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Influence of Amendments and Flooding with Saline and Non-Saline Water on Changes in Physico-Chemical Characteristics of a Sodic Soil

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Laboratory experiments were conducted with a highly sodic soil (pH, 10.6, exchangeable sodium percentage(ESP) 96) to evaluate the effect of amendments viz. gypsum @ 50% gypsum requirements (GR), gypsum @ 100% GR, pyrite equivalent to 50% of GR on sulphur (S) basis, pyrite equivalent to 100% of GR on S basis, farm yard manure (FYM) @ 1%, gypsum @ 50% of GR + FYM @ 1%, gypsum @ 100% of GR + FYM @ 1%, pyrite @ 50% of GR on S basis + FYM @ 1%, Pyrite @ 100% of GR on S basis + FYM @ 1% and a control (no amendment) with saline (EC_{iw} 4 dSm ^{1}) and non saline (EC 0.4 dSm ^{1}) irrigation water on the temporal changes in pH, EC, ESP, exchangeable Ca+Mg, Fe^{2+} and Mn^{2+} of the soil. With increase in the incubation period after flooding pH and ESP decreased, whereas EC, Fe^{2+}, Mn^{2+} and exchangeable Ca + Mg were increased following amendment applications. FYM alone and/or in combination with gypsum and pyrite brought about conspicuous increase in $Fe^{2+}$and Mn^{2+}, the effects being more pronounced with saline water as compared to non saline water. FYM also proved effective in enhancing the efficiency of gypsum and pyrite for the reclamation of sodic soils.

Key words: sodic soil, farmyard manure, saline irrigation water, iron and manganese availability, reclamation, gypsum, pyrite

Soil sodicity poses a serious problem for crop production in arid and semi arid regions of the world (Kovda, 1965). These soils occur extensively in the Indo Gangetic plains of India. They were formed under the influence of sodium carbonate and are characterized by high pH (>8.5) and high exchangeable sodium percentage (>15) throughout the soil profile, impervious surface soil and reduced availability or increased toxicity of some essential plant nutrients. Efforts are being made to reclaim these soils by using various organic and inorganic amendments and growing rice as a first crop because of its high tolerance to exchangeable Na and high reclaiming effect (Swarup, 1985). During growth of rice continuous submerged condition is required, which plays an important role in influencing pH, EC, ESP and nutrient availability especially that of Fe^{2+} and Mn^{2+} (Swarup, 1988). The importance of submergence in sodic soils assumes greater role in view of its profound effect on the reclamation process. Saline water has also been used to reclaim sodic soils quickly and more effectively (Reeve and Bower, 1960; Cass and Summer, 1974; Dubey *et al.,* 1987; Dubey and Mondal, 1993 and 1994). However, information about changes in various physico-chemical properties as a result of amendments with saline irrigation water is scarce. Therefore, the present investigation reported herein was undertaken.

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Materials and Methods

A sample of surface soil (0-15cm) was taken from CSSRI farm, Gudha, India. The soil was air dried and crushed to pass through 2 mm sieve. The soil was thoroughly mixed and analysed for various physico chemical properties (Table 1). The experiment consisted of 20 treatment combinations of different levels and type of amendments *viz*. gypsum @ 50% GR, gypsum @ 100% GR, equivalent quantity of pyrite @ 50% GR on sulphur basis, pyrite 100% GR, FYM @ 1%, gypsum @ 50% GR + FYM @ 1%, gypsum @ 100% GR + FYM @ 1% pyrite @ 50% GR + FYM @ 1%, Pyrite @ 100% GR + FYM @ 1% and a control (no amendment) with two irrigation water qualities *viz*. non saline (EC_{iw} 0.4 dSm ^{1}) and saline water (EC_{iw} 4 dSm ^{1}, SAR 10). Saline water was prepared by adding the required quantities of $CaCl_2$, $MgCl_2$ and NaCl salts in non saline water keeping the ratio of Ca:Mg in 1:1. Required quantity of each amendment was mixed thoroughly in the 200 g soil. To ensure uniform mixing these soils were again passed through a funnel five times. Then these soils were packed in 500 ml beaker and water was added to maintain a level of 5 cm above soil surface. The experiments were replicated thrice and the samples were incubated at 27 ^{0}C in a BOD incubator and the water level was maintained daily by addition of water equivalent to water lost by evaporation. Soil samples were collected after 30, 60 and 90 days of incubation for exchangeable sodium percentage (ESP), exchangeable Ca + Mg and 10, 30, 50, 70, and 90 days for Fe^{2+} and Mn^{2+} determination. Another set of beakers (100 ml) having 20 g soil with similar treatments and soil:water ratio of 1:2 were also incubated for periodical determination of pH and EC. Ferrous iron was extracted with 1N NH_4OAC of pH 7.0 and analysed by orthophenanthroline method (Jackson, 1976). Exchangeable manganese was extracted with 1N NH_4OAC of pH 7.0, oxidised to permanganate and determined colorimetrically (Sherman *et al.,* 1942). The exchangeable fraction also included the water-soluble fraction, which was not extracted separately. Separate samples in triplicate were used for each determination.

Results and Discussion

Soil pH

Changes in soil pH under flooded conditions are presented in Fig.1. All the treatments with non-saline as well as saline water reduced the soil pH more effectively over control. The pH decreased very sharply during first eight days in all the treatments. The magnitude of decrease was lowest in control with non-saline water. The decrease in pH with saline and non saline water followed the following order: gypsum 100% GR + FYM > gypsum 100% GR > gypsum 50% GR + FYM > gypsum 50% GR > pyrite 100%GR+FYM > pyrite 100%GR > pyrite 50% GR+FYM > pyrite 50% GR > FYM > Control. After the termination of experiment, significant decreases in pH among the treatments were observed with non-saline water whereas with saline water the differences were very small. This fall in pH of the soil can be attributed to the accumulation of carbon dioxide and the production of organic acids. These results are in agreement with Ponnamperuma (1965) and Swarup (1981). The initial pH (10.6) was reduced to a minimum value of 8.4 with non saline water and 8.1 with saline water in Gypsum 100% GR + FYM treatment. In a sodic soil, a fall in pH helps in increasing the availability of nutrients, which helps in better growth of crop (Dubey *et al*., 1987; Dubey and Mondal, 1993 and 1994). The corresponding decrease in pH from the initial 10.6 with non-saline and saline water when averaged over treatments was 9.32 and 8.45, respectively.

Table 1. Physicochemical properties of the experimental Soil

pH	10.60	Cation exchange capacity($cmol_c$ kg^{-1})	10.0
EC(dSm^{-1})	3.75	Exchangeable Na^+(%)	95.0
Unit of Bulk Density$CaCO_3$(%)	2.75	Exchangeable Ca+Mg($cmol_c$ kg^{-1})	0.20
Organic carbon(g kg^{-1})	2.2	Sand(%)	57.9
Bulk density(Mg m^{-3})	1.68	Silt(%)	28.2
Particle density(Mg m^{-3})	2.68	Clay(%)	13.9
Gypsum requirement(Mg ha^{-1})	25.0	Texture	Sandy loam
		Classification	Aquic Natrustalf

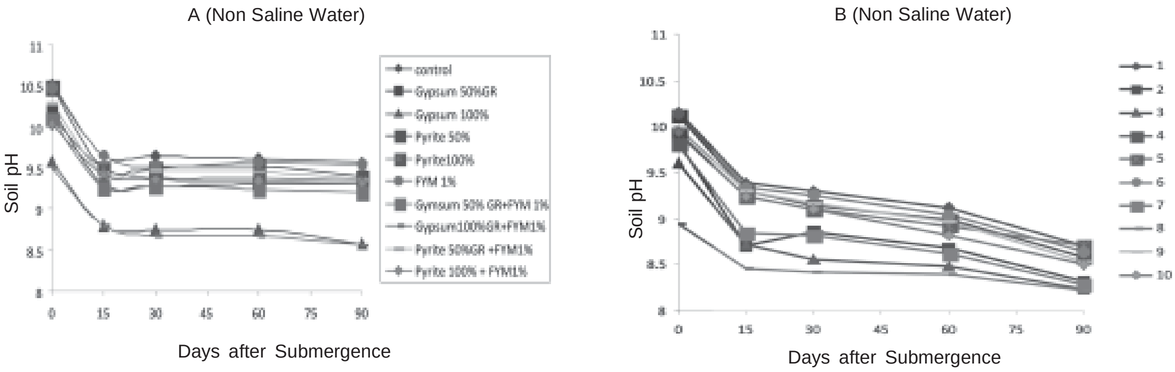

Fig 1. Effect of amendments and water quality on the periodic changes in soil pH.

Soil EC

The effect of amendments and flooding of soil with non saline and saline water is presented in Fig.2. As expected the application of amendments and saline water significantly increased the EC of soil with time. With the application of non-saline water and amendments, the increase in EC was found only upto two weeks. After this period it started reducing whereas with saline water it continued to increase till the termination of experiment in all the treatments. It could be because of continuous addition of salts in the form of saline water to the soil. The maximum increase in EC was found in

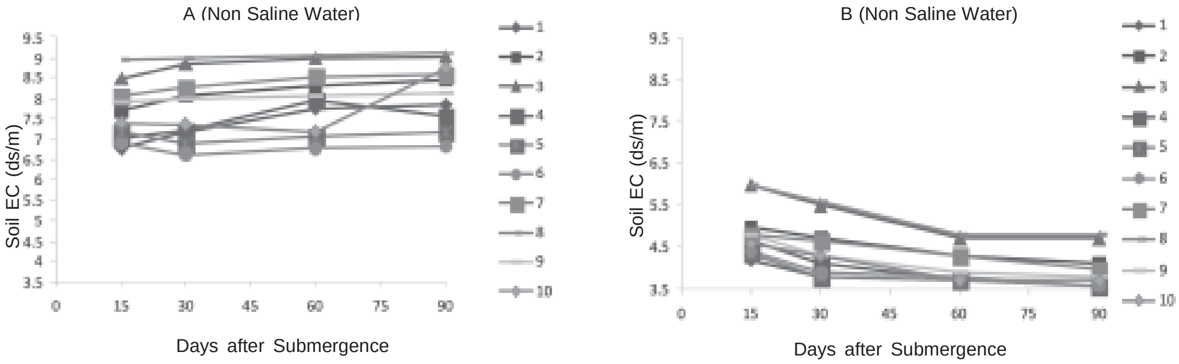

Fig 2. Effect of amendments and water quality on the periodic changes in soil EC.

Gypsum + FYM treatments. The differences among the amendments were more prominent with saline water as compared to non saline water. Moreover, EC also increased as Ca^{2+} and Mg^{2+} are mobilised by enhanced CO_2 and organic acids, Fe^{2+} and Mn^{2+} also go into soil solution following the reduction of their insoluble oxidised counter parts and accumulation of NH_4^+ (Swarup, 1992).

Exchangeable Ca + Mg and ESP

As revealed from Fig.3 and 4, application of amendments and saline water decreased

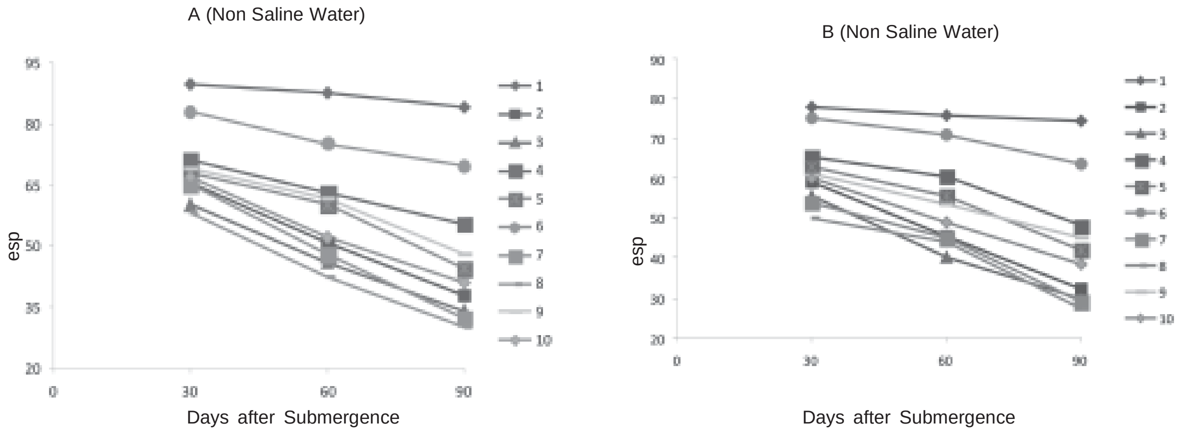

Fig 3. Effect of amendments and water quality on the periodic changes in exchangeable sodium percentage of soil.

exchangeable Na and increased exchangeable Ca + Mg with the increase in period of submergence. Flooding of such soils leads to the accumulation of CO_2 which solubilises the native $CaCO_3$ and releases Ca which in turn replaces Na from the exchange complex. Gypsum is also reported to increase the dissolution of native $CaCO_3$ and thus reduced the ESP increased the exchangeable Ca + Mg (Swarup, 1985). Maximum decrease in ESP and increase in exchangeable Ca + Mg was found

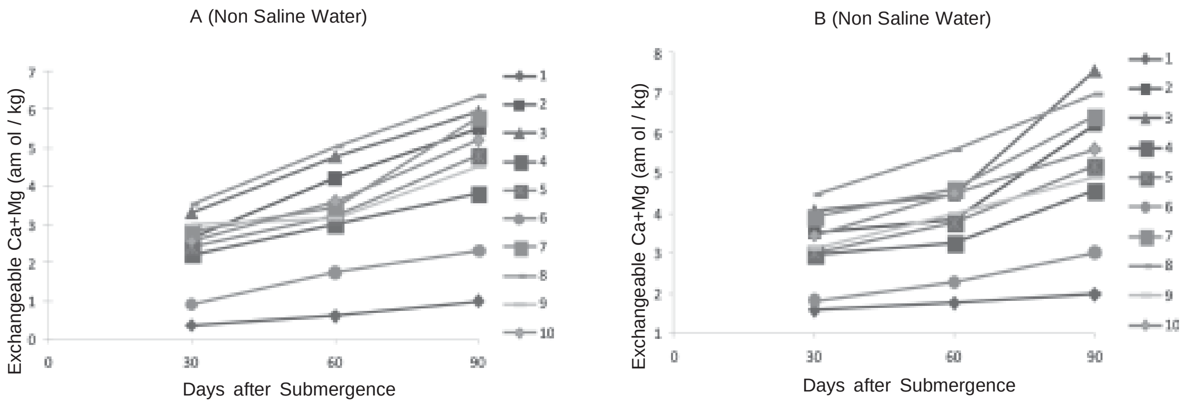

Fig 4. Effect of amendments and water quality on the periodic changes in exchangeable Ca+Mg of soil.

with gypsum 100% GR + FYM treatment with either of the water used. The reduction in ESP and increase in exchangeable Ca+Mg was recorded in the following order: gypsum 100% GR + FYM > gypsum 100% GR > gypsum 50% GR + FYM >gypsum 50% GR > pyrite 100% GR + FYM > pyrite 100% GR > pyrite 50% GR + FYM > Pyrite 50% GR > FYM > control. However, the maximum decrease in ESP and increase in exchangeable Ca+Mg was recorded when saline water was used with amendments.

Ferrous iron

Fe exists in soil as Fe^{2+} and Fe^{3+}. Changes in Fe^{2+} with amendments during incubation are shown in Fig.5. Maximum Fe^{2+} concentration was observed within 30 to 70 days irrespective of amendments and water used. The release of Fe^{2+} increased with

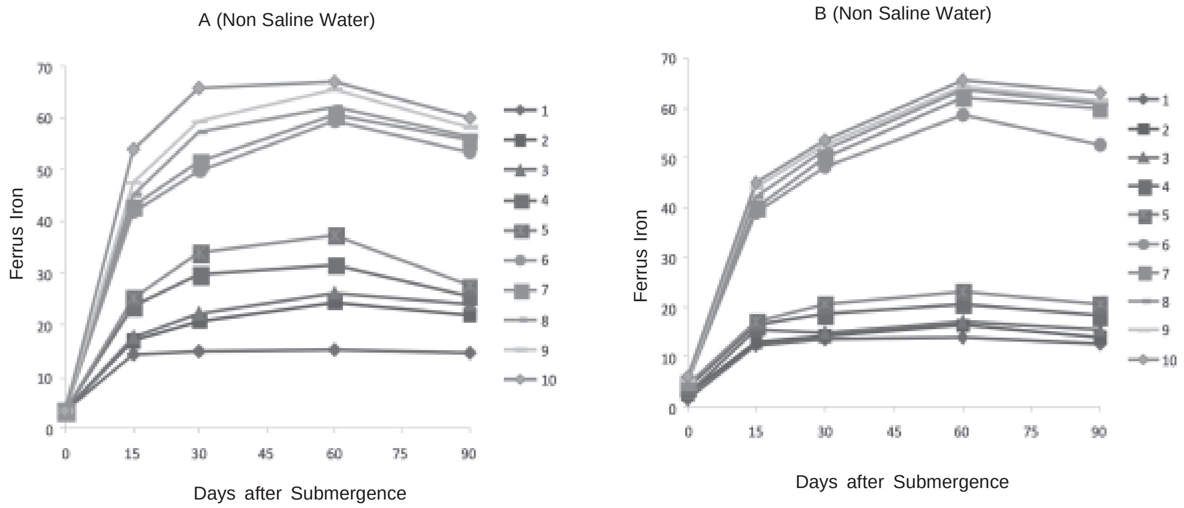

Fig 5. Effect of amendments and water quality on the periodic changes in ferrous iron of soil.

the decrease in the ESP of the soils. There was a conspicuous increase in Fe^{2+} by FYM, which may be attributed to the conversion of large amounts of Fe^{3+} to Fe^{2+} due to the strong reduced conditions of the soil (Swarup, 1988). The increase in the availability of iron upon flooding may be very beneficial to rice because wet land rice has a higher apparent iron requirement than other plants (Ponnamperuma, 1965). Moreover, iron deficiency has been reported in alkaline and calcareous sodic soils (Ponnamperuma, 1965).

Exchangeable manganese

Mn generally exists in soils as di, tri, and tetravalent forms. Exchangeable divalent manganese is in equilibrium with the tri- and tetravalent forms, which are favoured by high pH and oxidising conditions. Higher oxides of manganese (MnO_2, Mn_2O_3, and Mn_3O_4) become more soluble on flooding the soil. Submergence increased the exchangeable manganese by 3 to 5 times with all the treatments irrespective of water used for flooding (Fig.6). FYM produced a marked effect in increasing the Mn^{2+} concentration, which could be due to the reduction of higher amounts of manganic oxides to manganous form. This effect was more pronounced during 30 to 70 days of flooding with all the treatments. The increased

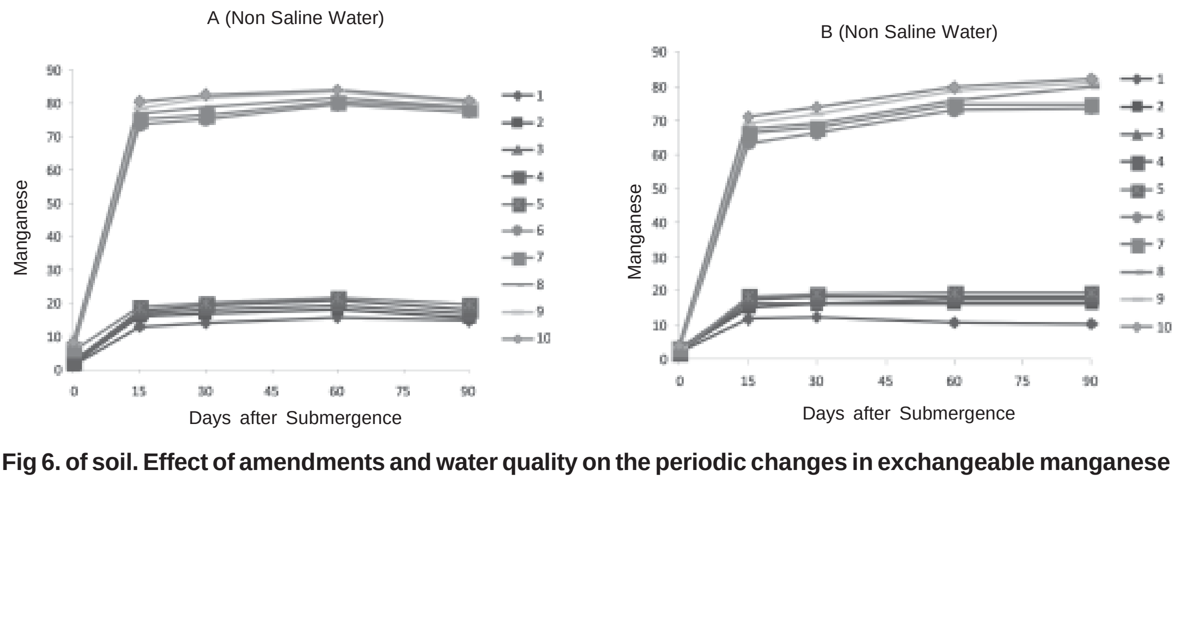

Fig 6. of soil. Effect of amendments and water quality on the periodic changes in exchangeable manganese

availability of Mn upon flooding is beneficial to rice because wetland rice has a comparatively high requirement for manganese (Yamasaki, 1965). This probably accounts for part of the beneficial effect of waterlogging on rice growth.

Conclusion

The flooding of sodic soil in the presence of soil amendments such as gypsum, pyrite and FYM reduced the pH and ESP and increased the Fe and Mn availability. Therefore, the results of this study clearly suggested that highly deteriorated sodic soils could be reclaimed quickly and more effectively with the use of gypsum, pyrite and FYM in conjunction with saline irrigation water for better crop production.

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