and the Salam- Canal's irrigation water (of EC= 1.4 to 1.6 dSm^{-1}). The quantities of amendments (gypsum requirement) required were calculated by equation (see page 26) on the basis of attaining a final ESP of 10 for the top 15 cm of soil surface which had an ESP of about 39. The original EC of the top 15 cm was about 18 dSm^{-1}. Applied quantities were done on two basis. (a) The exact gypsum requirement (GR) amount; and (b) The GR with excess 25% of it in order to cater for sodium ions in the soluble phase of the colloidal system of soil water. The ESP was reduced to reach a range of about 11 to 26, and the EC was also reduced to reach a range of about 2 to 7 dSm^{-1} by completion of the leaching operation. The reclamation response was more prominent in the topsoil than in the subsoil.

4.1.1. Effect on soil salinity:

I- Salinity in top soil (0-15 cm), Table 3:

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 application of amendments mixed into the soil surface (3.95 dSm^{-1}). The two 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.

II- Salinity in sub soil (15-30 cm), Table 4:

The EC before leaching was high; it was 12.81 dSm^{-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 (surface application) and 4.86 dSm^{-1} (mixed into the soil surface). 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 were equal in effect, but the "ML" treatment gave EC lower than; "G" and this was evident with the non-mix method. Rate 2 was particularly superior to rate 1 only in the case of "S". The surface application was particularly superior to the mixing application in the case of "ML" and "G" amendments.

III- Overall assessment of effect on soil salinity:

Leaching of the soil, specially with amendments resulted in a marked decrease in soil salinity. Reclamation reduced the EC of about 12.81 to 17.71 to between 2.04 to 5.64 dSm^{-1}. Taking into consideration the salinity of the water used for reclamation, which had an EC of between 1.4 to 1.6 dSm^{-1}, the outcome of leaching reclamation was, in the case of leaching with manured lime is nearly in accordance with the empirical equation given by FAO (1976). 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 thus, expected estimate of EC would be between 2.1 and 2.4 dSm^{-1}. Results show that the lowest obtained EC was in the case of leaching with "ML", it was 2.31 in the topsoil and 2.04 dSm^{-1} in subsoil. Both are near enough to the theoretical values which relate the water's EC according to the aforementied equation. Presence of manure must have improved the physical conditions of the soil. Besides, decomposition of organic matter and the contents of organic acids may have accelerated the desalination of the soil. Applying manure to soil leads to presence of organic colloids which would adsorb more salt ions from soil solution, thus decreasing salinity of soil water. Physical improvement of soil structure and infiltration rate which may have occurred in the manured-lime treatment (due to the organic manure) may have contributed to more removal of soluble salts in the ML-treatment.

4.1.2. Effect on soil pH.

I- Soil pH in top soil (0-15 cm), Table 5

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".

The two methods of application were equally effective giving pH between 8.16 (mixed into the soil surface) and 8.21 (surface application); i.e. non-mix. 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. Mixing application was superior to the surface application particularly in the case of the high rate of application.

II- Soil pH in subsoil (15-30 cm), Table 6 :

The pH before leaching was 8.00; after leaching it ranged between 8.03 and 8.67. Treatments where soil was not amended "NA" had a mean pH of 8.20. Those where soil was amended showed mean values of 8.23 "ML", 8.25 "G", 8.27 "L", and 8.50 "S". Application of amendments mixed into the soil surface was more effective (pH 8.25) than surface application (pH 8.37).

Rate 2 showed a mean pH of 8.23, and the rate 1 showed 8.39. The amendments "ML", "G", and "L" were equally similar in effect and showed values lower than "S".

III- 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, which would lead to lower Na, and manured lime which contained organic manure. This illustrates the indirect effect of decreased sodium and the direct effect of organic acids which must have been formed during decomposition of manure. The addition of materials on the surface without mixing caused low reduction in soil pH particularly in the soil surface. This is expected since in this case concentration of amendments would be more in the topsoil than in the subsoil. El-Kobbia et al., (1969) *obtained a 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 in Tal El-Kabeer, Egypt. Gypsum and sulphuric acid were shown equally effective by Milapchand et al., (1977). Starkey (1966) reported that some of the important micro-organisms which oxidized sulphur perform their highest activity with a pH range of 2 to 4.7; therefore with a rather high soil pH, sulphur oxidation may not be considerable.

4.1.3. Effect on sodium Adsorption Ratio (SAR) of soil water:

I- SAR in top soil (0-15 cm), Table 7.

SAR before leaching was high, it was 30.80. After leaching it decreased to between 8.58 and 23.01. Treatments where soil was not amended "NA" had a mean SAR 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.

The two methods of application were equally effective on average giving SAR between 16.73 (surface application) and 16.97 (mixed into the soil 0-15 cm surface). However the use of "S", mixing reduced SAR to a greater extent than no-mixing: mean SAR values being 15.01 and 17.97 for each technique, respectively. Both rates showed no significant difference (mean value of 16.71 for rate 1 and 16.99 for rate 2).

The efficient effect of gypsum over the other materials in reducing SAR was in both methods of mixing as well as surface application. The other 3 materials showed slight differences with the surface application, but when mixed into the soil surface, sulphur was significantly superior to manured lime, which in turn showed significant superiority over lime.

II- SAR in subsoil (15-30 cm), Table 8.

SAR before leaching was high; it was 40.8. After leaching it decreased to 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 and more effective in reducing SAR than the other two materials which in turn were similar. Such a pattern was particularly true with surface non-mix application. However, ML when applied using the mixing technique resembled the other materials using the same technique.

The mean SAR values for the two methods of application were not significantly; different 25.95 for the surface application and 27.33 for the mixed application. The mean values for the two rates were also, not significant giving SAR of 25.61 at rate 1 and 27.67 at rate 2. However, there was a significant interaction: rate 2 was more effective than rate 1 when the material was manured lime or gypsum applied mixed with the soil.

III- Overall assessment of effect on SAR:

Leaching, even without amendments reduced SAR since: most of the soluble salts was sodium, in topsoil and subsoil. Amendment, in most cases reduced SAR. Regarding the topsoil (0-15 cm soil surface), gypsum followed by sulphur showed the most marked effect and lime showed the least effect concerning lowering SAR. Gypsum is of greater solubility than lime. Mixing sulphur within the soil was more superior 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. Sulphur was reported by Kowalenko and Lowe (1975) to be oxidized in the soil within 14 weeks of its application. In the current experiment, sulphur was allowed to be oxidized in the soil for a period of 12 weeks for the first applied half and 6 weeks for the second half, before analysing the soil. Regarding the (15-30 cm) subsoil, manured lime along with gypsum showed more efficiency than sulphur indicating a slow dissolution of calcium materials especially with decomposing organic materials. The higher efficiency of sulphur in the topsoil than in the subsoil reflects the greater biological activity in the topsoil. Oxidation of sulphur depends mainly on biological activities.

4.1.4. Effect on exchangeable sodium percentage (ESP).

I- ESP in top soil (0-15 cm), Table 9.

ESP before leaching was high; it was 38.93. 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", 19.60 "S", 21.83 "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 application); also at both rates i.e. no significant interaction: neither with the method of application, nor with the rate of application, nor with both.

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

II- ESP in subsoil (15-30 cm), Table (10).

ESP before leaching was high; it was 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; and at the high rather than the low rate. When application was done by mixing the amendments within the surface 15 cm of topsoil, all materials affected the subsoil to the same degree. Having amendments incorporated into the soil seemed to allow soil colloids equal chances for exchange equilibria between calcium ions of the soil solution and sodium ions on the adsorption sites of soil colloids.

The two methods of application were equally effective giving mean ESP values of 27.84 (for surface non-mix application) and 28.35 (for the mix in soil application). Rate 1 showed mean ESP of 26.96 and rate 2 showed 29.23.

III- Overall assessment of effect on soil ESP:

The process of leaching was highly effective weather or not amendments were used. The ESP of the soil was very high to start with, amounting to 40 within the 0 to 30 cm of the soil surface. Reclamation leaching caused a reduction in ESP to reach the non – sodic level of below 15 in the topsoil treated with gypsum in particular. The use of water alone for reclamation, reduced ESP. This is most probably due to its contents of Ca + Mg and low SAR (Table 1) and its marked contents of soluble cations (14-16 meL^{-1}). However the reduction 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 and manured lime) proved 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 and Singh (1985) prefer surface application of easily soluble calcium salts in sodic soils reclamation.

However, the final ESP which was obtained after leaching with amendment was in the majority of treatments greater than the calculated value of 10 upon which the gypsum requirement (GR) was estimated. The nearest values of ESP was obtained with gypsum: values ranged from 11 to 17. The other three materials showed greater ESP values ranging between 18 to 25 with sulphur the lowest of the three and lime is the highest. Such difference between the theoretically calculated final ESP and the practically obtained ESP upon application of the theoretically calculated GR may be due to a number of reasons: (1) The high contents of free sodium carbonates in soil solution. (2) Insufficiency of time for equilibrium between amendments and soil since gypsum was the amendment which gave the nearest ESP value; and lime gave the farthest; therefore, allowing enough time for equilibrium is of great importance. (3) actually, obtained 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 0-15 cm and 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 for the gypsum material, the requirements applied were more than satisfied the quantity of $cmol_c\ kg^{-1}$ to be substituted with divalent cations. The mean of ESP in the gypsum-treated topsoil (about 14) is less than the original ESP of the topsoil (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}).

4.1.5. Effect on soluble ions.

A. Effect on soluble calcium

I. Soluble Ca^{++} in top soil (0-15 cm), Table 11

Concentration of soluble Ca^{++} before leaching was 12.20 me L^{-1}. After leaching it ranged between 1.23 and 12.47 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Ca^{++} of 1.70 me L^{-1}. Those where soil was amended showed mean values of 1.43, "L", 1.63 "ML", 2.18 "S", and 10.78 me L^{-1} "G". Gypsum was superior to all other amendments since its treatments showed higher concentration of Ca^{++} compared with other amendments by five to ten folds. The other three amendments were rather similar and contents of soluble Ca^{++} in soils treated with them were around 1 to 2 me L^{-1}. The increase of Ca^{++} concentration in the soil solution caused by gypsum over the other amendments occurred under both methods of application as well as at both rates of application; i.e. there was no interaction between the method of application and the source of amendment; or between the rate of application and the source of amendment. Thus, the superior efficient action of gypsum is mainly due to its production of abundant amount of Ca ions.

The two methods of application were equally effective giving mean values of soluble Ca^{++} of between 3.86 me L^{-1} (surface application) and 4.15, me L^{-1} (mixed into the soil surface). The two rates were equally effective giving soluble Ca^{++} between 3.91 me L^{-1} (rate 1) and 4.10 me L^{-1} (rate 2).

II. Soluble Ca^{++} in subsoil (15-30 cm), Table 12.

The soluble Ca^{++} before leaching was 5.20 me L^{-1}; after leaching it ranged between 0.70 and 4.03 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Ca^{++} of 2.47 me L^{-1}. Those where soil was amended showed mean values of 1.48 "L", 1.87 "S", 2.03 "ML", and 3.26 me L^{-1} "G".

The two methods of application were equally effective giving mean values of soluble Ca^{++} of between 2.13 me L^{-1} (surface non-mix application) and 2.19 me L^{-1} (mixed into the soil surface). The two rates were equally effective giving soluble Ca^{++} of 1.93 (rate 1) and 2.40 me L^{-1} (rate 2). The four treatments were equally effective.

III- Overall assessment of effect on soluble Ca^{++}:

Soluble Ca^{++} was high in the soil before reclamation leaching. This is a predicted result of the very high salinity in general in this soil. Since leaching flushed a considerable part of soluble salts (decreasing the EC from about 18 to between 2 – 6 dS m^{-1} see (Table 3 and Figure 5), therefore soluble Ca^{++}

was among other soluble was suffering a considerable decrease by leaching. Such a decrease was not considerable when gypsum in particular was the amendment, but it was high where no amendment was used, or where lime, manured lime, or sulphur was used. The higher solubility of gypsum in comparison with lime or manured lime on one hand, and the slow process of sulphur oxidation on the other hand are most certainly the causes for greater Ca^{++} in the gypsum-treated soils. Since the topsoil contained far more soluble salts than the subsoil, and the amendments were applied either on top of its surface or within its surface 0-15 cm, soluble Ca^{++} was considerably greater in the topsoil than in the subsoil. Koriem (1994) reported a decrease in soluble ions of a saline-sodic soil by using gypsum during its reclamation.

B- Effect on soluble Magnesium

I. Soluble Mg^{++} in top soil (0-15 cm), Table 13

Soluble Mg^{++} before leaching was 32.90 me L^{-1}. After leaching it ranged between 1.70 and 8.73 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Mg^{++} of 3.60 me L^{-1}. Those where soil was amended showed mean values of 2.74 "ML", 3.32 "L", 3.63 "S", and 7.26 me L^{-1} "G". Thus gypsum treatments contain significantly more soluble Mg^{++} over contents in treatments receiving the other three amendments, which did not significantly differ. This occurred under all techniques and under both rates. However, gypsum gave more Mg^{++} over the other materials particularly when the rate was low and the materials were mixed with the soil. Thus to obtain the best result from gypsum if the application rate is low, mixing must be carried out.

Application of amendments mixed into the soil surface was more effective (4.74 me L^{-1}) than the surface application (3.73 me L^{-1}). The two rates gave soluble Mg^{++} of 4.19 (rate 1) and 4.28 me L^{-1} (rate 2) which were not much different from each other.

II. Soluble Mg^{++} in subsoil (15-30 cm), Table 14

The soluble Mg^{++} before leaching was 14.30 me L^{-1}. After leaching it ranged to between 0.37 and 6.40 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Mg^{++} of 3.93 me L^{-1}. Those where soil was amended showed mean values of 2.18 "S", 2.61 "ML", 3.43 "L", and 4.10 me L^{-1} "G". The greater soluble Mg^{++} found in the gypsum-treated soil over those treated with any of the other amendments was true under the high rate and not the low one. This was the only significant interaction, i.e. an interaction between amendments and the rate of their application.

The two methods of application were equally effective giving soluble Mg^{++} of 2.74 (surface application) and 3.43 me L^{-1} (mixed into the soil surface). The two rates gave mean values of soluble Mg^{++} of 2.59 for rate 1 and 3.57 me L^{-1} for rate 2, such values were not significantly different. However, the significant interaction between amendments and the rate of application was manifested as follows: with the gypsum amendment the high rate showed significantly greater Mg^{++} than the low rate, but with any of the other amendments, there was no difference between the two rates.

III- Overall assessment of effect on soluble Mg^{++}:

The considerably high content of soluble Mg^{++} in this saline sodic soil, before leaching, reflects its history, being an old fish-farm, with far more soluble Mg^{++} (14-33 me L^{-1}) than Ca^{++} (5-12 me L^{-1}). Application of leaching operation (with or without amendments) reduced such Mg^{++} contents considerably reaching a very small fraction of their original values and getting rid of 73-94 % of Mg^{++} of the topsoil and 58-97 % of Mg^{++} of the subsoil. This reflects the dominance of soluble Mg^{++} over soluble Ca^{++} ; and the ease of removing soluble Mg^{++} by leaching because Mg^{++} salts are easily soluble, this is reflected by higher Mg^{++} in subsoil than in top soil. The gypsum material may have contented Mg sulphate along with Ca sulphate. Also, soluble Ca^{++} would substitute exchangeable Mg on soil colloids thus releasing Mg^{++} to the soil solution. Marcos et al., (1984) reported a decrease in exchangeable Mg^{++} due to application of gypsum.

C. Effect on soluble sodium

I. Soluble Na^+ in top soil (0-15 cm), Table 15

Soluble Na^+ before leaching was very high. It was 146.10 me 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 "non mix" application method (surface application) gave less soluble Na^+ (27.52 me L^{-1}) than application of amendments mixed into the soil surface (31.73 me L^{-1}). This was particularly true when gypsum or lime was used. (The mixing of any of these materials may have enhanced displacement of adsorbed Na^+ thus giving more Na^+ in the soluble phase) The two rates gave rather similar soluble Na^+ of 29.30 (rate 1) and 29.95 me L^{-1} (rate 2). Here there was another interaction with the method of application. When amendments were mixed, rate 2 showed clearly 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.

II. Soluble Na^+ in subsoil (15-30 cm), Table 16

Soluble Na^+ before leaching was high it was 127.30 me L^{-1}. After leaching it *decreased to between 20.57 and 72.13 me L^{-1}. Treatments where* soil was not amended "NA" had a mean soluble Na^+ of 46.97 me 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 similar and higher than in the other two amended treatments which were also similar to each other. Such a pattern occurred under conditions of mixing amendments with soil.

The "non mix" application method (surface application) showed an average of 35.00 me L^{-1} whereas mixing the amendments with the soil gave greater soluble Na^+ of 44.03 me L^{-1}. Such pattern was particularly true in the case of gypsum. The two rates were equally effective giving averages of 36.28 (rate 1) and 42.74 me L^{-1} (rate 2).

III- Overall assessment of effect on soluble Na^+:

The very high Na^+ in solution of the original saline sodic soil decreased considerably by leaching (with or without amendments) to become less than 1-3 its original level. Soils amended with sulphur and manured lime showed less soluble Na^+ than those amended with lime or gypsum. 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. Besides, the manure material provides colloidal surface for adsorption of soluble Na^+. As results on

ESP show, gypsum was the most effective in reducing ESP; and as results on pH shows, manured lime showed the lowest pH value. The mixing of materials must have enhanced displacement of adsorbed Na^+.

D- Effect on soluble potassium.

I- Soluble K^+ in top soil (0-15 cm), Table 17

Soluble K^+ before leaching was 1.90 me L^{-1}. After leaching it ranged between 0.80 and 1.70 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble K+ of 1.47 me L^{-1}. Those where soil was amended showed mean values of 1.06 "L", 1.14 "S", 1.41 "ML" and 1.43 me L^{-1} "G". Gypsum and manured lime were equally effective and showed more soluble K^+ than the other two amendments. The two methods of application were equal in effect giving soluble K^+ between 1.24 (surface application) and 1.28 me L^{-1} (mixed into the soil surface). The two rates were also of equal effect giving soluble K^+ between 1.22 (rate 2) and 1.30 me L^{-1} (rate 1).

II. Soluble K^+ in subsoil (15-30 cm), Table 18

Soluble K^+ before leaching was 1.40 me L^{-1}. After leaching it ranged between 0.77 and 1.29 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble K^+ of 1.17 me L^{-1}. Those where soil was amended showed mean values of 0.88 "S", 0.94 "L", 1.01 "ML" and 1.02 "G" with no significant difference between amendments. However, there was an interaction between treatments and the rate of application: at the high rate manured lime showed greater K^+ than the others except gypsum; at the low rate they were all equal. The two methods of application were equally effective giving means of soluble K^+ of 0.96 (surface application) and 0.97 me

L^{-1} (mixed into the soil surface). The two rates were also equally effective giving soluble K^+ between 0.95 (rate 2) and 0.97 me L^{-1} (rate 1).

III- Overall assessment of effect on soluble K^+:

Soluble K^+ was not very high in the original soil before leaching. Leaching decreased soluble K^+, with little differences between amendments. The very high contents of other cations particularly sodium renders the part of K^+ ion very small in cations relationships. However, it seems that the general trend of relationships between amendments was similar to the trend shown relating soluble Na^+: i.e. with manured lime and gypsum having: more soluble K^+ in their soil treatments than in treatments of the other two amendments.

E- Effect on soluble bicarbonate

I. Soluble HCO_3^- in top soil (0-15 cm), Tale 19

Soluble HCO_3^- before leaching was 0.60 me L^{-1}. After leaching it ranged between 0.60 and 1.80 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble HCO_3^- of 1.37 me L^{-1}. Those where soil was amended showed mean values of 0.74 "G", 1.08 "S", 1.15 "L" and 1.33 me L^{-1} "ML". The manured lime gave the highest value particularly with mixing and where the rate of amendments application was high. The two method of application were equally effective giving soluble HCO_3^- between 1.05 (surface application) and 1.09 me L^{-1} (mixed into the soil surface). The two rates were equally effective giving soluble HCO_3^- between 1.05 (rate 2) and 1.10 me L^{-1} (rate 1). However, there was an interaction between the method, the rate, and the amendment. Manured lime gave greatest HCO_3^- particularly when amendments were added at the high rate and when they were mixed with the soil.

II. Soluble HCO_3 in subsoil (15-30 cm), Table 20

Soluble HCO_3^- before leaching was 0.70 me L^{-1}. After leaching it ranged between 0.83 and 1.40 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble HCO_3^- of 1.07 me L^{-1}. Those where soil was amended showed mean values of 0.93 "G", 0.98 "S", 1.06 "ML" and 1.23 me L^{-1} "L". Both lime and manured lime showed greater HCO_3^- than gypsum or sulphur. The former amendments were equal in effect. This occurred under all rates and all application methods i.e. there was no interaction.

The two methods of application were equally effective giving soluble HCO_3^- between 1.02 (mixed into the surface) and 1.08 me L^{-1} (surface application). The low application rate gave greater HCO_3^- than the high application rate with averages of 1.12 and 0.98 me L^{-1} for each rate respectively.

III- Overall assessment of effect on soluble HCO_3^-:

Manured lime and lime gave greater HCO_3^- contents since both are carbonates. However, contents were not exceeding soluble cations of Ca^{++} + Mg^{++}; therefore no hazards concerning residual sodium carbonates would be expected.

F- Effect on soluble chloride.

I. Soluble Cl^- in top soil (0-15 cm), Table 21

Soluble Cl^- before leaching was high, it was 178.60 me L^{-1}. After leaching it decreased to between 11.00 and 34.00 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble Cl of 28.00 me L^{-1}. Those where soil was amended showed mean values of 17.13 "ML", 20.57 "S", 21.57 G and 24.65 me 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^- between 21.60 (mixed into soil surface) and 20.36 me L^{-1} (surface application), and the two rates were generally equally effective giving soluble Cl^- between 20.38 (rate 1) and 21.58 me L^{-1} (rate 2): However there was an interaction between the method and the 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.

II. Soluble Cl^- in subsoil (15-30 cm), *Table 22*

Soluble Cl^- before leaching was 116.40 me L^{-1}. After leaching it decreased to between 5.90 and 41.00 me 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 given by manured lime but similar to sulphur and lower than given by lime. However: 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 1 showed average contents of 22.84 as compared with 30.75 me L^{-1} shown by rate 2 and the non-mix method showed average Cl^- content of 24.20 as compared with 29.39 me L^{-1} given by the mix method.

III- Overall assessment of effect on soluble Cl^-:

The original saline sodic soil contained very high contents of chlorides which were drastically reduced to one sixth of their original concentration, or less, 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 rate of water, thus, more removals of soluble ions including chlorides. Results on salinity improvement (Tables 3 and 4) show that manured lime soil showed the lowest EC compared with soils treated with other amendments.

G. Effect on soluble sulphate:

I. Soluble $SO_4^=$ in top soil (0-15 cm), Table 23

Content of soluble $SO_4^=$ before leaching was 13.90 me L^{-1}. After leaching it ranged to between 8.73 and 39.54 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble $SO_4^=$ of 26.15 me L^{-1}. Those where soil was amended showed mean values of 12.19 "L", 12.86 "S", 14.61 "ML" and 28.64 me L^{-1} "G". However, there was an interaction envolving the *type of amendment, the rate of application and the method of application.*

Surface application showed average $SO_4^=$ content of 14.94 me L^{-1} as compared with 12.21 me L^{-1} shown by the mix method. The two rates were equally effective giving soluble $SO_4^=$ between 16.94 (rate 2) and 17.22 me L^{-1} (rate 1).

Gypsum showed the highest soluble $SO_4^=$ under all conditions of application rate and application method. Lime showed the lowest soluble $SO_4^=$ except when the rate of amendments application was high and where amendments were mixed into the soil surface; under these conditions combined together, lime was as effective as gypsum giving $SO_4^=$ similar to those given by the gypsum treatment

II. Soluble $SO_4^{=}$ in subsoil (15-30 cm), Table 24

Content of soluble $SO_4^{=}$ before leaching was 31.10 me L^{-1}. After leaching it ranged between 7.77 and 30.13 me L^{-1}. Treatments where soil was not amended "NA" had a mean soluble $SO_4^{=}$ of 19.47 me L^{-1}. Those where soil was amended showed mean values of 12.67 "L", 16.45 "S", 18.90 "ML and 23.47 me L^{-1} "G". Gypsum gave the highest $SO_4^{=}$ of all amended treatments only when amendments were mixed with the soil.

Mean values for rates of amendments were 17.81 me L^{-1} for rate 1 and 17.94 me L^{-1} for rate 2. Method of non-mix application showed a mean value of 15.54 me L^{-1} and the method of mix application showed 20.21 me L^{-1}.

III- Overall assessment of effect on soluble $SO_4^{=}$:

Since gypsum is a sulphate salt, soils treated with it showed the highest contents of $SO_4^{=}$ ions. Mixing the amendment helped increase contents of the sulphates.

4.2. Cultivation of the reclaimed soil and evaluating its productivity of rice crop:

4.2. 1. Rice grain yield, Table 25

Following reclamation of the soil, rice crop grown in the reclaimed soil gave grain yields ranging between 1.10 and 3.23 ton /fed. Treatment where soil was leached but not amended "NA" gave 1.80 ton/fed. Where soil was leached with amendments mean yields were 1.57 "L", 2.47 "G", 2.68 "S" and 2.98 ton/fed "ML". The treatment which received manured lime gave the highest yield. Gypsum was similar to sulphur and both were superior to the "lime" treatment which gave the lowest yield of the amended treatments.

The two methods of application were equally effective giving grain yield between 2.40 (mixed into the soil surface) and 2.45 ton/fed (surface, non-mix, application); and the two rates were equally effective giving grain yield between 2.34 (rate 1) and 2.501 ton/fed (rate 2).

4.2. 2. Rice straw yield, Table 26

Yields ranged between 1.97 and 3.83 ton/fed. Treatments where soil was not amended "NA" gave 1.93 ton/fed. Those where soil was amended showed mean values of 2.40 "L", 2.90 "G", 3.05 "S" and 3.56 Ton /fed "ML".

The pattern of response was mainly similar to that concerning the grain yield. As the case with grain yield, results of the straw yield show that manured lime gave the highest yield. All amended treatments gave more yields than the non-amended one. Gypsum and sulphur were similar, but both were superior to the lime treatment. The two methods of application were equally effective giving straw yield between 2.89 (mixed into the soil surface) and 3.07 ton/fed (Surface, non-mix, application). The two rates were equally effective giving straw yield between 2.93 (rate 1) and 3.03 ton/fed (rate 2).

4.2. 3. Rice total (grain + straw) yield, Table 27

The pattern of response resembled those of grain yield and straw yield. Manured lime gave the highest followed by gypsum and sulphur which were similar and lime giving the lowest of the amended treatments. Yield of (grain + straw) ranged between 3.07 and 7.07 ton/fed. Treatments where soil was not amended "NA" gave 3.73 ton/fed. Those where soil was amended showed mean values of 3.97 "L", 5.37 "G", 5.73 "S" and 6.53 ton/fed "ML". The two methods of application gave (grain + straw) yield of 5.28 (mixed into the soil surface)and 5.52 ton/fed (surface application). The two rates were equally effective giving (grain + straw) yield of 5.27 (rate 1) and 5.53 ton/fed (rate 2).

III- Overall assessment of effect on yield:

Assessing soil productivity, taking in consideration the different amendments would envolve the nutritive aspect of the amendment. Since manured lime has a higher nutritive value than the other amendments, yield of rice was highest in treatments receiving this amendment. In the case of lime, the low yield given by this amendment may indicate some imbalances in plant nutrition caused by it. Lime-treated plots showed generally the highest values of some parameters of negative effect on plant growth such as soluble Na^+, soluble Cl^-, SAR, ESP; on the other hand those soils also, showed, in general, the lowest values of soluble K^+, and soluble Ca^{++} (see Tables 7 to 12; and 15 to 18; and 21 – 22). Increased contents of calcium carbonate in soil treated with lime would lead to other nutritional disorders involving precipitation of a number of important trace elements and phosphorus, problems encountered in calcareous soils (Dahiya and Singh 1977, Tisdala and Nelson 1975).

Table (3): Salinity (expressed as EC "dSm^{-1}") in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

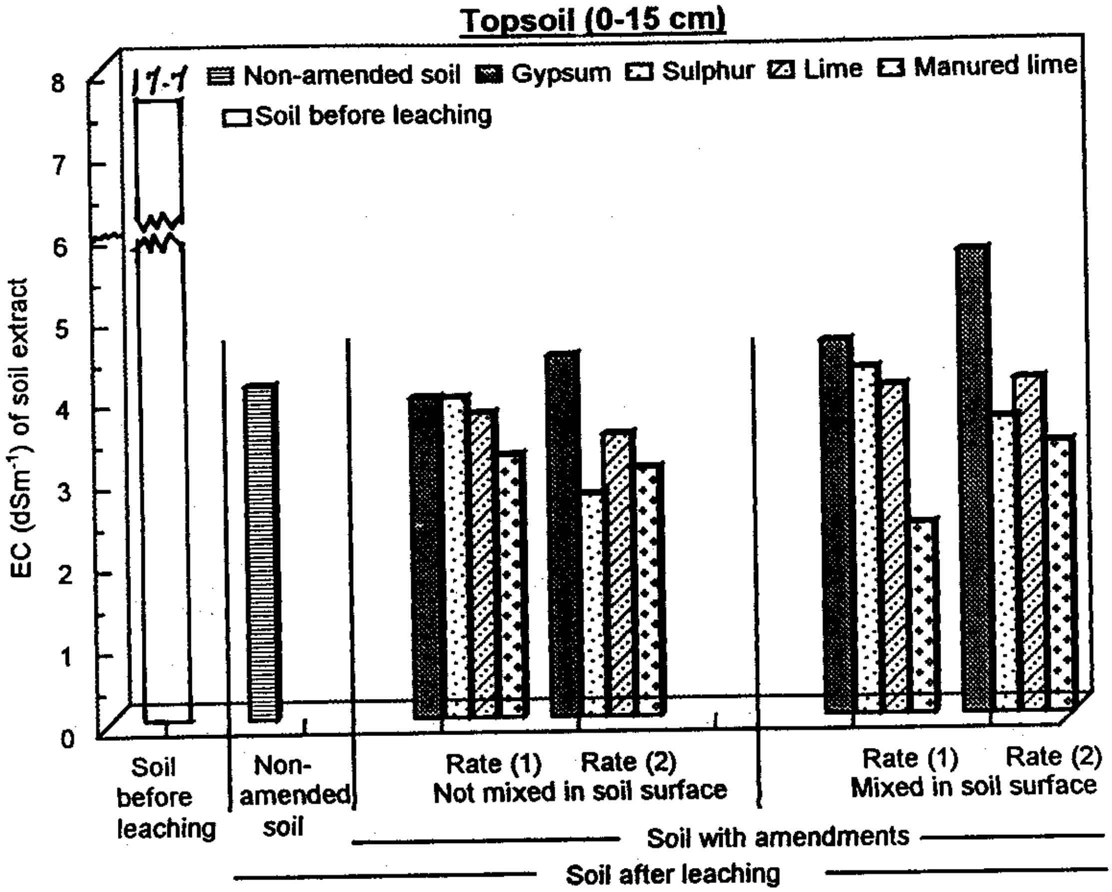
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	3.90	4.55	4.23
	Rate 2	4.40	5.64	5.02
	Mean	4.15	5.10	4.62
Sulphur	Rate 1	3.89	4.21	4.05
	Rate 2	2.70	3.59	3.15
	Mean	3.30	3.90	3.60
Lime	Rate 1	3.70	3.99	3.84
	Rate 2	3.42	4.06	3.74
	Mean	3.56	4.02	3.79
Manured lime	Rate 1	3.18	2.31	2.75
	Rate 2	3.01	3.28	3.15
	Mean	3.10	2.80	2.95
	Mean of rates			
	Rate 1	3.67	3.76	3.72
	Rate 2	3.38	4.14	3.76
G. Mean		3.53	3.95	
Non-amended soil (Leached with no amendments)		4.06		

LSD 0.05: T = 0.54 R = ns S = 0.38 TR = 0.76
TS = ns RS = ns TRS = ns

Table (4): Salinity (expressed as EC "dSm^{-1}") in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S)		Mean
		Non-mix	Mix	
Gypsum	Rate 1	3.07	4.92	3.99
	Rate 2	4.47	7.43	5.93
	Mean	3.75	6.17	4.96
Sulphur	Rate 1	5.73	4.34	5.03
	Rate 2	3.37	3.98	3.68
	Mean	4.55	4.16	4.36
Lime	Rate 1	4.50	5.23	4.87
	Rate 2	5.62	4.62	5.12
	Mean	5.06	4.93	4.99
Manured lime	Rate 1	2.04	3.62	2.83
	Rate 2	4.57	4.71	4.64
	Mean	3.31	4.17	3.74
	Means of rates			
	Rate 1	3.83	4.53	4.18
	Rate 2	4.50	5.19	4.84
G. Mean		4.17	4.86	
Non-amended soil (Leached with no amendments)		5.48		

LSD 0.05: T = ns R = ns S = ns TR =1.56
TS = 1.56 RS = ns TRS = ns



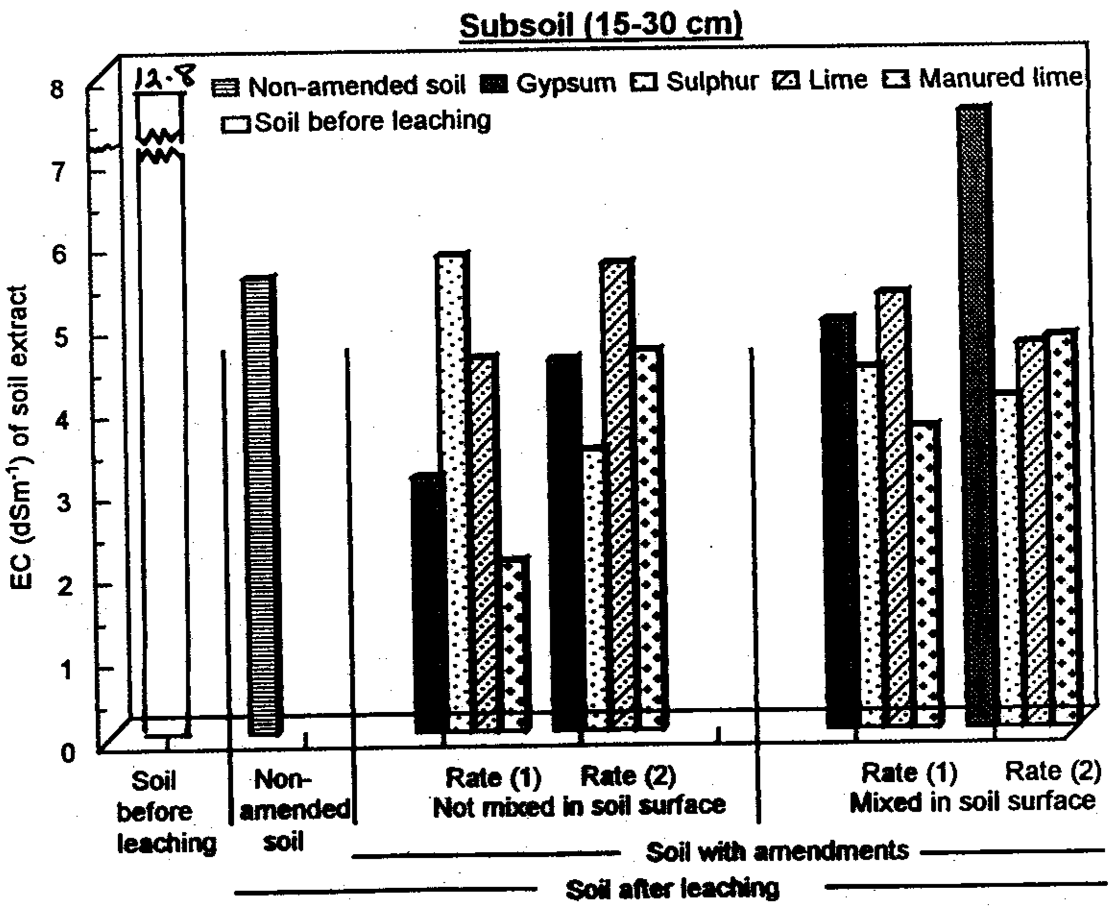


Fig. (1): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soil salinity (expressed as EC of soil saturation extract).

Table (5): Soil pH in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

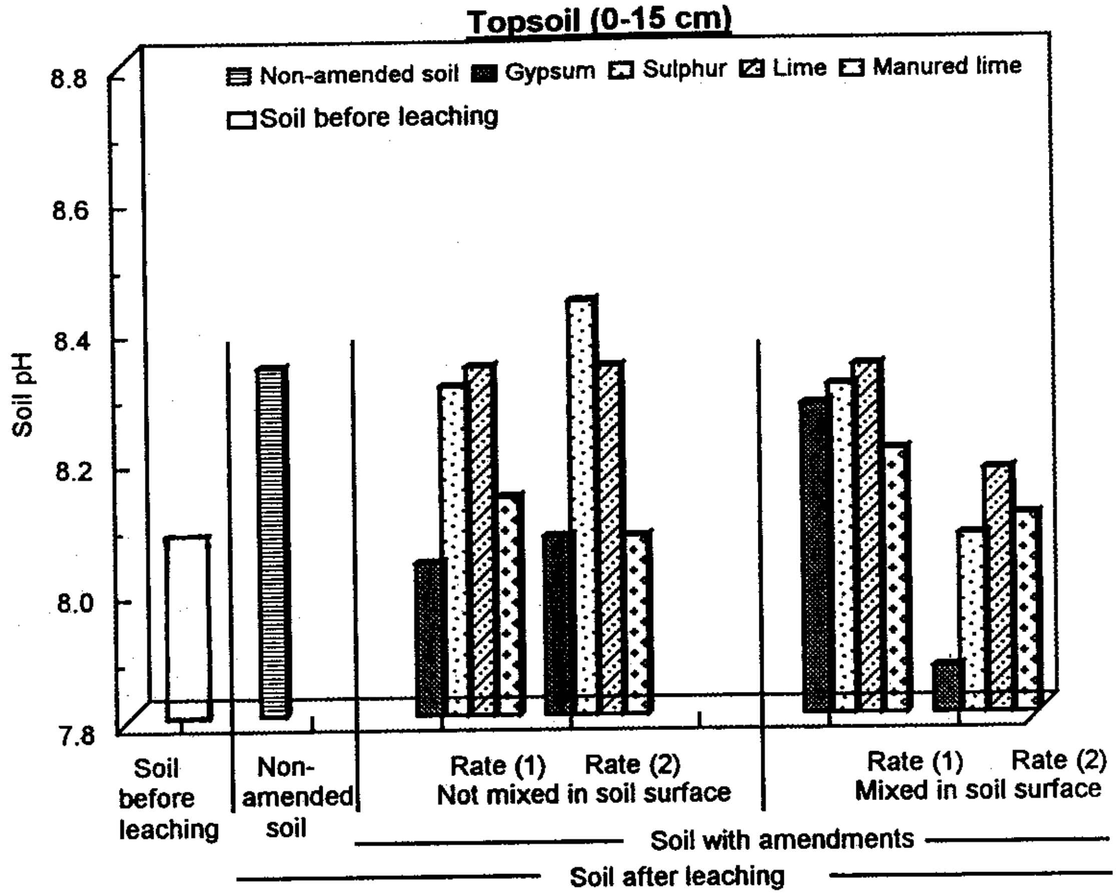
Material (T)	Rate (R)	Methods(S) Non-mix	Mix	Mean
Gypsum	Rate 1	8.03	8.27	8.15
	Rate 2	8.07	7.87	7.97
	Mean	8.05	8.07	8.06
Sulphur	Rate 1	8.30	8.30	8.30
	Rate 2	8.43	8.07	8.25
	Mean	8.37	8.18	8.28
Lime	Rate 1	8.33	8.33	8.33
	Rate 2	8.33	8.17	8.25
	Mean	8.33	8.25	8.29
Manured lime	Rate 1	8.13	8.20	8.17
	Rate 2	8.07	8.10	8.08
	Mean	8.10	8.15	8.13
	Mean of rates			
	Rate 1	8.20	8.28	8.24
	Rate 2	8.23	8.05	8.14
G. Mean		8.21	8.16	
Non-amended soil (Leached with no amendments)		8.33		

LSD 0.05: T = 0.09 R = 0.06 S = ns TR = ns
TS = ns RS = 0.09 TRS = ns

Table (6): Soil pH in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	8.37	8.33	8.35
	Rate 2	8.27	8.03	8.15
	Mean	8.32	8.18	8.25
Sulphur	Rate 1	8.53	8.43	8.48
	Rate 2	8.67	8.37	8.52
	Mean	8.60	8.40	8.50
Lime	Rate 1	8.40	8.33	8.37
	Rate 2	8.27	8.07	8.17
	Mean	8.33	8.20	8.27
Manured lime	Rate 1	8.37	8.33	8.35
	Rate 2	8.10	8.13	8.12
	Mean	8.23	8.23	8.23
	Mean of rates			
	Rate 1	8.42	8.36	8.39
	Rate 2	8.33	8.15	8.23
G. Mean		8.37	8.25	
Non-amended soil (Leached with no amendments)		8.20		

LSD 0.05: T = 0.17 R = 0.12 S = 0.12 TR = ns
TS = ns RS = ns TRS = 0.33



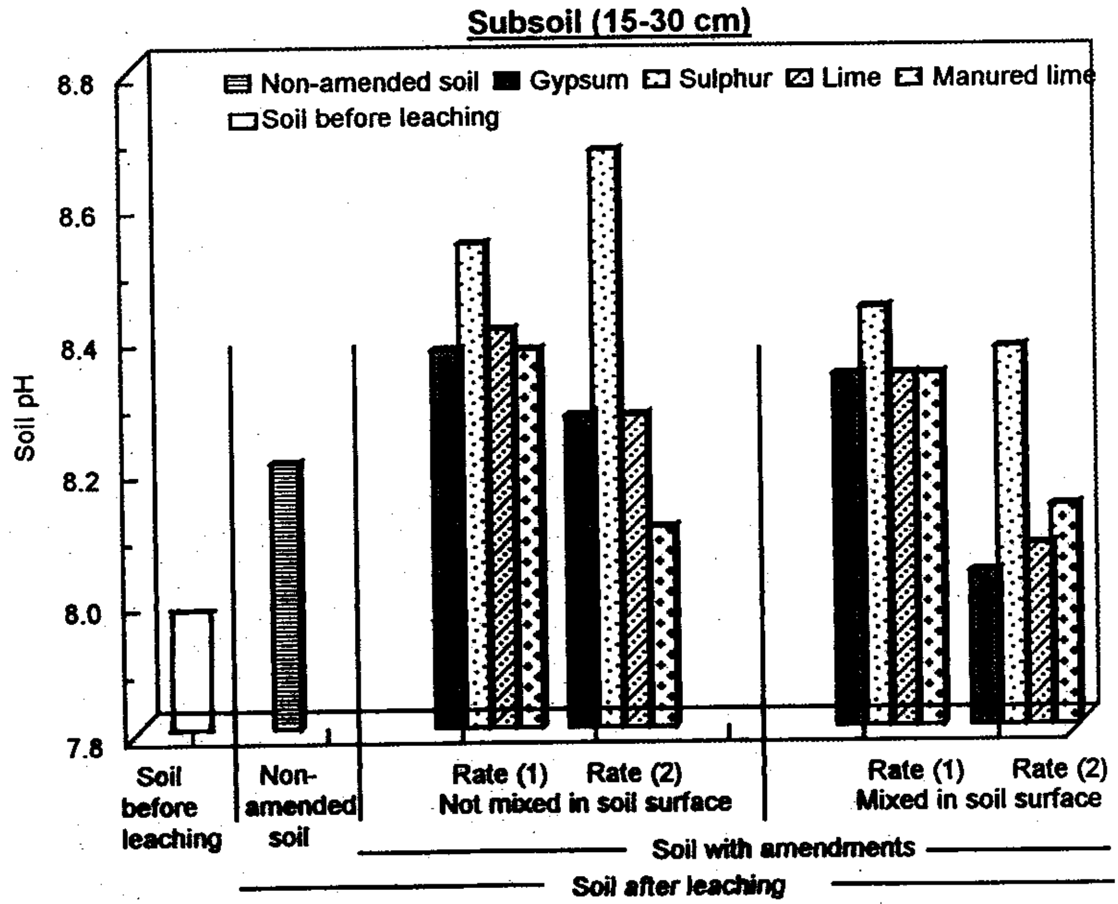


Fig. (2): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soil pH(of soil saturation extract).

Table (7): Sodium adsorption ratio (SAR) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

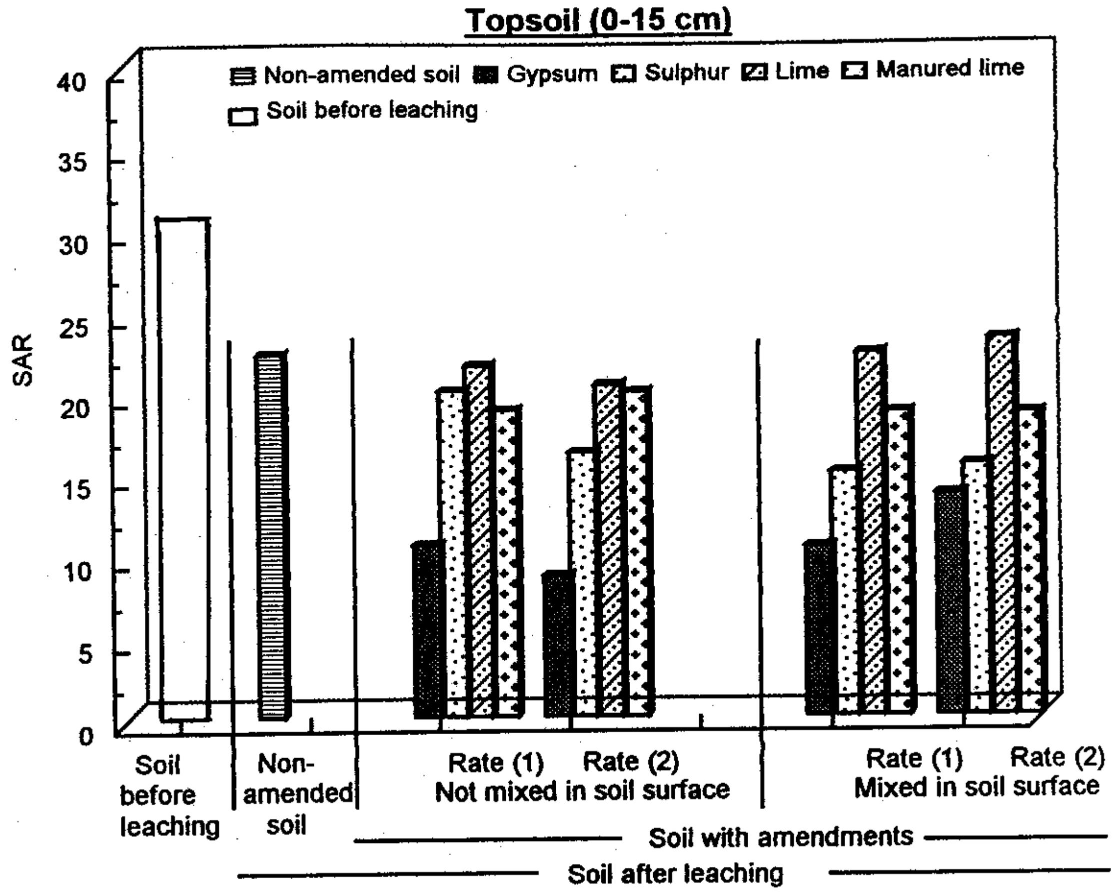
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	10.43	10.30	10.37
	Rate 2	8.58	13.44	11.01
	Mean	9.51	11.87	10.69
Sulphur	Rate 1	19.90	14.77	17.34
	Rate 2	16.03	15.25	15.64
	Mean	17.97	15.01	16.49
Lime	Rate 1	19.00	22.13	20.57
	Rate 2	21.43	23.01	22.22
	Mean	20.22	22.57	21.39
Manured lime	Rate 1	18.68	18.47	18.58
	Rate 2	19.77	18.39	19.08
	Mean	19.23	18.43	18.83
	Mean of rates			
	Rate 1	17.00	16.42	16.71
	Rate 2	16.46	17.52	16.99
G. Mean		16.73	16.97	
Non-amended soil (Leached with no amendments)		22.21		

LSD 0.05: T = 2.05 R = ns S = ns TR = ns
TS = 2.90 RS = ns TRS = ns

Table (8): Sodium adsorption ratio (SAR) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	24.23	22.46	23.35
	Rate 2	19.27	34.78	27.03
	Mean	21.75	28.62	25.19
Sulphur	Rate 1	27.30	25.43	26.37
	Rate 2	34.01	25.49	29.75
	Mean	30.66	25.46	28.06
Lime	Rate 1	33.51	28.38	30.95
	Rate 2	29.77	28.26	29.02
	Mean	31.64	28.32	29.98
Manured lime	Rate 1	20.70	22.90	21.80
	Rate 2	18.78	30.98	24.88
	Mean	19.74	26.94	23.34
	Mean of rates			
	Rate 1	26.44	24.79	25.61
	Rate 2	25.46	29.88	27.67
G. Mean		25.95	27.33	
Non-amended soil (Leached with no amendments)		26.11		

LSD 0.05: T = 4.48 R = ns S = ns TR = ns
TS = 6.32 RS = 4.48 TRS = 8.94



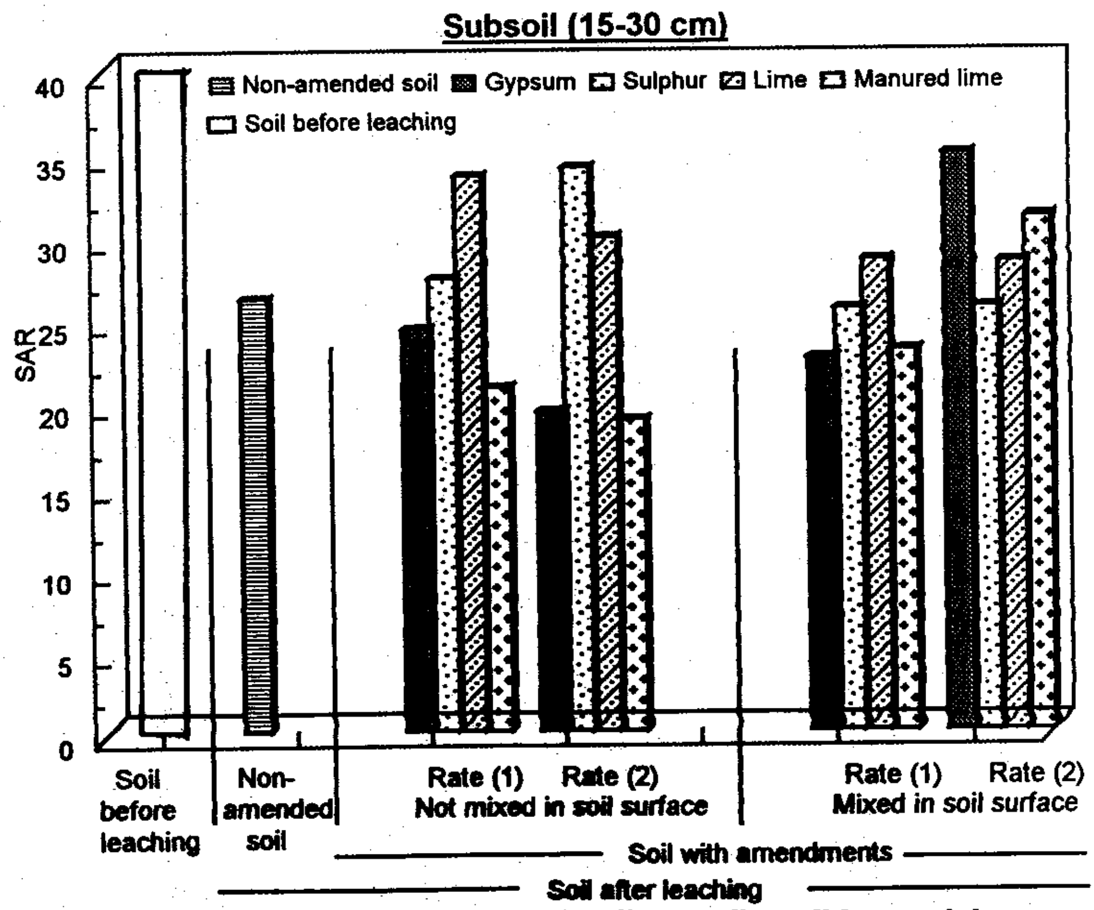


Fig. (3): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on sodium adsorption ratio (SAR).

Table (9): Exchangeable sodium percentage (ESP) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

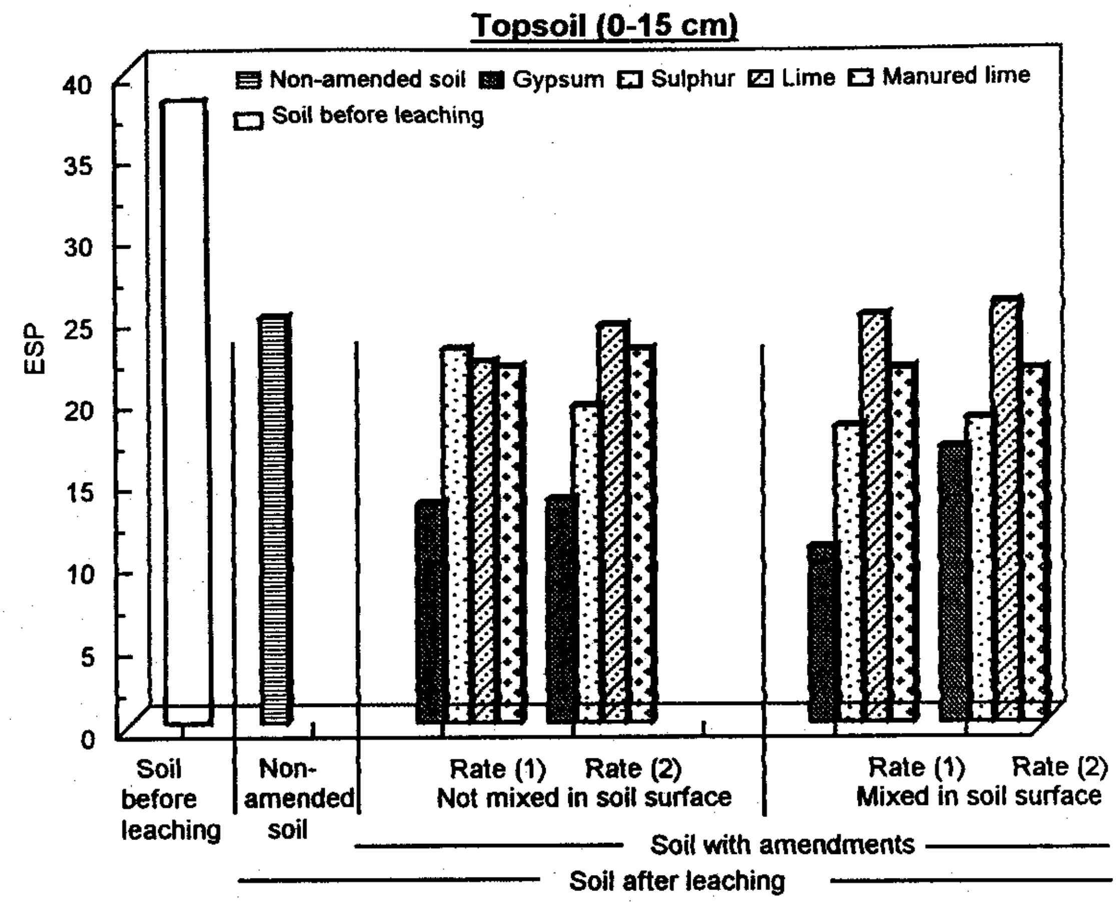
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	13.27	10.61	11.94
	Rate 2	13.51	16.68	15.09
	Mean	13.39	13.65	13.52
Sulphur	Rate 1	22.75	17.97	20.36
	Rate 2	19.22	18.45	18.84
	Mean	20.99	18.21	19.60
Lime	Rate 1	21.95	24.76	23.36
	Rate 2	24.15	25.53	24.84
	Mean	23.05	25.15	24.10
Manured lime	Rate 1	21.64	21.51	21.58
	Rate 2	22.71	21.44	22.08
	Mean	22.18	21.48	21.83
	Mean of rates			
	Rate 1	19.91	18.72	19.31
	Rate 2	19.90	20.52	20.21
G. Mean		19.90	19.62	
Non-amended soil (Leached with no amendments)		24.70		

LSD 0.05: T = 2.07 R = ns S = ns TR = ns
TS = ns RS = ns TRS = ns

Table (10): Exchangeable sodium percentage (ESP) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	26.52	21.44	23.98
	Rate 2	24.40	34.72	29.56
	Mean	25.46	28.08	26.77
Sulphur	Rate 1	28.92	27.50	28.21
	Rate 2	33.75	27.30	30.52
	Mean	31.34	27.40	29.37
Lime	Rate 1	33.33	29.59	31.46
	Rate 2	30.80	29.46	30.13
	Mean	32.06	29.53	30.79
Manured lime	Rate 1	23.18	25.20	24.19
	Rate 2	21.81	31.57	26.69
	Mean	22.50	28.38	25.44
	Mean of rates			
	Rate 1	27.99	25.93	26.96
	Rate 2	27.69	30.76	29.23
G. Mean		27.84	28.35	
Non-amended soil (Leached with no amendments)		27.98		

LSD 0.05: T = 3.19 R = 2.26 S = ns TR = ns
TS = 4.51 RS = 3.19 TRS = 6.37



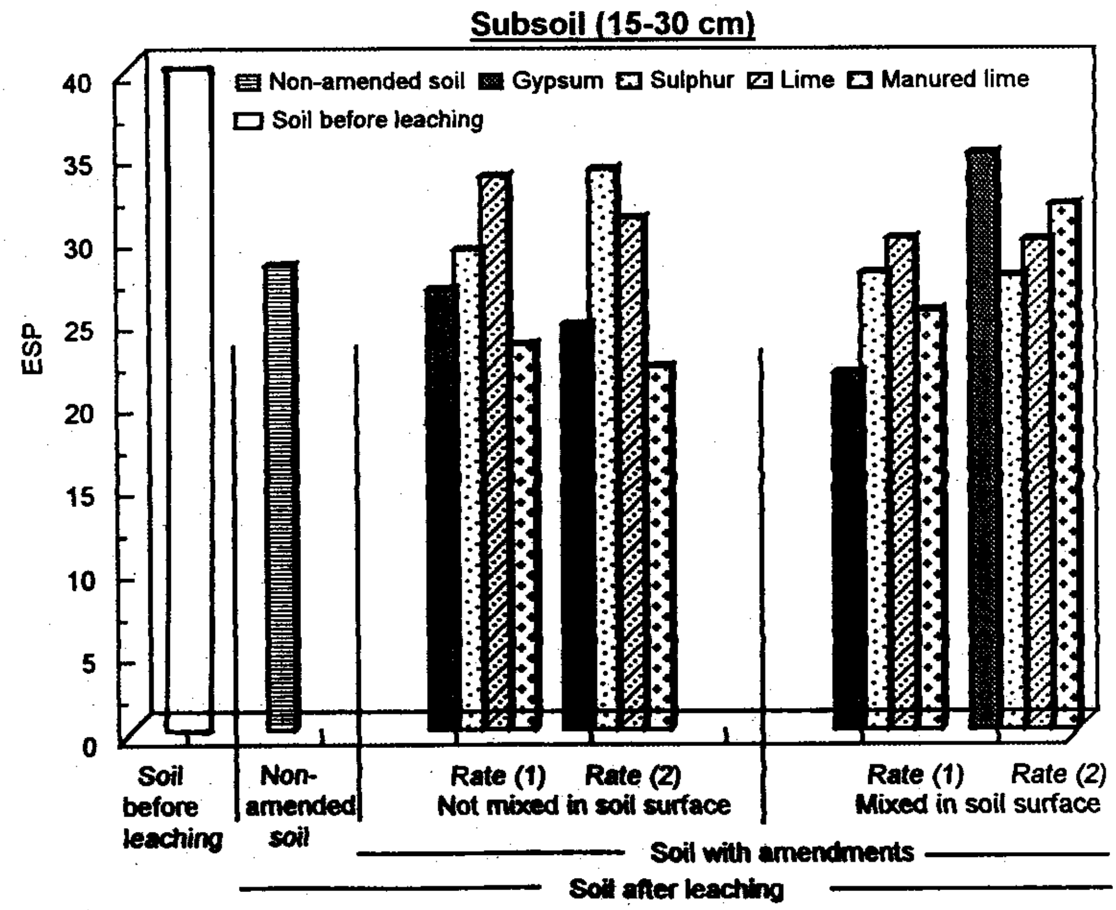


Fig. (4): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on exchangeable sodium percentage (ESP).

Table (11): Soluble calcium (Ca^{++}, $me.L^{-1}$) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

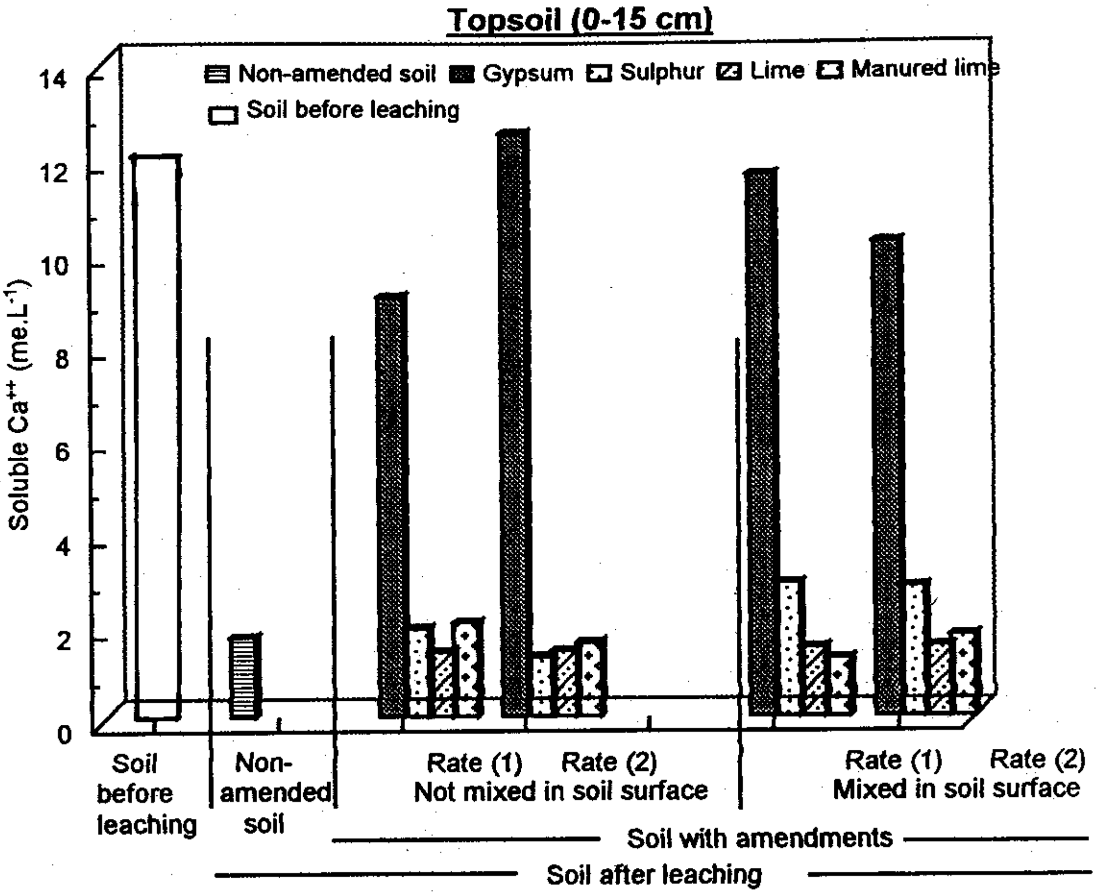
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	8.97	11.57	10.27
	Rate 2	12.47	10.13	11.30
	Mean	10.72	10.85	10.78
Sulphur	Rate 1	1.87	2.83	2.35
	Rate 2	1.27	2.77	2.02
	Mean	1.57	2.80	2.18
Lime	Rate 1	1.37	1.47	1.42
	Rate 2	1.40	1.50	1.45
	Mean	1.38	1.48	1.43
Manured lime	Rate 1	2.00	1.23	1.62
	Rate 2	1.57	1.73	1.65
	Mean	1.78	1.48	1.63
	Mean of rates			
	Rate 1	3.55	4.28	3.91
	Rate 2	4.18	4.03	4.10
G. Mean		3.86	4.15	
Non-amended soil (Leached with no amendments)		1.70		

LSD 0.05: T = 1.00 R = ns S = ns TR = ns
TS = ns RS = ns TRS = 2.00

Table (12): Soluble calcium (Ca^{++}, $me.L^{-1}$) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	2.43	3.93	3.18
	Rate 2	4.00	2.67	3.33
	Mean	3.22	3.30	3.26
Sulphur	Rate 1	1.77	1.57	1.67
	Rate 2	0.70	3.43	2.07
	Mean	1.23	2.50	1.87
Lime	Rate 1	1.27	1.70	1.48
	Rate 2	1.73	1.23	1.48
	Mean	1.50	1.47	1.48
Manured lime	Rate 1	1.13	1.60	1.37
	Rate 2	4.03	1.37	2.70
	Mean	2.58	1.48	2.03
	Mean of rates			
	Rate 1	1.65	2.20	1.93
	Rate 2	2.62	2.18	2.40
G. Mean		2.13	2.19	
Non-amended soil (Leached with no amendments)			2.47	

LSD 0.05: T = ns R = ns S = ns TR = ns
TS = ns RS = ns TRS = ns



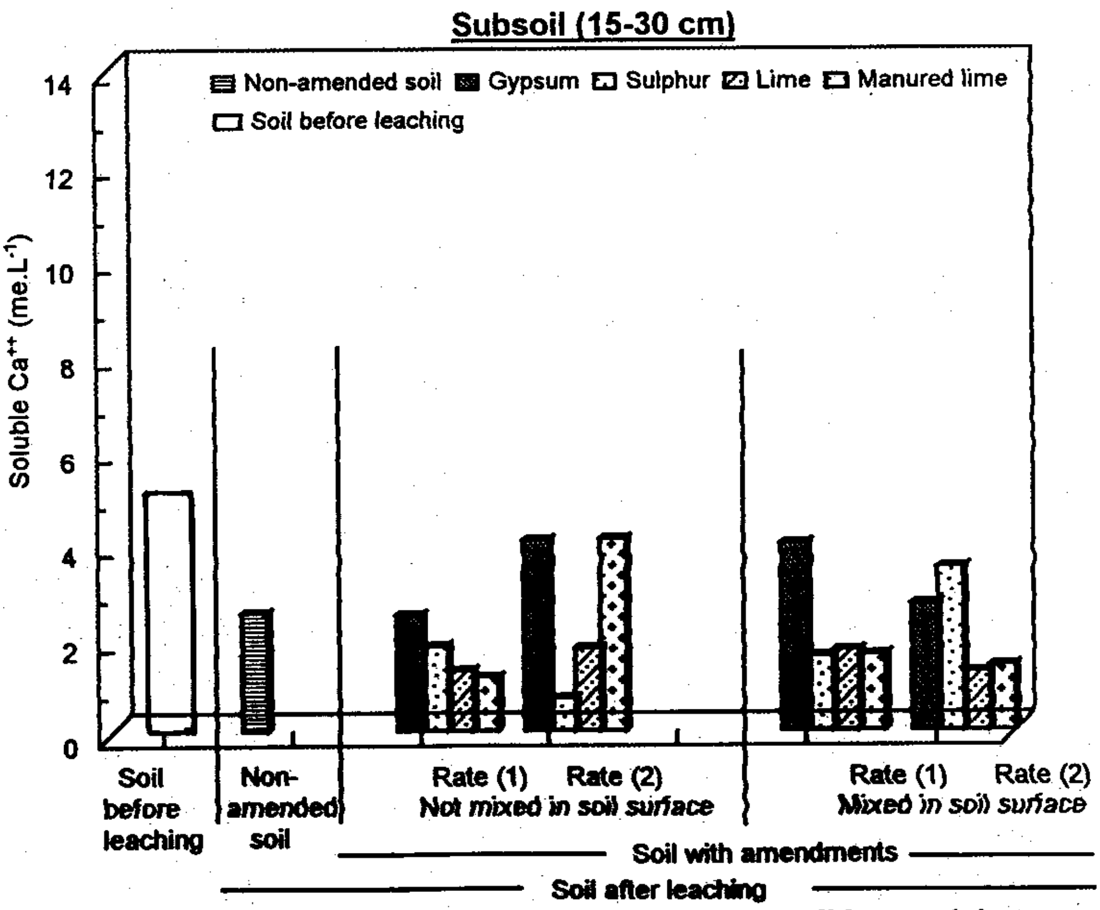


Fig. (5): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble Ca^{++} (me L^{-1}) of soil saturation extract

Table (13): Soluble magnesium (Mg^{++}, $me.L^{-1}$) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	4.77	8.73	6.75
	Rate 2	8.40	7.13	7.77
	Mean	6.58	7.93	7.26
Sulphur	Rate 1	3.40	5.10	4.25
	Rate 2	2.47	3.53	3.00
	Mean	2.93	4.32	3.63
Lime	Rate 1	3.57	3.10	3.33
	Rate 2	1.70	4.90	3.30
	Mean	2.63	4.00	3.32
Manured lime	Rate 1	3.03	1.83	2.43
	Rate 2	2.53	3.57	3.05
	Mean	2.78	2.70	2.74
	Mean of rates			
	Rate 1	3.69	4.69	4.19
	Rate 2	3.78	4.78	4.28
G. Mean		3.73	4.74	
Non-amended soil (Leached with no amendments)		3.60		

LSD 0.05: T = 1.03   R = ns   S =0.73   TR = ns
TS = ns   RS = ns   TRS = 2.05

Table (14): Soluble magnesium (Mg^{++}, $me.L^{-1}$) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	0.37	3.63	2.00
	Rate 2	6.40	6.00	6.20
	Mean	3.38	4.82	4.10
Sulphur	Rate 1	3.33	2.73	3.03
	Rate 2	0.93	1.73	1.33
	Mean	2.13	2.23	2.18
Lime	Rate 1	2.03	5.17	3.60
	Rate 2	3.30	3.23	3.27
	Mean	2.67	4.20	3.43
Manured lime	Rate 1	1.33	2.13	1.73
	Rate 2	4.20	2.77	3.48
	Mean	2.77	2.45	2.61
	Mean of rates			
	Rate 1	1.77	3.42	2.59
	Rate 2	3.71	3.43	3.57
G. Mean		2.74	3.43	
Non-amended soil (Leached with no amendments)		3.93		

LSD 0.05: T = ns R = ns S = ns TR =2.42
TS =ns RS = ns TRS = ns

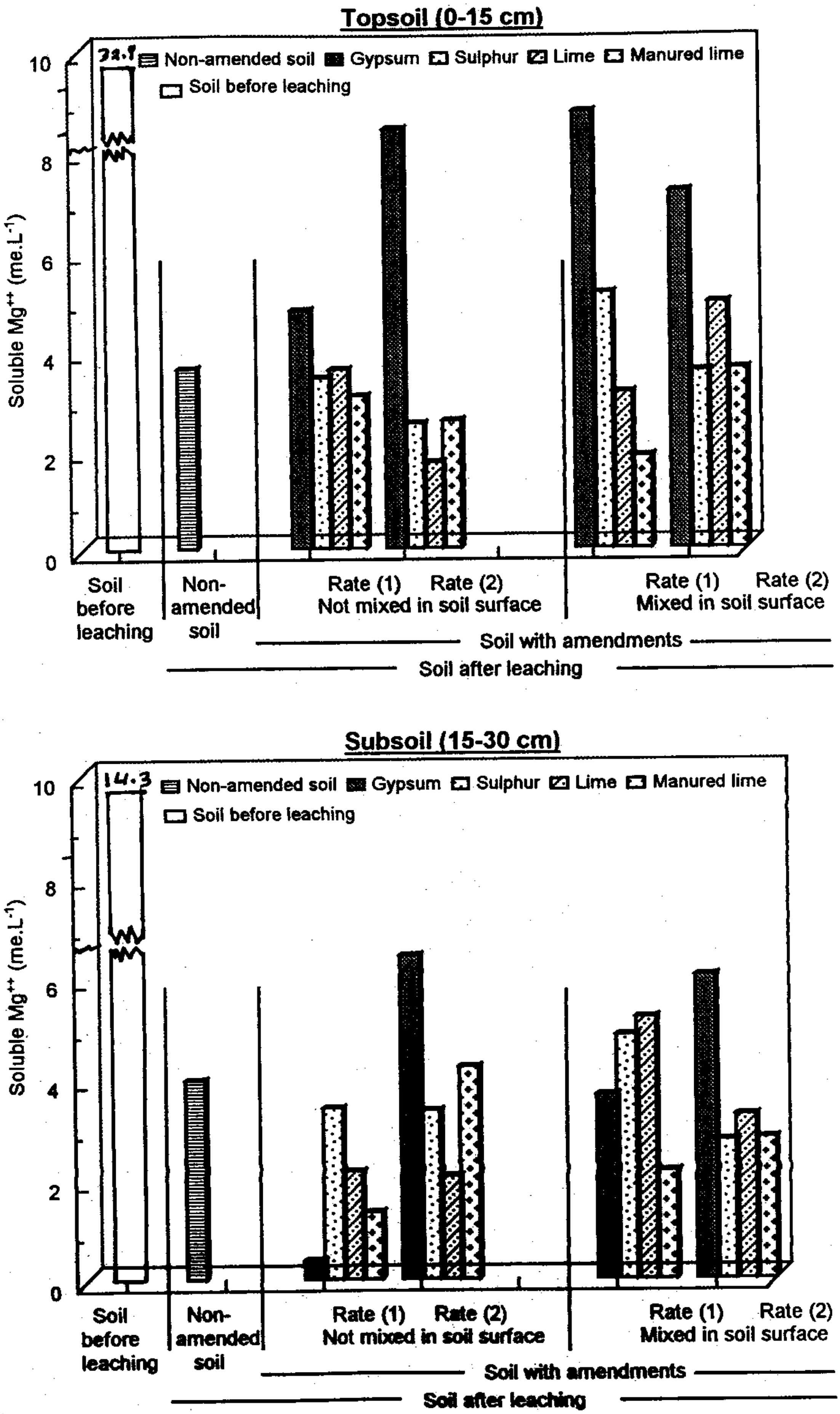


Fig. (6): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble Mg^{++} (me L^{-1}) of soil saturation extract.

Table (15): Soluble sodium (Na^{+}, $me.L^{-1}$) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

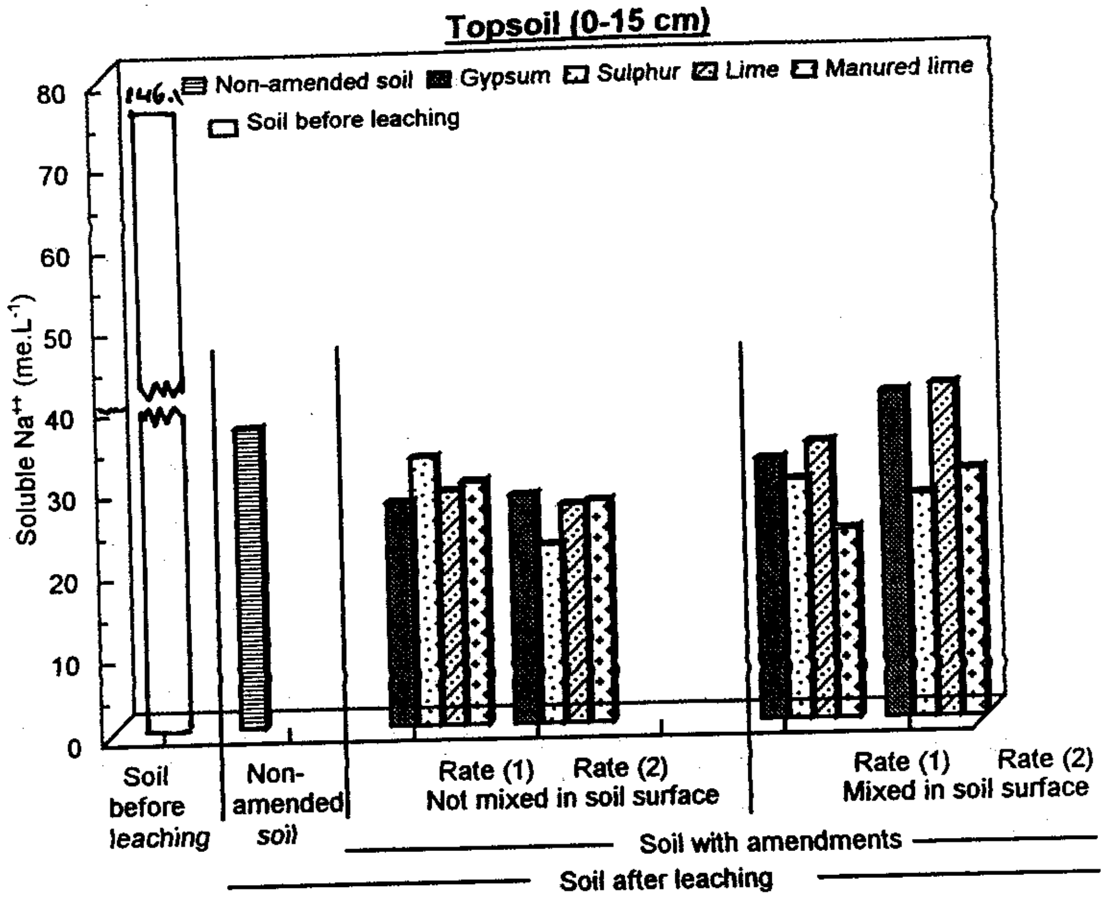
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	27.10	31.57	29.33
	Rate 2	27.73	39.50	33.62
	Mean	27.42	35.53	31.48
Sulphur	Rate 1	32.50	29.00	30.75
	Rate 2	21.67	27.07	24.37
	Mean	27.08	28.03	27.56
Lime	Rate 1	28.40	33.50	30.95
	Rate 2	26.47	40.37	33.42
	Mean	27.43	36.93	32.18
Manured lime	Rate 1	29.43	22.87	26.15
	Rate 2	26.87	29.97	28.42
	Mean	28.15	26.42	27.28
	Mean of rates			
	Rate 1	29.36	29.23	29.30
	Rate 2	25.68	34.23	29.95
G. Mean		27.52	31.73	
Non-amended soil (Leached with no amendments)		36.43		

LSD 0.05: T = ns R = ns S = 2.61 TR = ns
TS = 5.21 RS = 3.70 TRS = ns

Table (16): Soluble sodium (Na^+, $me.L^{-1}$) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	27.43	41.43	34.43
	Rate 2	34.87	72.13	53.50
	Mean	31.15	56.78	43.97
Sulphur	Rate 1	43.70	36.80	40.25
	Rate 2	30.03	35.53	32.78
	Mean	36.87	36.17	36.52
Lime	Rate 1	41.20	49.93	45.57
	Rate 2	45.43	42.57	44.00
	Mean	43.32	46.25	44.78
Manured lime	Rate 1	20.57	29.20	24.88
	Rate 2	36.73	44.67	40.70
	Mean	28.65	36.93	32.79
	Mean of rates			
	Rate 1	33.23	39.34	36.28
	Rate 2	36.77	48.73	42.74
G. Mean		35.00	44.03	
Non-amended soil (Leached with no amendments)		46.97		

LSD 0.05: T = 9.24 R = ns S = 6.54 TR =13.03
TS = 13.03 RS = ns TRS = ns



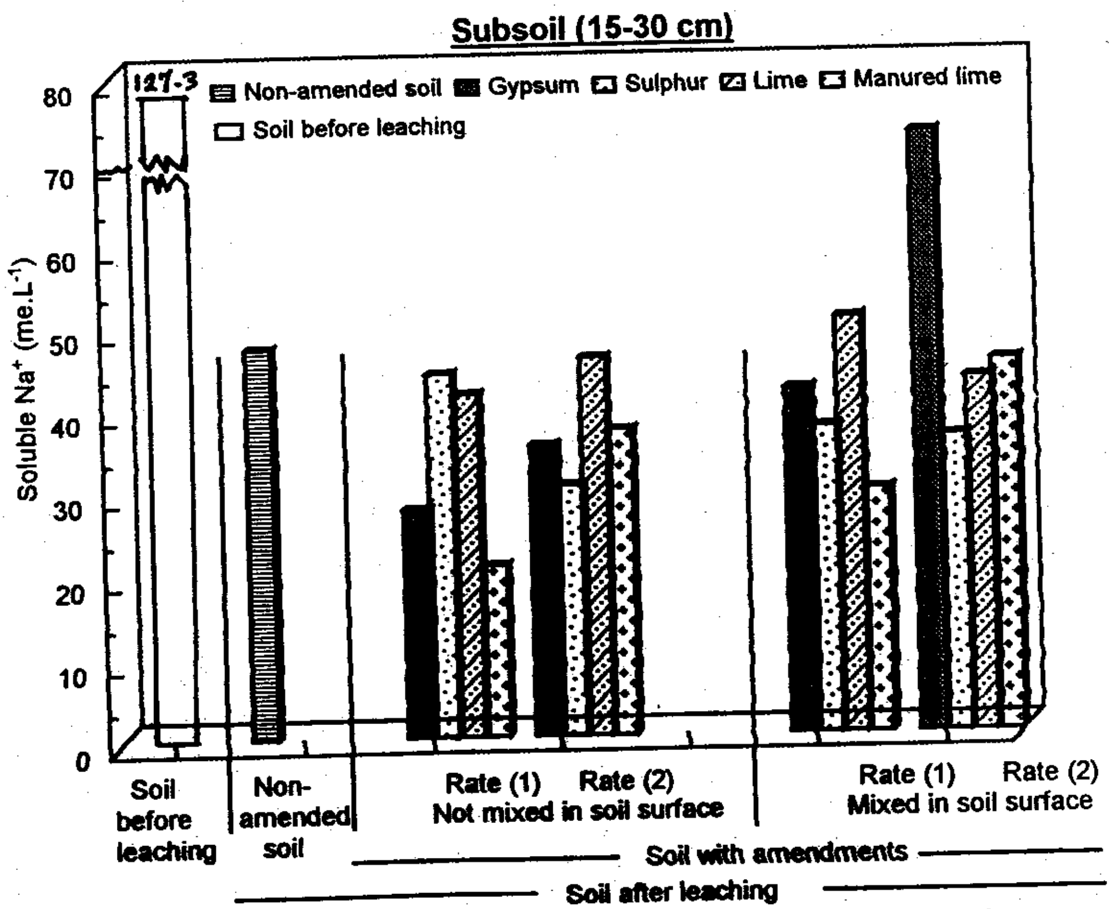


Fig. (7): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble Na^+ (me L^{-1}) of soil saturation extract.

Table (17): Soluble potassium (K^+, me.L^{-1}) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

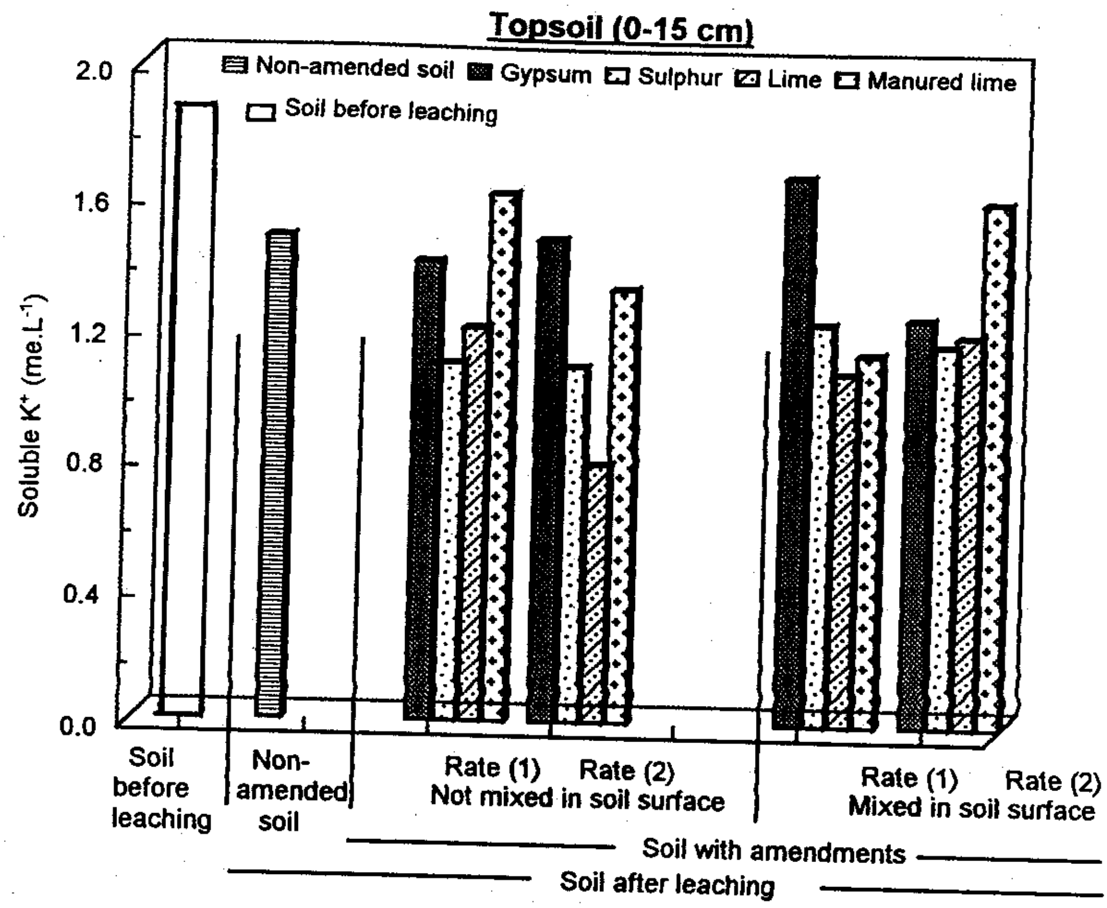
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	1.40	1.67	1.53
	Rate 2	1.47	1.24	1.33
	Mean	1.41	1.46	1.43
Sulphur	Rate 1	1.09	1.22	1.15
	Rate 2	1.08	1.16	1.12
	Mean	1.08	1.19	1.14
Lime	Rate 1	1.20	1.07	1.13
	Rate 2	0.78	1.19	0.98
	Mean	0.99	1.13	1.06
Manured lime	Rate 1	1.61	1.13	1.37
	Rate 2	1.32	1.60	1.46
	Mean	1.47	1.36	1.41
	Mean of rates			
	Rate 1	1.32	1.27	1.30
	Rate 2	1.15	1.30	1.22
G. Mean		1.24	1.28	
Non-amended soil (Leached with no amendments)		1.47		

LSD 0.05: T = 0.17 R = ns S = ns TR = ns
TS = ns RS = ns TRS = 0.34

Table (18): Soluble potassium (K^+, $me.L^{-1}$) in subsoil (15-30 *cm*) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Method (S) Mix	Mean
Gypsum	Rate 1	0.80	1.23	1.01
	Rate 2	1.12	0.95	1.04
	Mean	*0.96*	*1.09*	*1.02*
Sulphur	Rate 1	0.96	0.91	0.93
	Rate 2	0.78	0.87	0.82
	Mean	0.87	0.89	0.88
Lime	Rate 1	0.94	1.17	1.00
	Rate 2	0.89	0.77	0.83
	Mean	0.92	0.97	0.94
Manured lime	Rate 1	0.90	0.87	0.88
	Rate 2	1.29	0.98	1.13
	Mean	1.09	0.92	1.01
	Mean of rates			
	Rate 1	0.90	1.04	0.97
	Rate 2	1.02	0.89	0.95
G. Mean		0.96	0.97	
Non-amended soil (Leached with no amendments)		1.17		

LSD 0.05: T = ns; R = ns; S = ns; TR =0.24; TS = ns; RS = ns; TRS = ns



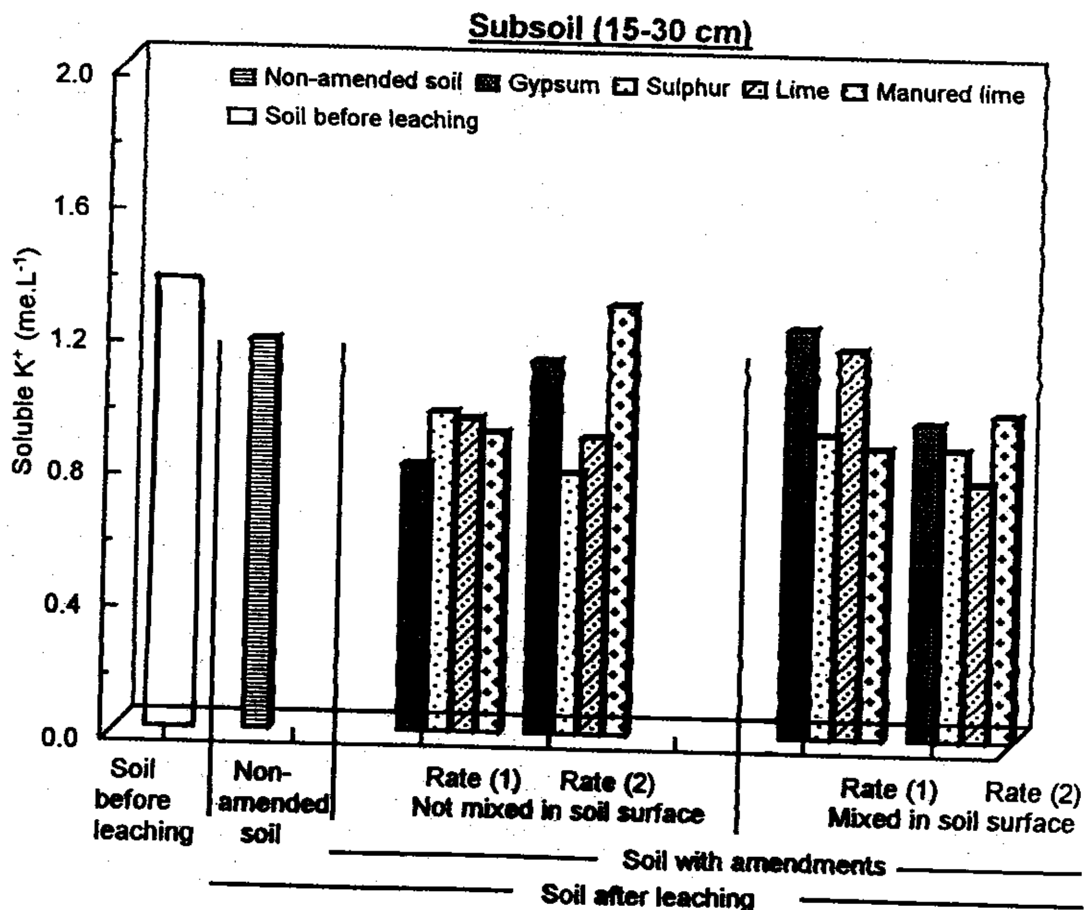


Fig. (8): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble K^+ (me L^{-1}) of soil saturation extract.

Table (19): Soluble bicarbonate (HCO_3^-, me.L^{-1}) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

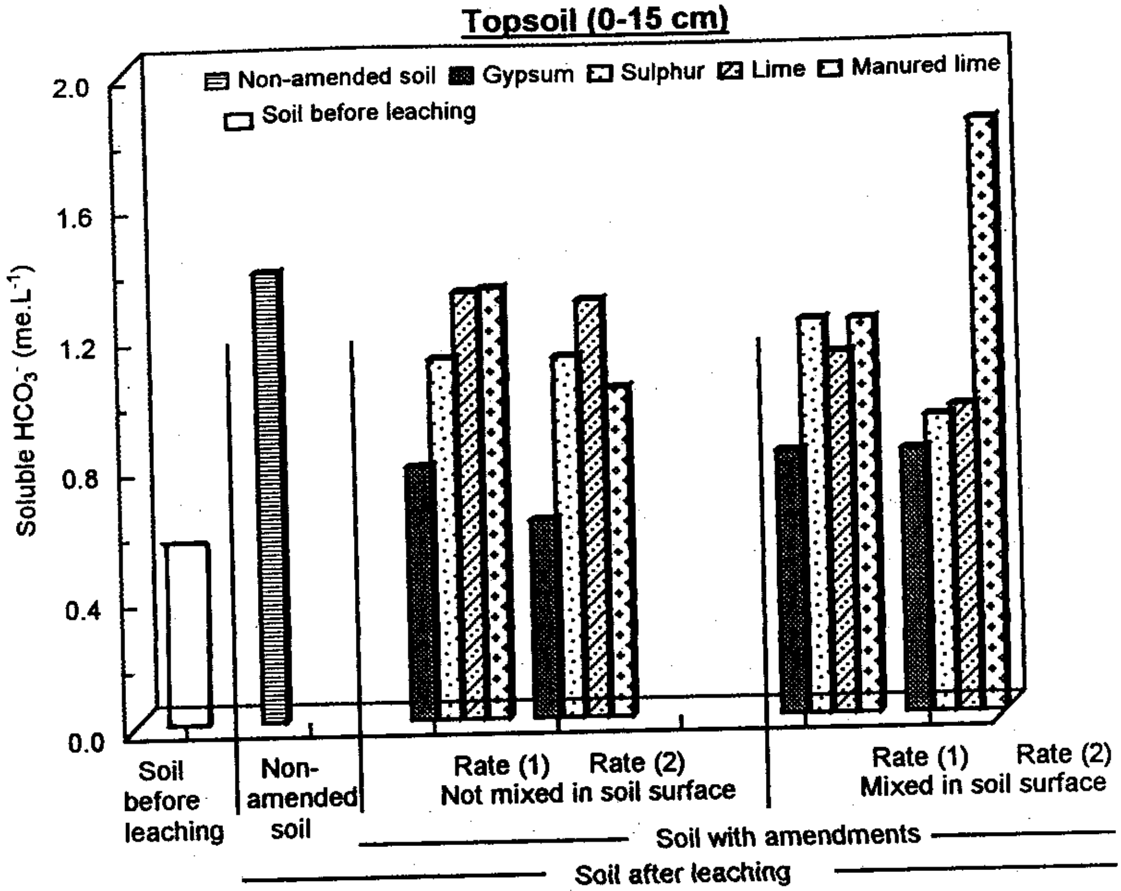
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	0.77	0.80	0.78
	Rate 2	0.60	0.80	0.70
	Mean	0.68	0.80	0.74
Sulphur	Rate 1	1.10	1.20	1.15
	Rate 2	1.10	0.90	1.00
	Mean	1.10	1.05	1.08
Lime	Rate 1	1.30	1.10	1.20
	Rate 2	1.27	0.93	1.10
	Mean	1.28	1.02	1.15
Manured lime	Rate 1	1.30	1.20	1.25
	Rate 2	1.00	1.80	1.40
	Mean	1.15	1.50	1.33
	Mean of rates			
	Rate 1	1.12	1.08	1.10
	Rate 2	0.99	1.11	1.05
G. Mean		1.05	1.09	
Non-amended soil (Leached with no amendments)		1.37		

LSD 0.05: T = 0.16 R = ns S = ns TR = ns
TS = 0.23 RS = ns TRS = 0.32

Table (20): Soluble bicarbonate (HCO_3^-, $me.L^{-1}$) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	0.97	1.00	0.98
	Rate 2	0.93	0.83	0.88
	Mean	0.95	0.92	0.93
Sulphur	Rate 1	1.03	1.07	1.05
	Rate 2	0.83	0.97	0.90
	Mean	0.93	1.02	0.98
Lime	Rate 1	1.37	1.30	1.33
	Rate 2	1.13	1.13	1.13
	Mean	1.25	1.22	1.23
Manured lime	Rate 1	1.40	0.83	1.12
	Rate 2	1.00	1.00	1.00
	Mean	1.20	0.92	1.06
	Mean of rates			
	Rate 1	1.19	1.05	1.12
	Rate 2	0.98	0.98	0.98
G. Mean		1.08	1.02	
Non-amended soil (Leached with no amendments)		1.07		

LSD 0.05: T = 0.18 R =0.12 S = ns TR = ns
TS = ns RS = ns TRS = ns



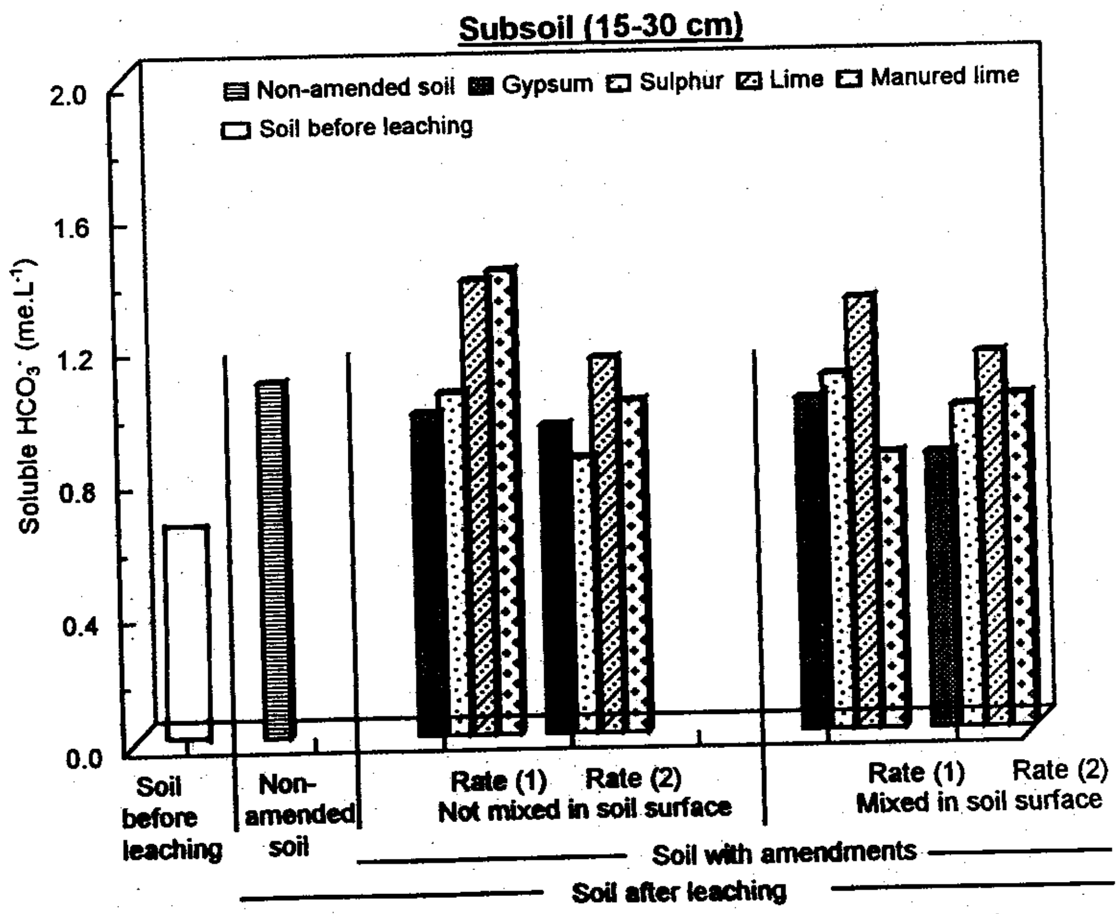


Fig. (9): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble HCO_3^- (me L^{-1}) of soil saturation extract

Table (21): Soluble chloride (Cl^-, $me.L^{-1}$) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	16.60	13.20	14.40
	Rate 2	23.47	34.00	28.23
	Mean	19.53	23.60	21.57
Sulphur	Rate 1	26.00	23.50	24.75
	Rate 2	15.27	17.50	16.38
	Mean	20.63	20.50	20.57
Lime	Rate 1	24.50	29.00	26.75
	Rate 2	20.00	25.10	22.55
	Mean	22.25	27.05	24.65
Manured lime	Rate 1	19.27	11.00	15.13
	Rate 2	18.77	19.50	19.13
	Mean	19.02	15.25	17.13
	Mean of rates			
	Rate 1	21.59	19.18	20.38
	Rate 2	19.13	24.03	21.58
G. Mean		20.36	21.60	
Non-amended soil (Leached with no amendments)		28.00		

LSD 0.05: T = 4.81 R = ns S = ns TR = 6.79
TS = ns RS = 4.81 TRS = ns

Table (22): Soluble chloride (Cl^-, me. L^{-1}) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	9.73	19.10	14.42
	Rate 2	31.70	51.27	41.48
	Mean	20.72	35.18	27.95
Sulphur	Rate 1	38.77	24.77	31.77
	Rate 2	16.27	16.27	16.27
	Mean	27.52	20.52	24.02A
Lime	Rate 1	29.77	37.27	33.52
	Rate 2	41.00	38.90	39.95
	Mean	35.38	38.08	36.73
Manured lime	Rate 1	5.90	17.43	11.67
	Rate 2	20.50	30.10	25.30
	Mean	13.20	23.77	18.48
	Mean of rates			
	Rate 1	21.04	24.64	22.84
	Rate 2	27.37	34.13	30.75
G. Mean		24.20	29.39	
Non-amended soil (Leached with no amendments)		34.00		

LSD 0.05: T = 9.33 R = 6.60 S = ns TR = 13.16
TS = ns RS = ns TRS = ns

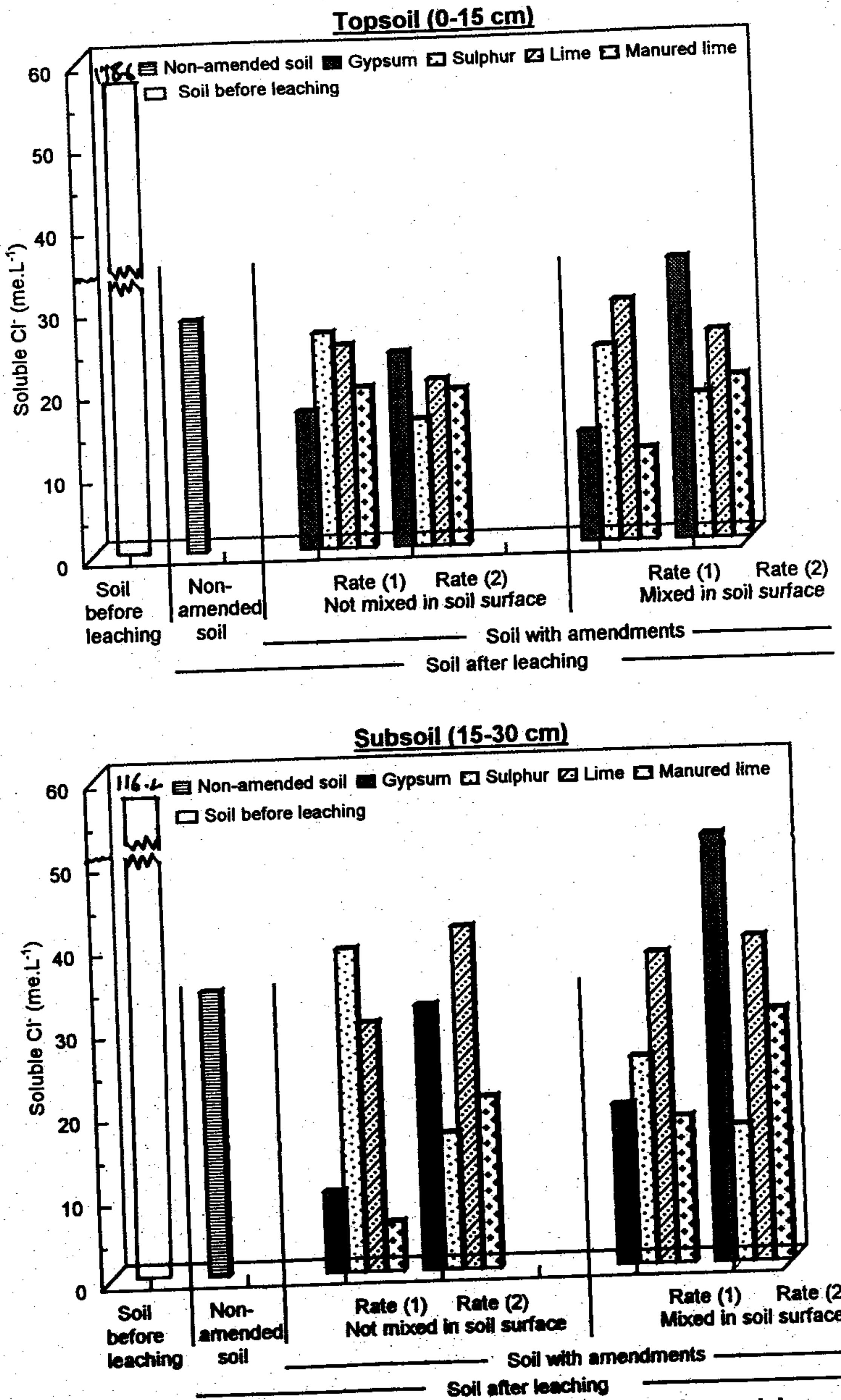


Fig. (10): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble Cl^- (me L^{-1}) of soil saturation extract.

Table (23): Soluble sulphate ($SO_4^{=}$, $me.L^{-1}$) in topsoil (0-15 cm) after reclamation by leaching a saline sodic soil using different amendments and methods of application.

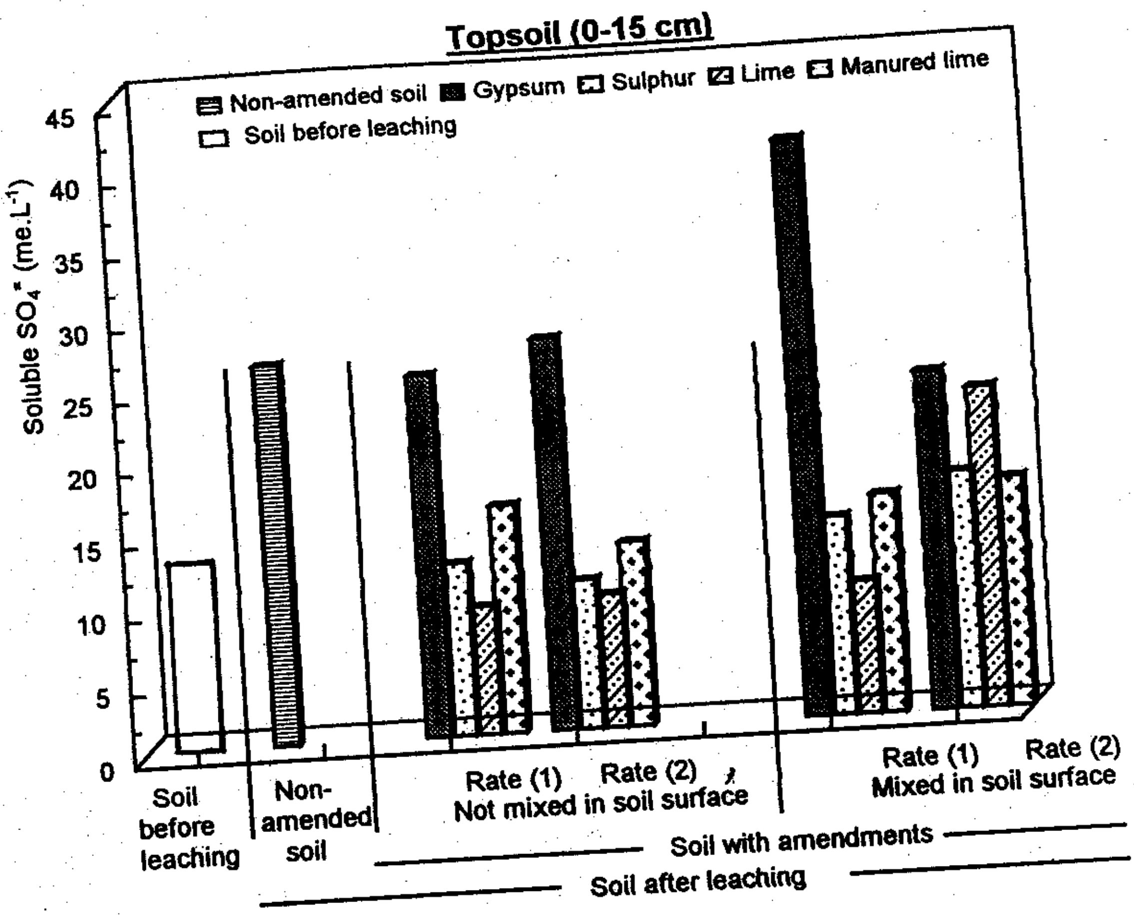
Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	24.86	39.54	32.20
	Rate 2	26.96	23.21	25.08
	Mean	25.91	31.37	28.64
Sulphur	Rate 1	11.76	13.45	12.60
	Rate 2	10.11	16.12	13.12
	Mean	10.93	14.79	12.86
Lime	Rate 1	8.73	9.03	8.88
	Rate 2	9.08	21.92	15.50
	Mean	8.90	15.48	12.19
Manured lime	Rate 1	15.51	14.86	15.19
	Rate 2	12.52	15.56	14.04
	Mean	14.02	15.21	14.61
	Mean of rates			
	Rate 1	15.22	19.22	17.22
	Rate 2	14.67	19.20	16.94
G. Mean		14.94	19.21	
Non-amended soil (Leached with no amendments)		26.15		

LSD 0.05: T = 2.34 R = ns S = 1.65 TR = 3.30
TS = ns RS = ns TRS = 4.67

Table (24): Soluble sulphate ($SO_4^=$, me. L^{-1}) in subsoil (15-30 cm) after reclamation by leaching a saline sodic soil using different *amendments and methods of application.*

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	20.33	30.13	25.23
	Rate 2	13.76	29.65	21.70
	Mean	17.05	29.89	23.47
Sulphur	Rate 1	9.96	16.17	13.07
	Rate 2	15.35	24.33	19.84
	Mean	12.65	20.25	16.45
Lime	Rate 1	14.31	19.40	16.86
	Rate 2	9.22	7.77	8.49
	Mean	11.77	13.58	12.67
Manured lime	Rate 1	16.63	15.54	16.08
	Rate 2	24.76	18.68	21.72
	Mean	20.69	17.11	18.90
	Mean of rates			
	Rate 1	15.31	20.31	17.81
	Rate 2	15.77	20.11	17.94
G. Mean		15.54	20.21	
Non-amended soil (Leached with no amendments)		19.47		

LSD 0.05: T = 5.49 R = ns S =3.88 TR =7.74
TS = 7.74 RS = ns TRS = ns



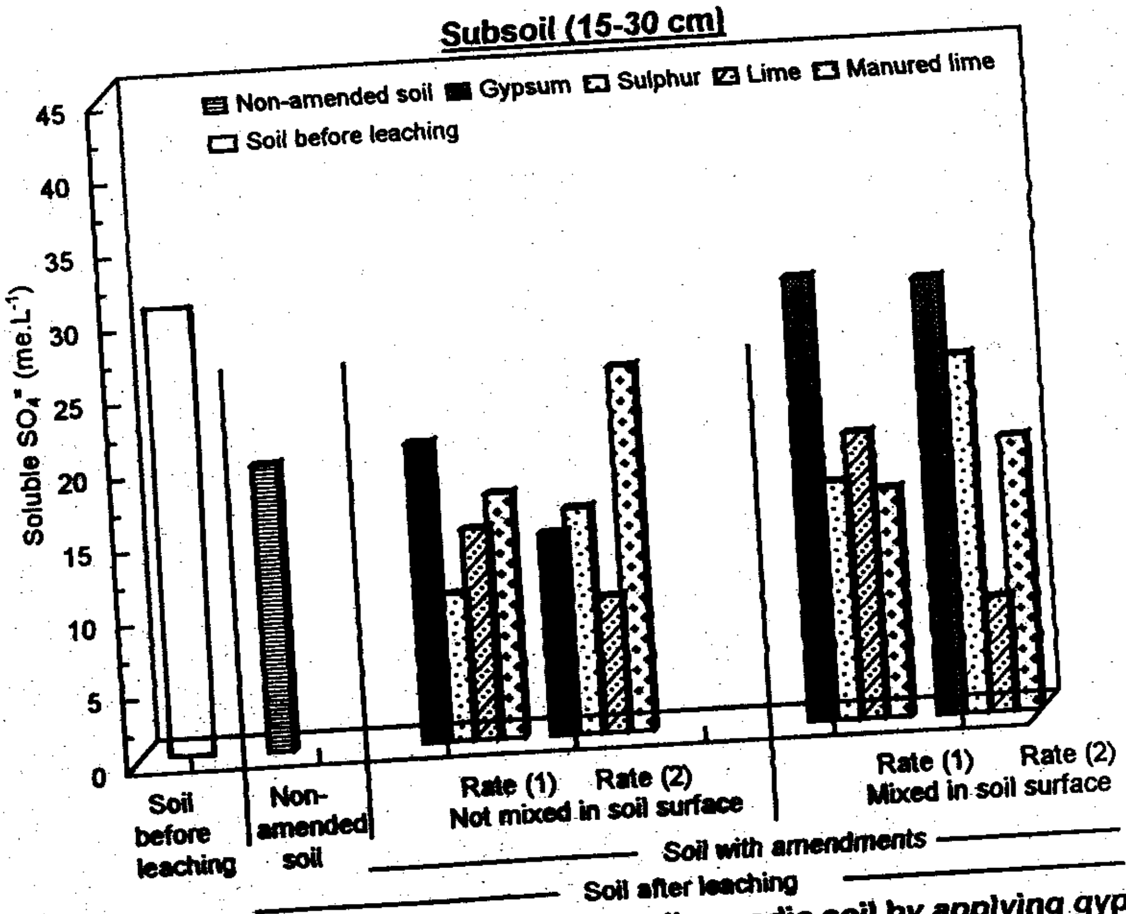


Fig. (11): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on soluble $SO_4^=$ (me L^{-1}) of soil saturation extract.

Table (25): Grain yield of rice (ton/fed.) as affected by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S)		Mean
		Non-mix	Mix	
Gypsum	Rate 1	2.87	2.37	2.62
	Rate 2	2.57	2.07	2.32
	Mean	2.72	2.22	2.47
Sulphur	Rate 1	2.40	2.83	2.62
	Rate 2	2.67	2.83	2.75
	Mean	2.53	2.83	2.68
Lime	Rate 1	1.43	1.10	1.27
	Rate 2	1.97	1.77	1.87
	Mean	1.70	1.43	1.57
Manured lime	Rate 1	2.77	2.97	2.87
	Rate 2	2.93	2.23	3.08
	Mean	2.85	3.10	2.98
	Mean of rates			
	Rate 1	2.37	2.32	2.34
	Rate 2	2.53	2.48	2.50
G. Mean		2.45	2.40	
Non-amended soil (Leached with no amendments)	1.80			

LSD 0.05: T = 0.40 R =ns S =ns TR =ns
TS = ns RS = ns TRS = ns

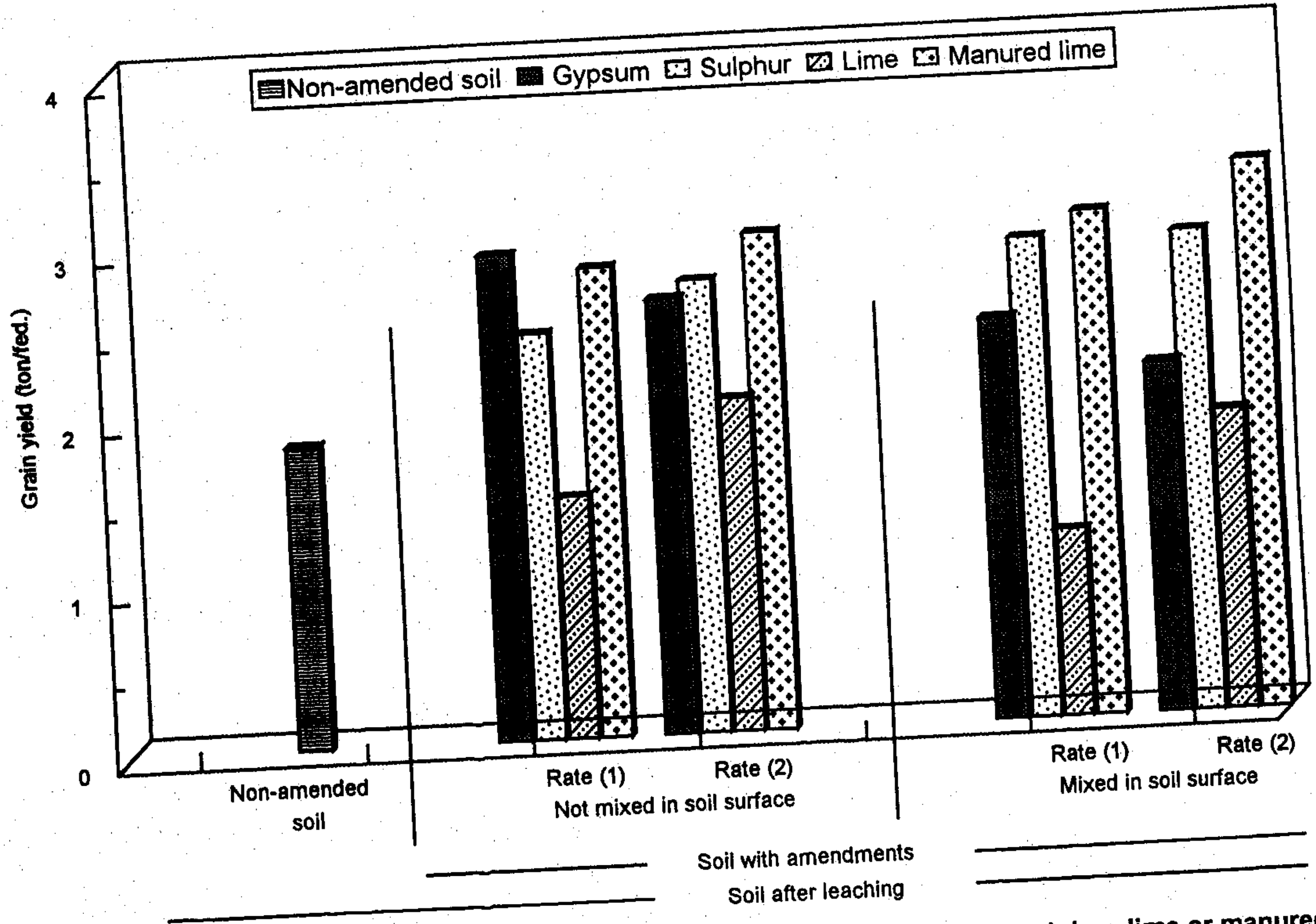


Fig. (12): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on grain yield.

Table (26): Straw yield of rice (ton/fed.) as affected by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	3.13	2.43	2.78
	Rate 2	3.17	2.87	3.02
	Mean	3.15	2.65	2.90
Sulphur	Rate 1	2.93	3.03	2.98
	Rate 2	3.07	3.17	3.12
	Mean	3.00	3.10	3.05
Lime	Rate 1	2.83	1.97	2.40
	Rate 2	2.57	2.23	2.40
	Mean	2.70	2.10	2.40
Manured lime	Rate 1	3.50	3.57	3.53
	Rate 2	3.33	3.83	3.58
	Mean	3.42	3.70	3.56
	Mean of rates			
	Rate 1	3.10	2.75	2.93
	Rate 2	3.03	3.03	3.03
G. Mean		3.07	2.89	
Non-amended soil (Leached with no amendments)		1.93		

LSD 0.05: T = 0.45 R = ns S = ns TR = ns
TS = ns RS = ns TRS = ns

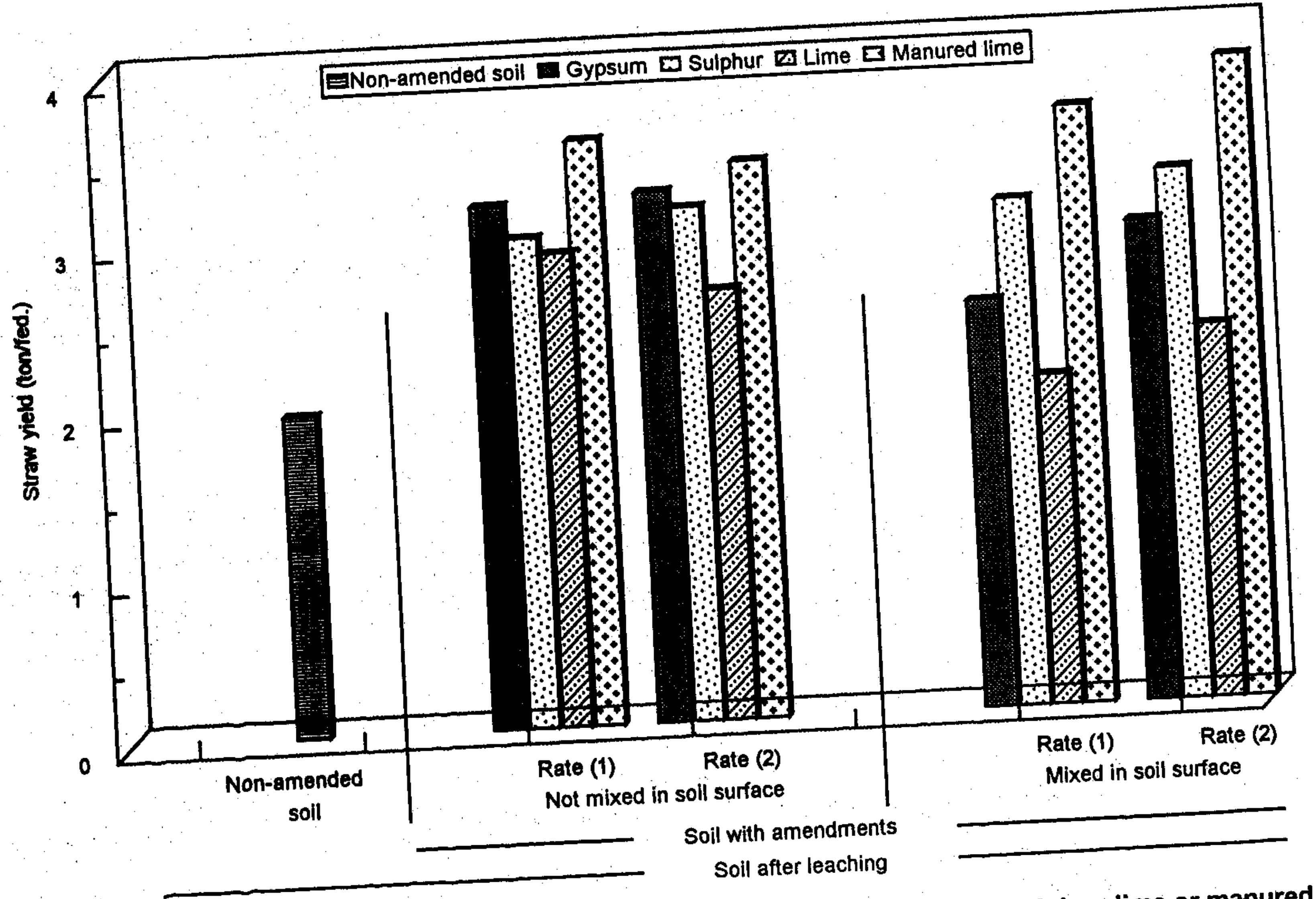


Fig. (13): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on straw yield.

Table (27): (Grains + straw) yield of rice (ton/fed.) as affected by leaching a saline sodic soil using different amendments and methods of application.

Material (T)	Rate (R)	Method (S) Non-mix	Mix	Mean
Gypsum	Rate 1	6.00	4.80	5.40
	Rate 2	5.73	4.93	5.33
	Mean	5.87	4.87	5.37
Sulphur	Rate 1	5.33	5.87	5.60
	Rate 2	5.73	6.00	5.87
	Mean	5.53	5.93	5.73
Lime	Rate 1	4.27	3.07	3.67
	Rate 2	4.53	4.00	4.27
	Mean	4.40	3.53	3.97
Manured lime	Rate 1	6.27	6.53	6.40
	Rate 2	6.27	7.07	6.67
	Mean	6.27	6.80	6.53
	Mean of rates			
	Rate 1	5.47	5.07	5.27
	Rate 2	5.57	5.50	5.53
G. Mean		5.52	5.28	
Non-amended soil (Leached with no amendments)	3.73			

LSD 0.05: T = 0.78 R = ns S = ns TR = ns
TS = ns RS = ns TRS = ns

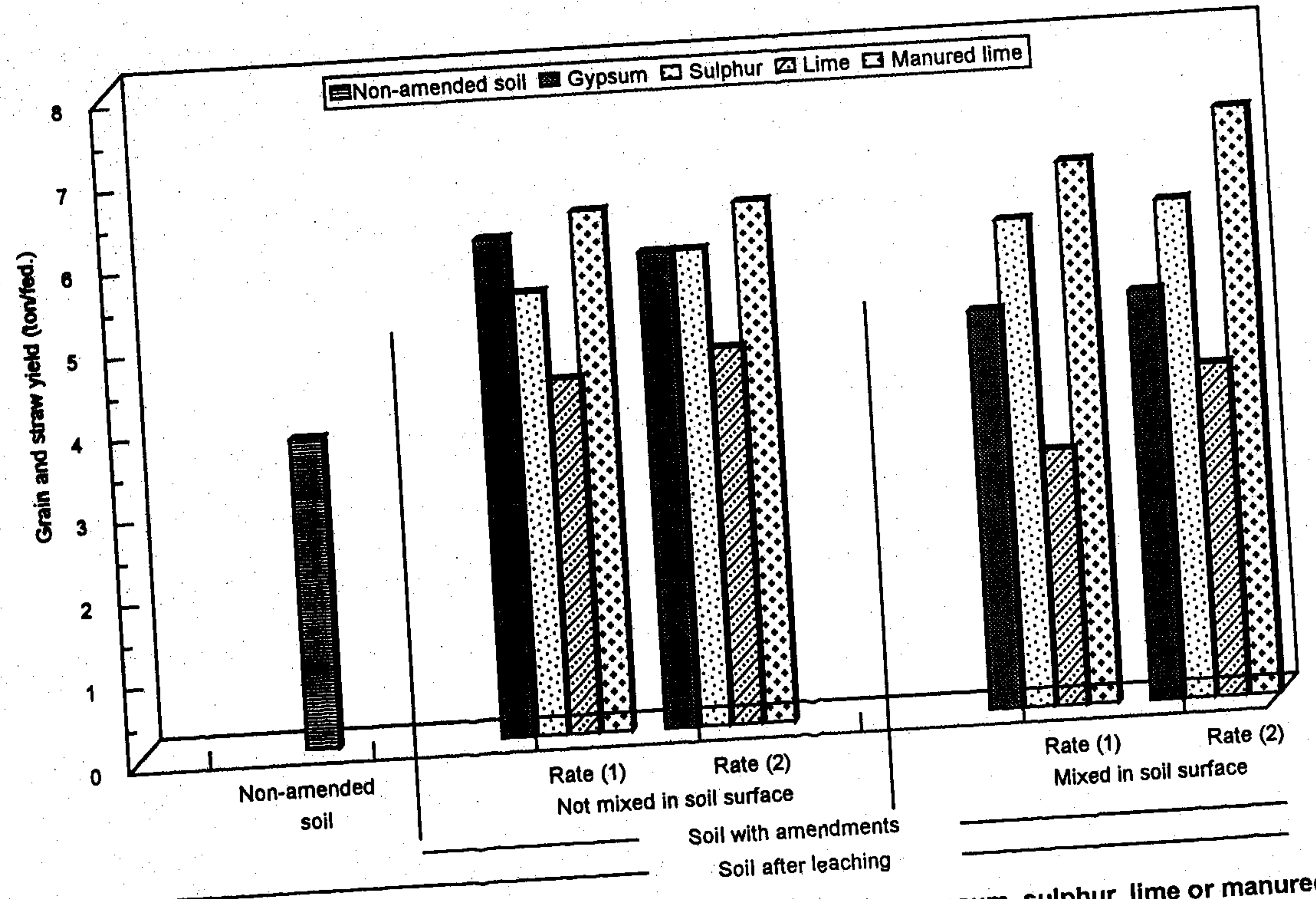


Fig. (14): Reclamation leaching of a saline sodic soil by applying gypsum, sulphur, lime or manured lime: Effect on grain and straw yield.