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Influence of Amendments on Reclamation and Yield of Rice in Alkali Soil of Cauvery Command Area, Karnataka

HARI MOHAN MEENA AND H. C. PRAKASHA
Department of Soil Science & Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
E-mail : harimohanmeena46@gmail.com

ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station (ZARS), Vishweshwaraiah Canal (VC) Farm, Mandya to know the effect of different amendments *viz.,* gypsum, press mud and mangala setright and chemical fertilizers on reclamation and rice production in alkali soil. The growth and yield parameters *viz*., plant height, number of tillers $hill^{-1}$, length of panicle, number of panicles $hill^{-1}$, grains $panicle^{-1}$ and test weight of rice increased significantly by application of soil test value based fertilizers recommendation along with press mud (T_8) followed by gypsum (T_7) over famers' practice. Grain and straw yield of rice increased significantly due to application of fertilizers along with press mud and gypsum as amendments compared to package of practice and farmers' practice, especially in the treatment which received soil test value based fertilizers recommendation + FYM + $ZnSO_4$ along with press mud. Application of amendments (gypsum press mud and mangala setright) along with the soil test value based fertilizers recommendation significantly decreased the soil pH, electrical conductivity (EC), exchangeable sodium and exchangeable sodium percentage (ESP) as compared to farmers' practice.

Keywords: Alkali soil, Reclamation, Rice yield, Gypsum, Press mud, Setright application

Soil alkalinity is a serious worldwide soil degradation issue and has its negative impact on agricultural sustainability. In all over the world, about 1.5 billion hectares of land are salt affected (Yuan *et al*., 2010). In many arid and semi-arid regions of the world, soil degradation induced by salinity is one of the major constraints to sustainable agricultural production. In India, arid and semi-arid regions occupy 127.4 million hectares area out of 329 million hectares of total geographical area. The salt affected soils in these zones occupy 7.4 m ha spread over in 15 states of the country. Alkali soils occupy 4.41 million hectares followed by 3.26 million hectares of saline soil out of total 7.4 million hectares of land affected with salt. Nearly 0.17 m ha of land is being affected by this problem in Karnataka state (Bajwa and Anand, 2009).

Among these salts affected soils, alkali soils are found to be highly problematic for crop production because of very poor physical and chemical environment particularly in irrigated areas. Sodicity problem in irrigated agriculture is becoming more and more serious because of faulty methods of irrigation, intensive cultivation of high water requirement crops, use of poor quality water, lack of adequate knowledge about soils and poor management practices. The amelioration of these alkali soils is not only expensive but also time consuming and laborious. The accumulation of excessive salt adversely affects physical and chemical properties of soils, and also microbiological processes (Lakhdar *et al*., 2009).

Generally, alkali and saline-alkali soils display structural problems like dispersion of clay, slaking, swelling, and surface crusting. These problems of alkali soils may impede water and movement of air, reduce availability of nutrient, decrease plant available water, reduce root penetration and seedling emergence and increase water runoff and erosion potential. Crop cultivation becomes very difficult without any modification in sodic soils. Restoring and maintaining the soil quality is one of the major challenges in recent times. In context of sustainable agriculture production, characterization of soil in relation to evaluation of soil inherent fertility of a region or area is a vital aspect. Good quality soils not only produce better food and fibre but also help to establish natural ecosystems and enhance air and water quality (Griffiths *et al*., 2010).

The reclamation of alkali soils basically requires the removal of excess sodium on the exchange complex with calcium and the replaced sodium leached out from root zone. Among the amendments, gypsum is the cheapest and most convenient one for reclamation of sodic soils. But, now-a-days due to its non-timely availability, there is a need to search for alternate source of amendment particularly for alkali soils. Amendments such as press mud, gypsum and setright supply calcium (Ca^{2+}) ions into soil solution upon dissolution or indirectly after a series of chemical and biological reactions in case of elemental sulphur and acids to replace sodium (Na^{+}) ions from soil exchange site and improve physical and chemical properties of soil and result in leaching of sodium salts.

Press mud from sugar mill is another amendment, which is enriched source of organic matter and contains substantial quantities of nutrients for improving physical conditions and improvement of soil inherent fertility. It also contains sulphur, which helps to acidify the soil. This acidification makes soluble Ca available and thus improves soil structure and increases the leaching of salts. Gypsum helps to rectify sodium abundance through leaching down the excess sodium from clay particles as a sodium sulphate and thus makes physical and chemical conditions conducive for plant optimum nutrient uptake. By understanding the relative effectiveness of different amendments and extent of reclamations of alkali soils to support high yields of rice crop required a balanced fertilizers application. Thus, the present investigation was carried out with the objective to know the effect of amendments on the reclamation and growth and yield of rice crop in alkali soils.

Material and Methods

The field experiment was carried out during *kharif* 2016 in alkali soils at Zonal Agricultural Research Station (ZARS), Vishweshwaraiah Canal (VC) Farm, Mandya (Karnataka). The experimental site is situated 12°57'03'' North latitude and 76°82'05'' East longitude with an average of 705 m above mean sea level. The experimental location falls under southern dry zone (Zone-6) of Karnataka. The soil of the experiment site was sandy clay loam in texture. Some important chemical characteristics of the surface soil (0-15 cm) at the initiation of the experiment are given in Table 1.

Table 1

Initial soil properties of the experiment

Parameters	Value
Mechanical composition (%)	
Sand	57.30
Silt	14.50
clay	28.20
Soil texture	Sandy clay loam
Soil pH	8.60
EC (dS m^{-1})	1.24
OC(g kg^{-1})	3.20
Available N (kg ha^{-1})	228.60
Available P_2O_5 (kg ha^{-1})	22.46
Available K_2O (kg ha^{-1})	159.90
Exchangeable calcium (cmol kg^{-1})	5.24
Exchangeable magnesium (cmol kg^{-1})	02.12
Exchangeable sodium (cmol kg^{-1})	03.82
ESP (%)	29.75

The experiment was conducted in randomized complete block design (RCBD) with eight treatments and three replications. The eight treatments were as follows: T_1: Farmers' practice, T_2: RDF + FYM + Zn (POP), T_3: T_2 + gypsum, T_4: T_2 + press mud, T_5: T_2 + mangla setright, T_6: Soil test value based fertilizer recommendation + FYM + $ZnSO_4$, T_7: T_6 + gypsum, and T_8: T_6 + press mud. The field experiment plot size was 10.8 m^2 (3.6m × 3m). As per UAS package of practice the recommended dose of NPK fertilizer for rice in alkali soil was applied @ 125, 62.5 and 62.5 kg N, P_2O_5 and K_2O ha^{-1}, respectively, Farm Yard Manure (FYM) and $ZnSO_4$ were applied at the rate 10 tones ha^{-1} and 40 kg ha^{-1}, respectively. In farmers' practice treatment (T_1), 150, 40 and 35 kg N, P_2O_5 and K_2O ha^{-1}, respectively was applied. The initial value of available nitrogen and phosphorus in experimental soil was low therefore nitrogen and phosphatic fertilizer in the treatments T_6, T_7 and T_8 were applied based on soil test value which accounts to 25 per cent more than recommended dose of fertilizers.

Calculated quantities of fertilizers were applied to each plot in the experiment where 50 per cent of the recommended dose of nitrogen and potassium and 100 per cent recommended dose of phosphorus were applied as basal dose at the time of transplanting through urea, single superphosphate and muriate of potash, respectively. The remaining half nitrogen and potassium were top dressed in two equal splits at 30 and 60 days after transplanting of rice. FYM @ 10 t ha^{-1} and $ZnSO_4$ @ 40 kg ha^{-1} were applied in common for all the treatments except treatment T_1 (Farmers' practice). Gypsum requirement of the soil was computed for initial soil sample of experimental site. Gypsum was applied at the rate 5.4 tones ha^{-1} as gypsum requirement by Schoonover's method. Press mud was applied at the rate of 10.0 tones ha^{-1} as equal to FYM. A mangla setright dose of 247 kg ha^{-1} was directly applied on the basis of soil pH. All the amendments were applied to the respective experimental plot one month before planting and mixed by ploughing. The chemical characteristics of the amendments are given in Table 2.

TABLE 2

Characterization of amendments (press mud, gypsum and mangala setright)

Particulars	Press mud	Gypsum	Mangala setright
pH	6.74	4.21	4.54
EC (dS m^{-1})	4.19	2.58	1.66
Organic carbon (%)	27.5	ND	ND
Nitrogen (%)	1.12	0.03	0.04
Phosphorus (%)	0.55	0.02	0.01
Potassium (%)	1.61	0.14	0.08
Calcium (%)	5.70	20.71	15.00
Magnesium (%)	3.24	3.76	3.00
Sulphur (%)	4.10	18.00	5.00

The rice crop variety Vikas (21 days old seedling) was transplanted on 20th August 2016 and harvested on 19th December 2016. After harvesting of rice (*kharif*, 2016-17), data on grain and straw yields were recorded in each plot separately. Grain yield of rice was computed at 14 per cent moisture content, while the straw yield of rice from the individual plot was recorded on a dry weight basis.

The soil samples collected from a depth of 0-15 cm after the harvest of crops were used for the determination of various chemical parameters. The processed soil samples were analyzed for the soil pH, electrical conductivity (EC), organic carbon, exchangeable sodium, exchangeable sodium percentage (ESP). The soil pH was determined by the method outlined by Jackson (1973), organic carbon was determined by method given by Walkley and Black (1934), exchangeable Na was determined by using a flame photometer as outlined by Jackson (1973), ESP was calculated by using exchangeable sodium and cation exchange capacity values of soils

$$\text{ESP (\%)} = \frac{\text{Exchangeable sodium}}{\text{Cation exchange capacity}} \times 100$$

The data were analyzed as per the standard statistical procedure. The analysis of variance (ANOVA) for RCBD was performed using an 'F' test as per the procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Influence of amendments on growth and yield parameters of rice

Application of amendments along with chemical fertilizers increased the growth and yield parameters of rice crop viz., plant height, no of tillers $hill^{-1}$, length of panicle, no of panicles $hill^{-1}$ and grains $panicle^{-1}$ at 30 DAP, 60 DAP and at harvest significantly over the farmers' practice (Table 3 and 4).

Plant height and no of tillers $hill^{-1}$

Application of soil test value based fertilizers recommendation + FYM + $ZnSO_4$ along with press mud (T_8) recorded taller plants at all growth stages

TABLE 3

Plant height (cm) and no of tillers hill^{-1} of paddy as influenced by application of different amendments in alkali soil

Treatments	Plant Height (cm)			No of tillers hill^{-1}		
	30 DAP	60 DAP	AT HARVEST	30 DAP	60 DAP	AT HARVEST
T_1 – Farmers' practice	35.33	47.29	53.62	10.87	12.47	11.53
T_2 - RDF + FYM + $ZnSO_4$ (POP)	39.27	56.04	62.51	13.23	14.07	14.40
T_3 - T_2 + Gypsum	44.87	63.42	70.42	16.67	18.00	18.87
T_4 - T_2 + Press mud	46.60	71.00	77.00	18.07	19.53	20.76
T_5 - T_2 + Mangala Setright	41.67	60.27	66.60	15.20	16.63	17.03
T_6 - STV + FYM + $ZnSO_4$	40.13	57.97	65.27	14.60	15.80	16.00
T_7 - T_6 + Gypsum	45.27	64.31	74.40	17.23	18.63	19.23
T_8 - T_6 + Press mud	47.67	70.20	81.62	19.20	20.20	21.03
S.Em±	1.34	3.44	1.70	0.45	0.50	0.59
CD (p=0.05)	NS	10.44	5.17	1.37	1.50	1.80

Note: STV – Soil test value based fertilizers recommendation; POP - Package of practice

TABLE 4

Length of panicle (cm), no of panicles hill^{-1}, grains panicle^{-1} and 1000-seeds weight (g) of paddy as influenced by application of different amendments in alkali soil

Treatments	Length of panicle (cm)	No of panicles hill^{-1}	Grains panicle^{-1}	1000- seeds weight (g)
T_1 – Farmers' practice	13.36	8.50	86.00	20.13
T_2 - RDF + FYM + $ZnSO_4$ (POP)	16.40	10.73	115.00	21.40
T_3 - T_2 + Gypsum	23.05	14.63	130.00	23.22
T_4 - T_2 + Press mud	25.70	16.47	141.00	24.52
T_5 - T_2 + Mangala Setright	20.87	12.87	135.00	22.83
T_6 - STV + FYM + $ZnSO_4$	17.63	11.03	120.33	22.24
T_7 - T_6 + Gypsum	24.02	15.87	135.00	23.87
T_8 - T_6 + Press mud	26.63	17.53	146.13	24.93
S.Em±	0.70	0.51	3.42	0.54
CD (p=0.05)	2.13	1.54	10.33	1.65

Note: STV – soil test value based fertilizer recommendation

viz., 30, 60 DAP and at harvest (47.67, 70.20 and 81.62 cm, respectively) over package of practice (39.27, 56.04 and 62.51 cm, respectively) and farmers' practice (35.33, 47.29 and 53.62 cm, respectively).

No of tillers hill^{-1} also followed almost similar trend, as followed by the plant height at 30, 60 DAP and at harvest of rice varied from minimum values of 10.87, 12.47 and 11.53 under farmers' practice (T_1) to maximum values of 19.20, 20.20 and 21.03, respectively in plots which received press mud with soil test value based fertilizer recommendation + FYM + $ZnSO_4$ (T_4). Application of press mud and gypsum in combination with package practice (T_4 and T_3) significantly increased no of tillers hill^{-1} as compared to application package of practice alone (Table 3).

Length of panicle (cm), no of panicles hill^{-1}, grains panicle^{-1} and 1000-seeds weight (g) of rice

Table 4 embodies the data with respect to length of panicle (cm), no of panicles hill^{-1} and grains panicle^{-1} of rice as influenced by application of different amendments in alkali soil. A perusal of the data revealed length of panicle (cm), number of panicles hill^{-1} and grains panicle^{-1} of rice varied from a lowest of 13.36 cm, 8.50 and 86.00 in the farmers' practice where no amendments were used (T_1) to a highest of 26.63 cm, 17.53 and 146.13, respectively in the plots which received press mud in combination with soil test value based fertilizer recommendation + FYM + $ZnSO_4$ (T_8) followed by press mud with package of practice (T_4). Application of gypsum in combination with soil test value based fertilizer recommendation + FYM + $ZnSO_4$ (T_7) followed by gypsum with package of practice (T_3) increased the length of panicle (cm), number of panicles hill^{-1} and grains panicle^{-1} of rice significantly over package of practice (T_2).

Test (1000-seeds) weight (g)

A perusal of the data given in the table 4 revealed test weight of rice varied from a lowest of 20.13 g in the farmers' practice (T_1) to a highest of 24.93 g in the plots which received press mud in combination with soil test value based fertilizer recommendation + FYM + $ZnSO_4$ (T_8) followed by press mud with package of practice (T_4). The improvement of growth and yield parameters of rice crop could be ascribed to continuous and controlled supply of nutrients throughout the crop growth period due to reclamation of soil sodicity by application of press mud and gypsum. Similar results were reported by Sharma *et al*., 2014

Influence of amendments on grain and straw yield of rice

Application of amendments along with chemical fertilizers increased the grain and straw yields of rice crop significantly over recommended dose of fertilizers and farmers' practice (Table 5). A perusal of the data revealed grain and straw yield of rice varied from a lowest of 21.95 and 34.67 q ha^{-1} in the farmers' practice (T_1) and the highest of 49.43 and 64.72 q ha^{-1}, respectively in the treatment which received soil test value based fertilizers recommendation + FYM + $ZnSO_4$ along with press mud (T_8), which was significantly superior to the rest of the treatments except treatment T_4. Grain and straw yield of rice significantly increased in the treatment which received package of practice in combination with gypsum (T_3) and press mud (T_4) as compared to package of practice alone (T_2) and farmers' practice (T_1).

Application of soil test value based fertilizers application increased the yield of rice crop might be

TABLE 5

Grain and straw yield of rice as influenced by application of different amendments in alkali soil

Treatments	Grain Yield(q ha^{-1})	Straw Yield(q ha^{-1})	Biological Yield(q ha^{-1})
T_1 – Farmers' practice	21.95	34.67	56.62
T_2 - RDF + FYM + $ZnSO_4$ (POP)	31.71	45.47	77.18
T_3 - T_2 + Gypsum	39.09	53.62	92.70
T_4 - T_2 + Press mud	46.41	63.52	109.93
T_5 - T_2 + Mangala Setright	37.10	49.24	87.34
T_6 - STV + FYM + $ZnSO_4$	34.64	47.37	82.00
T_7 - T_6 + Gypsum	40.32	55.50	95.82
T_8 - T_6 + Press mud	49.43	64.72	114.15
S.Em±	2.17	2.61	3.81
CD (p=0.05)	6.59	7.91	11.66

Note: STV – soil test value based fertilizer recommendation attributed to the balanced fertilization with nitrogen, phosphorus and potash. The lowest grain and straw yield of rice obtained in farmers' practice plot might be due to losses of nitrogen through NH_4^+ volatilisation in alkali soil which decreased the growth and yield parameters of rice. Also available plant nutrients are not efficiently utilized by crop because of poor root environment due to higher exchangeable sodium percentage. Similar low yield of rice grown in unamended alkali soils has reported by Suwiphaporn *et al*. (2014).The significantly higher grain and straw yield of rice was obtained with amendments might be attributed to decrease in soil pH and exchangeable sodium percentage of alkali soil upon incorporation of amendments, which might have helped in better nutrient utilization by rice crop. Similar results were reported by Kumar and Sharma (2009) and Lal Bahadur *et al*. (2013).

Influence of amendments on reclamation of alkaline soil

Soil pH

A perusal of the data given in the table 6 revealed that soil pH varied from a minimum of 7.82 in the treatment which received soil test value based fertilizers application+ FYM + $ZnSO_4$ with gypsum(T_7) and a maximum of 8.58 in the farmers' practice treatment (T_1). Compared to POP (T_2), application package of practice along with gypsum (T_3) significantly decreased the soil pH (7.99). Application of soil test value based fertilizers application + FYM + $ZnSO_4$ in combination with gypsum (T_7) and press mud (T_8) brought the soil pH to near neutrality by lowering the pH to 7.94 and 7.82, respectively from the initial value of 8.60, which clearly indicated the ameliorative effect of gypsum and press mud on soil alkalinity.

The reduction in soil pH by application of gypsum, press mud and setright could be ascribed to the displacement of exchangeable Na^+ by Ca^{2+} ions which is present in the amendments, that resulted in the formation of sodium sulphate which gets leached out through drainage process. Reclamation is also due to decomposition of press mud liberation of carbon dioxide (CO_2) and organic acid which solubilized the native $CaCO_3$ and moderating the soil sodicity (Trilok *et al*., 2010). The reclamation effect of gypsum and press mud on soil alkalinity has been reported earlier by Archana and Jithendra (2014) and Rayudu *et al*. (2014).

Electrical conductivity (EC)

Application of gypsum in combination with package of practice (T_4) recorded lower EC value of 0.82 dS m^{-1} and a higher value of 1.21 dS m^{-1} in the farmers' practice (Table 6).

Application of package of practice along with gypsum (T_3), press mud (T_5) and setright (T_4) amendments significantly decreased the EC of soil (0.82, 0.91 and 0.95 dS m^{-1}, respectively) as compared to farmers' practice (1.21 dS m^{-1}). Application of sulphitation press mud, gypsum and setright decreased the electrical conductivity (EC) which might be due to replace Na salts by the calcium through drainage in amendments treated plots. Similar results were also reported by Negim and Mustafa (2016).

Soil organic carbon

Application of soil test value based fertilizers recommendation + FYM + $ZnSO_4$ along with press mud (T_8) and gypsum (T_7) increased the soil organic carbon content to 3.84 and 3.53 g kg^{-1}, respectively from its initial soil organic carbon content of 3.20 g kg^{-1} (Table 6). Significantly higher soil organic carbon content was recorded in the treatments which received package of practice along with press mud (T_4) over no amendments treatments package of practice (T_2) and farmers' practice (T_1).

The low soil organic carbon content in the package of practice plots and the farmers' practice plots could be attributed to the poor crop growth and hence low root biomass addition to the soil. Press mud treated plots recorded highest organic carbon content as it serves as an organic source. Highest soil organic carbon content was observed in the treatments which received press mud as compared to without amendment application might be ascribed to the direct addition of organic matter and also better root growth by the

TABLE 6
chemical properties of alkali soil as influenced by application of different amendments

Treatments	Soil pH	EC(dS m^{-1})	OC(g kg^{-1})	Exchangeable Na{cmol (p^+) kg^{-1}}	ESP (%)
T_1 - Farmer's practice	8.58	1.21	3.19	3.77	28.16
T_2 - RDF + FYM + $ZnSO_4$ (POP)	8.43	0.99	3.35	3.47	24.56
T_3 - T_2 + Gypsum	7.99	0.82	3.44	3.14	17.05
T_4 - T_2 + Press mud	7.88	0.91	3.72	2.99	15.74
T_5 - T_2 + Mangala Setright	8.29	0.95	3.42	3.24	18.95
T_6 - STV + FYM + $ZnSO_4$	8.38	1.01	3.39	3.41	23.94
T_7 - T_6 + Gypsum	7.94	0.85	3.53	3.08	16.72
T_8 - T_6 + Press mud	7.82	0.93	3.84	2.95	15.14
S.Em±	0.07	0.03	0.11	0.11	1.33
CD (p=0.05)	0.22	0.10	0.33	0.32	4.18

Note: STV – soil test value based fertilizer recommendation

improved soil condition. Similar results have been reported by Shang-Dong *et al*. (2013).

Exchangeable sodium

Application of amendments significantly influenced the exchangeable sodium content of alkali soil (Table 6). Application of soil test value based fertilizers recommendation + FYM + $ZnSO_4$) along with press mud (T_8) and gypsum (T_7) decreased the exchangeable sodium content to 2.95 and 3.08 cmol (p^+) kg^{-1}, respectively from its initial sodium content of 3.82 cmol kg^{-1}. As compared to farmers' practice (T_1), exchangeable sodium content significantly decreased in the treatments which received package of practice in combination with gypsum (T_3), press mud (T_4) and setright (T_5).

The application of amendments decreased exchangeable sodium content which could be ascribed to replacement of sodium ion by calcium ion and its subsequent leaching due to solubilisation of produces calcium (Ca^{2+}) and sulphate (SO_4^{-2}) ions in soil solution when amendments were added to soil. Replacement of sodium (Na^+) on exchange complex by calcium (Ca^{2+}) ion in solution and formed sulphate salts which is leached out of soil during subsequent leaching. Exchangeable sodium content was decreased in without amendments plots may be attributed to leaching of soluble salt during rice crop growth period. A similar result was reported by Trilok *et al*. (2010) and Shaimaa *et al.* (2012).

Exchangeable sodium percentage (ESP)

The decline in ESP was 15.14 and 16.72 per cent in the treatments which received soil test value based fertilizers recommendation + FYM + $ZnSO_4$ in combination with press mud (T_8) and gypsum (T_7), respectively from the initial value of 29.75 per cent (Table 6). The highest value of ESP recorded in the farmers' practice treatment (28.16 %) which was significantly inferior to the rest of the treatments. The exchangeable sodium percentage significantly decreased to 15.74, 17.05 and 18.95 per cent in the treatment which received package of practice along with press mud (T_4), followed by gypsum (T_3) and setright (T_5), respectively as compared to farmers' practice (28.16 %).

The decline in ESP due to use of press mud and gypsum might be due to the replacement of sodium (Na^+) by calcium (Ca^{2+}) ions from exchange complex and its replacement from the soil via leaching (Trilok *et al*., 2010). Similarly, the decline in exchangeable sodium percentage of soil due to application of gypsum in combination with FYM + Zinc has reported by Shaimaa *et al.* (2012).

It is evident from the results that the application of chemical fertilizers with amendments (gypsum, press mud and setright) brought out a marked increase in the productivity of rice. Use of gypsum and press mud as amendments along with chemical fertilizers resulted in a significantly increased the growth and yield of rice compared to package of practice and farmers' practice. Application of different amendments along with soil test value based fertilizers recommendation resulted in the decreased soil pH, electrical conductivity (EC), exchangeable sodium and exchangeable sodium percentage (ESP). The use of amendments along with chemical fertilizers is absolutely essential to increase the productivity of alkali soils and to improve the health of degraded soil.

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