Original Research Article

Management of zinc for rice in sodic soils

ABSTRACT

Influence of amendments on reclamation as well as availability of plant nutrients will vary. The response of crop for the applied Zn will also vary with amendments. However, field experiment was conducted in sodic soil with various amendments viz., gypsum @ 50 % GR + green manure (6.25 t ha^{-1}), green leaf manure (12.5 t ha^{-1}) and press mud (10 t ha^{-1}) as main-plot treatments. Different levels of zinc sulphate *viz.,* 50, 100 and 150 percent of recommended dose as basal with and without foliar spray of $ZnSO_4$ @ 0.5 per cent at panicle initiation (PI) and heading stage were imposed as sub-plot treatments.The rice (CO 52) was used as test crop. The results of field experiment revealed that reclamation of sodic soil with gypsum @ 50% GR + green manure @ 6.25 t ha^{-1} and $ZnSO_4$ application @ 100% recommended dose (25 kg ha^{-1}) along with foliar spray of 0.5% $ZnSO_4$ at panicle initiation and heading stages found to be the best for getting higher yield of rice in sodic soils. For un reclaimed sodic soil, $ZnSO_4$ application @ 150% recommended dose (37.5 kg ha^{-1}) along with foliar spray of $ZnSO_4$ @ 0.5% at panicle initiation and heading stages is found to be best. The amendments application significantly improved the physicochemical properties, exchangeable cations, available NPK, DTPA-micronutrients of soil. It also increased the uptake of NPK and micronutrients. The growth and yield parameters also showed a significant response for reclamation and $ZnSO_4$ application. Application of gypsum +GM or GLM or press mud can be effectively used as an amendment for the reclamation of sodic soil. The gypsum +GM exhibited its superiority over others.

Key words:Amendments, Gypsum +GM, GLM, Press mud, Sodic soil, Zinc sulphate.

1. INTRODUCTION

Sodicity is a term given to the amount of sodium held in a soil. The problem of alkali land is being faced by a large number of farmers throughout the country(Reference). These soils are generally characterized by poor physical condition, total and available (N), phosphorus (P), calcium (Ca) and magnesium (Mg). Micronutrients such as zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) also exhibit low levels of solubility in sodic soils, (Reference). which may result in micronutrient deficiencies. Influence of different amendments will vary in improving the soil properties, nutrients availability and yield of rice. Response of rice will also vary for the application of zinc sulphate under different amendments.Hence this study was undertaken to investigate the influence of amendmentsand zinc sulphate application on physicochemical properties, nutrient availability and yield of rice.(Need to be improved- none references – poor information of the problem that to be study by paper

2. MATERIAL AND METHODS

The study was conducted in sodic soil which belongs to clay loam in texture, alkaline pH (9.98), low in EC (0.35 dS m^{-1}), high in ESP (29.6%), low in organic carbon (0.46%), low in available nitrogen (221 kg ha^{-1}), medium in available phosphorus (11.2 kg ha^{-1}) and potassium (126 kg ha^{-1}).

The exchangeable cations viz., Ca, Mg, K, Na content of the initial soil was 7.12, 5.65, 0.12, 5.42 (cmol (p^+) kg^{-1}) respectively. The DTPA-micronutrients viz., Zn, Fe, Mn and Cu content of the initial soil was 0.36, 3.60, 1.69 and 0.65 mg kg^{-1} respectively. The amendments gypsum @ 50% GR+GM @ 6.25 t ha^{-1}(M_2), GLM @ 12.5 t ha^{-1}(M_3) and press mud @ 10 t ha^{-1}(M_4) were used as main-plot treatments for the reclamation of sodic soil by adopting standardized reclamation procedure and the treatments without amendments were maintained as control (M_1). Different levels of zinc sulphate *viz.,* 50(S_2), 100(S_3) and 150(S_4) percent of recommended dose of zinc sulphate as basal with and without foliar spray of $ZnSO_4$ @ 0.5 per cent at panicle initiation (PI) and heading stages(S_5, S_6, S_7) were imposed as sub-plot treatments. Control (S_1) was maintained without $ZnSO_4$ application. All treatments were uniformly applied with recommended levels of NPK fertilizers (150:50:50 N, P_2O_5 and K_2O kg ha^{-1}). The growth and yield attributes of rice were recorded. Pose harvest soil samples were analysed for pH, EC, ESP, exchangeable cations, available NPK and DTPA- micronutrients content. Plant samples were analysed for NPK and micronutrients uptake at harvest stage (More information of the plant! Varieties.

3. RESULTS AND DISCUSSION

3.1.1 Physicochemical properties

pH of the soil ranged from 9.95 to 8.34 (Table 1). Application of amendments(mud is a significantly decrease the soil pH. Maximum reduction in soil pH was recorded in gypsum+ GM applied plots (8.45). The reduction in soil pH on application of gypsum+ GM was attributed to the displacement of exchangeable Na by the calcium ions of gypsum which get leached out due to drainage provided[1].The addition of GM after gypsum leads to further reduction in pH by producing organic acids during decomposition which solubilizes the native Ca. The GLM proved its superiority over press mud in reducing the soil pH. The fresh organic materials present in the GLM might have readily decomposed and released higher amount of organic acids.Gypsum application, slightly increased the EC of the post harvest soil.

A decrease in ESP of 14.8, 4.4 and 3.5% was noted due to gypsum+ GM, GLM and press mud application respectively over the control. In case of gypsum, the reduction in ESP was attributed to replacement of exchangeable Naby Ca of the gypsum[2].The application of organic amendments also reduced the soil ESP from initial level which may be due to increase in exchangeable Ca and Mg ions due to solubilization during decomposition of organic matter and also due to supply of nutrients like K, Ca and Mg from the GLM and press mud.

3.1.2 Exchangeable Cations

Application of amendments significantly influenced the exchangeable Ca content of soil. The exchangeable Ca content was highest in Gypsum + GM treatments (9.70 cmol (p+) kg $^{-1}$). The highest Ca in the Gypsum + GM applied treatments was mainly due to Ca ions from gypsum ($CaSO_4.2H_2O$) and solubilization of native calcium on decomposition of green manure incorporated in the fields.Application of organic amendments also considerably increased the exchangeable Ca content. The release of CO_2 during the degradation process decreased the precipitation of Ca^{2+} and CO_3^{2-} ions in the $CaCO_3$ form [3].On the other hand, the organic acids released the Ca from $CaCO_3$.Application of amendments slightly increased theexchangeable Mg content of post harvest soil. Swarup [4] reported that application of organic matters increased the exchangeable Mg in sodic soilwhy.Application of organic amendments showed highest exchangeable K content followed by Gypsum+ GM.

Application of amendments drastically reduced theexchangeable sodium content of soil**.** The exchangeable sodium declined to the tune of 2.72, 0.82 and 0.55 cmol(p+) kg^{-1} due to Gypsum+ GM, GLM and press mud application respectively over control.The considerable reduction in exchangeable Na was attributed to replacement of exchangeable Na by Ca present in gypsum and dissolution of free lime on decomposition of GM applied along with gypsum [5].

3.1.3 Soil available NPK

Highest available N was observed in the treatments which received GLM (245 kg ha^{-1}) followed by press mud, gypsum+ GM and control. An increase in available N content was higher in organic material applied treatments.This might be due to release of N from the plant material during decomposition and sustained N mineralization in flooded soils [6]. In gypsum+ GM applied plots also available N increased upto 11 kg ha^{-1} over the control. This increase was because of GM application rather than gypsum application.

An increased of 2.0, 2.6 and 2.5 kg available P ha^{-1} were recorded due to application of gypsum+ GM, GLM, and press mud respectively over the control. Organic materials increasethe availability of P in sodic through the mechanisms of reduction, chelation and favourable changes in soil pH occurring in flooded soils. The organic matter serves as carbon substrate for microorganisms which solubilize and mineralize the organic forms of P into inorganic forms [7].In Gypsum+ GM treatment, the increase in available P status might be due to the presence of GM. The amendments viz., press mud, GLMand gypsum+ GM application showed a increased K content of 18, 12 and 6 kg ha^{-1} respectively over the control.

3.1.4 DTPA- Micronutrients

The available micronutrients viz., DTPA-Zn, DTPA-Fe, DTPA-Cu and DTPA- Mn content were significantly influenced by application of amendments. The DTPA- Zn was significantly increased by both amendments and zinc sulphate application. Among the amendments Gypsum+ GM treated plots showed highest DTPA-micronutrients content followed by GLM and press mud.

Application of gypsum+ GM decreased the soil pH. Decrease in pH, decreases the Zn precipitation as $Zn(OH)_2$ and hence the availability increases. Higher availability of applied Zn was observed by Dhaliwal *et al*. [8]in soils treated with organic amendments could be due to dissolution and greater decrease in pH of the soil besides contribution through added biomass.For every unit decrease in pH there may be a 100-fold increase in Zn concentration in soil solution [9]. Among the zinc sulphate application, DTPA-Zn content increased gradually from lower to higher doses of zinc sulphate, since it supplies inorganic form of zinc directly to the soil solution (Table 2).

An increase in the availability of Fe and Mn following submergence, addition of organic matter and amendments in sodic soil may be attributed to 1. Conversion of higher oxides of Fe (Fe_2O_3, Fe_3O. nH_2O, $Fe(OH)_3.nH_2O$) and Mn (MnO_2, Mn_2O_3 and Mn_3O_4) to Fe^{2+} and Mn^{2+} as a result of microbial and chemical reduction. 2. Decrease in pH and ESP of sodic soils upon submergence and application of organic matter. Added organic matter accelerated the process of reduction in soil by decreasing the redox potential and increasing $pCO_2$and this possibly resulted in the release of Fe^{2+} and Mn^{2+} from their oxides and hydroxides [10]. The increased available micronutrients with green manuring may be due to chemical, enzymatic and metabolic transformation of organic material, as the green manuring is continuously subject to degradation [11].The other reason might be due to increased chelation effect of organic matter in all the amended plots.

3.2 Effect of amendments and zinc sulphate on nutrient uptake

3.2.1 NPK uptake

Application of amendments significantly increased the macro nutrients uptake (Table 3). The highest uptake ofNPK was recorded in the treatment which received Gypsum+ GM as an amendment followed by GLM and press mud applied treatments.The higher uptake of N noticed in amended plots might be due to the higher DMP and also more root growth which might have increased the absorption. The significant rise in the uptake of N by rice was due to the combined effect of higher yield and increased absorption. Organic materials acting as slow release sources of N are expected to more closely match the N supply and rice N demand. In Gypsum+ GM and GLM and press mud applied plots, the P uptake was increased due to increase in DMP, direct supplement and also release of native P to the available pool. Application of amendments enhanced the uptake of K due to dissolution and release of mineral K by the action of organic acids released during decomposition [12].Application of graded doses of zinc sulphate application also increased the NPK uptake due to the enhanced DMP produced by Zn.

Among the zinc sulphate application 150% zinc sulphate as basal + foliar spray was registered the highest NPK uptake which might be due to the higher biomass production in these treatments. Mazhar *et al*. [13] reported that application of zinc narrowed the Na/K ratio and helped to increase the uptake of K.

3.2.2 Micronutrient uptake

Amendments application significantly enhanced the uptake of micronutrients. This might be due to increased solubility of their compounds which are present in sodic soil as higher oxides, hydroxides and carbonates and reduction of soil pH on reclamation enabled rice to mobilize high amounts of these micronutrients. The highest total micronutrient uptake was observed in Gypsum + GM treated plots followed by organic amendments. This is substantiated by the increased concentration of Fe and Mn in the soil after harvest of rice crop as compared to their initial values [14].

In zinc sulphate applied treatments, the highest uptake of zinc was noticed in the treatment which received 150 per cent RD of zinc sulphate as basal+ foliar spray which was on par with 100 per cent RD of zinc sulphate as basal+ foliar spray. The increase in the zinc content in grain and straw might be due to the presence of increased amount of zinc in soil solution by the application of zinc sulphate. Increase in Zn content in grain and straw due to zinc fertilization was also reported earlier [15]. Suganya*et al.*[16] reported that Zn uptake was increased with increased levels of zinc mainly due to the increase in dry matter production, yield and zinc concentration.

3.3 Grain and straw yield

Among the amendments, highest grain yield (5511 kg ha^{-1}) was recorded in the gypsum+ GM applied treatments owing to creation of favourable micro climate, increased availability of essential nutrients which in turn increased the yield. Next to gypsum+ GM, higher yield was noted in GLM and press mud applied treatments over the control (Table 4). The organic amendments not only reclaimed the sodic soil but also enhances soil carbon content and biological properties. Application of zinc sulphate significantly enhanced the grain and straw yield of rice crop. Naik and Das [17] reported that soil application of zinc as $ZnSO_4$ increased the rice filled grain percentage, 1000-grain weight, number of panicles, grain and straw yield.Higher yield due to zinc fertilization is attributed to its involvement in many metallic enzyme system, regulatory functions [18], enhanced synthesis of carbohydrates and their transport to the site of grain production.

Higher concentration of zinc in the grain maintained by the application of zinc in the rhizosphere with constant supply coupled with higher zinc uptake might have increased the grain yield. Zinc helps in inducing alkalinity tolerance to crops by enhancing its crop efficiency to utilize K, Ca and Mg and thus increases the crop yield [19].

Among the zinc sulphate applied treatments 100% zinc sulphate as basal+ foliar spray was superior over 150% RD $ZnSO_4$ as basal applications. In the treatments without any amendments (control), 100% RD+ foliar spray and 150% RD+ foliar sprayare significantly different from each other. However in amendments applied treatments100% RD+ foliar spray and 150% RD+ foliar sprayare comparable with each other. The combined effect of amendments and Zinc sulphate application on grain and straw yield of rice was also found to be significant. The treatments gypsum + GM + $ZnSO_4$ @ 150% RD as basal + foliar sprayrecorded the highest yield which was on par with gypsum + GM + $ZnSO_4$ @ 100% RD as basal + foliar spray.

In addition to soil application of zinc sulphate, significance response was observed for foliar spray of $ZnSO_4$ @ 0.5% at panicle initiation and heading stage. Though the amendments reduced the pH considerably, still the pH was maintained at higher level (8.45 to 9.13). Further the entire quantity of $ZnSO_4$ was applied as basal. Hence the applied some portion of applied $ZnSO_4$ might have been converted into insoluble from at later stages. Hence foliar spray of $ZnSO_4$ at later stages (PI and heading stages) might have enhanced the uptake and yield of rice crop in sodic soils. Hence it is recommended thatreclamation of sodic soil with gypsum @ 50% GR + green manure @ 6.25 t ha^{-1} and $ZnSO_4$ application @ 100% recommended dose (25 kg ha^{-1}) along with foliar spray of 0.5% $ZnSO_4$ at panicle initiation and flowering stages found to be the best for getting higher yield of rice in sodic soils. For unclaimed sodic soil, $ZnSO_4$ application @ 150% recommended dose (37.5 kg ha^{-1}) along with foliar spray of $ZnSO_4$ @ 0.5% at panicle initiation and flowering stages is recommended to get reasonable yield of rice crop.

4. CONCLUSION

The results of field experiment concluded that application of amendments improved the physicochemical properties, exchangeable cations, available NPK, DTPA micronutrients and nutrients uptake of soil. Highest exchangeable cations, available nutrients were observed with the gypsum+ GM followed by GLM and press mud treatments.Application of amendments to sodic soil significantly increased the yield parameters (DMP and grain and straw yield) of rice.

The conclusion doesn't relate to the title and the paper's objective

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Table 1. Effect of amendments on physicochemical properties, exchangeable cations, available NPK and micronutrientsof post harvest soil

Treatments *	**Unit**	**Control**	**Gypsum+GM**	**GLM**	**Press mud**	**S Ed**	**CD(0.05)**
pH	-	9.95	8.45	8.95	9.13	0.1	0.25
EC	dS m^{-1}	0.35	0.41	0.37	0.37	0.006	0.01
ESP	%	29.7	14.8	25.2	26.2	0.36	0.91
Ex. Ca		7.13	9.7	7.76	7.79	0.13	0.33
Ex. Mg	cmol	5.64	5.73	5.77	5.79	0.08	0.22
Ex. Na	$(p^{+})kg^{-1}$	5.43	2.71	4.61	4.88	0.07	0.17
Ex. K		0.11	0.13	0.15	0.16	0.002	0.01
Av N		223	235	245	240	3.48	9
Av P	kg ha^{-1}	11.4	13.3	14	13.9	0.2	0.52
Av K		130	136	142	147	2.17	5
DTPA- Fe		3.64	6.84	6.58	6.37	0.09	0.23
DTPA- Mn	mg kg^{-1}	1.71	3.6	3.44	3.21	0.05	0.12
DTPA- Cu		0.66	1.22	1.17	1.18	0.02	0.04

*Sub plot treatments and interactions were not significant

Table 2. Effect of amendments and zinc sulphate on DTPA-Zn content of soil at post harvest stage (mg kg^{-1})

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean
M_1	0.35	0.37	0.41	0.48	0.36	0.42	0.47	0.41
M_2	0.73	0.89	1.26	1.39	0.86	1.25	1.40	1.11
M_3	0.70	0.85	1.18	1.30	0.89	1.16	1.26	1.05
M_4	0.68	0.81	1.10	1.26	0.80	0.98	1.08	0.96
Mean	0.62	0.73	0.99	1.11	0.73	0.95	1.05	0.88

	M		S		M × S		S × M	
SE d	0.01		0.02		0.04		0.04	
CD (0.05)	0.04		0.04		0.09		0.09	

Table 3. Effect of amendments and zinc sulphate on NPK (kg ha^{-1}) and micronutrients uptake (g ha^{-1}) at harvest stage of rice.

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Mean
N uptake								
M_1	36.9	40.6	45.5	51.0	44.6	51.8	56.0	46.6
M_2	81.4	87.5	90.8	96.2	93.0	97.9	101.5	92.6
M_3	73.0	80.5	84.1	87.3	84.6	92.7	92.5	84.9
M_4	70.7	76.5	81.6	86.3	82.3	88.4	88.6	82.1
Mean	65.5	71.3	75.5	80.2	76.1	82.7	84.7	76.6
P uptake								
M_1	2.99	3.91	4.30	4.36	3.96	4.81	4.81	4.16
M_2	7.58	9.28	8.51	8.21	9.08	9.76	9.91	8.90
M_3	6.28	7.86	8.85	7.82	8.38	8.94	8.28	8.06
M_4	6.11	8.12	8.23	7.92	7.52	6.81	7.52	7.46
Mean	5.74	7.30	7.47	7.08	7.24	7.58	7.63	7.15
K uptake								
M_1	31.2	36.1	39.3	41.8	37.7	43.6	46.9	39.5
M_2	69.4	74.9	80.5	85.5	80.4	85.8	88.5	80.7
M_3	62.8	67.4	72.6	74.6	73.1	79.2	78.4	72.6
M_4	60.1	66.6	71.1	73.1	71.1	75.6	77.1	70.7
Mean	55.9	61.2	65.9	68.8	65.6	71.0	72.7	65.9
Zn uptake								
M_1	95.0	118	142	163	145	178	207	150
M_2	246	305	341	384	360	415	433	355
M_3	218	269	301	333	325	372	380	314
M_4	208	255	299	334	313	393	367	310
Mean	192	237	271	303	286	340	347	282
Fe uptake								

M_1	207	233	250	278	251	290	312	260
M_2	505	541	569	589	561	599	623	569
M_3	450	496	524	529	516	554	566	519
M_4	436	472	501	527	498	530	547	502
Mean	400	436	461	481	456	493	512	463
Cu uptake								
M_1	25.2	27.6	31.5	34.0	31.3	34.7	37.4	31.7
M_2	60.1	63.4	66.8	70.6	66.6	72.3	73.2	67.6
M_3	54.5	58.3	60.3	63.2	61.9	65.9	66.8	61.6
M_4	52.2	55.1	60.1	62.8	58.9	63.9	64.4	59.6
Mean	48.0	51.1	54.7	57.6	54.6	59.2	60.5	55.1
Mn uptake								
M_1	224	251	274	303	280	312	333	283
M_2	516	561	587	616	587	621	637	589
M_3	461	507	528	544	488	563	576	524
M_4	442	471	509	532	504	540	545	506
Mean	411	448	475	499	465	509	523	475

	M	S	M×S	S×M
N uptake				
SE d	1.25	1.43	2.95	2.88
CD (0.05)	3.06	2.90	6.14	5.79
P uptake				
SE d	0.10	0.12	0.24	0.24
CD (0.05)	0.25	0.24	0.52	0.47
K uptake				
SE d	1.07	1.23	2.54	2.48
CD (0.05)	2.64	2.50	5.28	4.98
Zn uptake				
SE d	4.4	4.9	10.3	10.1
CD (0.05)	11	10	22	20
Fe uptake				
SE d	6.77	7.75	16.1	15.7
CD (0.05)	16.7	15.8	33.4	31.5
Cu uptake				
SE d	0.83	0.95	1.96	1.92
CD (0.05)	2.03	1.94	4.09	3.85
Mn uptake				
SE d	7.72	8.84	18.3	17.9
CD (0.05)	19	18	38	36

Table 4. Effect of amendments and zinc sulphate on yield parameters (kg ha^{-1})of rice

M / S	**Levels of zinc sulphate (%)**				**Levels of zinc sulphate (%) + Foliar Spray**			**Mean**
	0	**50**	**100**	**150**	**50**	**100**	**150**	
Grain yield								
Control	2300	2550	2800	3052	2800	3082	3340	2846
Gypsum+ GM	4900	5200	5520	5700	5450	5860	5950	5511
GLM	4360	4680	4960	5100	4990	5320	5391	4972
Press mud	4280	4590	4900	5120	4900	5250	5290	4904
Mean	3960	4255	4545	4743	4535	4878	4993	4558
Straw yield								
Control	2714	3009	3304	3632	3304	3698	4012	3382
Gypsum+ GM	5831	6188	6545	6840	6486	6973	7081	6563
GLM	5232	5616	5902	6018	5988	6384	6372	5930
Press mud	5093	5416	5880	6093	5782	6195	6266	5818
Mean	4718	5057	5408	5646	5390	5813	5933	5423

	M	S	M x S	S x M
Grain yield				
SEd	74.1	84.8	176	171
CD(0.05)	182	173	365	344
Straw yield				
SE d	88.2	101	209	204
CD (0.05)	217	206	435	410