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RESEARCH ARTICLE

Influence of Soil Application of Zinc Sulphate along with Foliar Spray on Growth and Yield of Rice in Sodic Soil under Different Amendments

R. Vinothini* and M. Baskar
Department of Soil Science and Agricultural Chemistry
Anbil Dharmalingam Agricultural College and Research Institute
Tamil Nadu Agricultural University, Trichy.

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Abstract

Field experiment was conducted in sodic soil using rice (CO 52) as a test crop with various amendments *viz.,* gypsum+ green manure, green leaf manure and press mud as main-plot treatments and 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 as sub-plot treatments. The amendments application significantly reduced the pH, ESP and slight increase in the EC of the post harvest soil. The growth and yield parameters also showed a significant response on reclamation and $ZnSO_4$ application. The DTPA -Zn content of soil and Zn uptake of plant at various stages were significantly enhanced due to soil 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. However, the gypsum +GM exhibited its superiority over others. Hence, it is recommended 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. $ZnSO_4$ 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 recommended for un-reclaimed sodic soils.

Keywords: *Gypsum +GM, GLM, Press mud, Sodic soil, Rice crop, Zinc sulphate.*

Introduction

Currently more than 20 per cent of the world's irrigated land is salt affected. Of that about 60 per cent are sodic soils. Sodic soil contains high pH of more than 8.5, ESP of 15 or more and EC less than 4.0 dS m^{-1} (Siyal *et al*., 2002) thereby adversely affecting the transformation and availability of several plant nutrient elements. Micronutrient cations get precipitated as insoluble hydroxides or oxides in sodic soils particularly Zn. Sodic soils can be reclaimed by different amendments *viz*., gypsum, GLM, GM, press mud etc to make these nutrients available to plants. Supply and availability of nutrients will vary with different amendments. Although rice is moderately resistant to soil sodicity, it is sensitive for Zn deficiency.Hence this study was undertaken to investigate the influence of amendments and zinc sulphate application on soil properties and crop yield.

Material and Methods

Field experiment was laid out in split plot design with rice (var. CO 52) as a test crop. The soil of the experimental site belongs to Madukkur series, clay loam in texture, highly sodic (pH 9.98), low in organic carbon (0.46 %), low in available nitrogen (221 kgha^{-1}), medium in available phosphorus (11.2 kg ha^{-1}) and potassium (126 kg ha^{-1}) having ESP 29.6 % and EC 0.35 dS m^{-1}. 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 (6.8 t ha^{-1}) + GM @ 6.25 t ha^{-1}, GLM @ 12.5 t ha^{-1} and press mud @ 10 t ha^{-1} 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. Different levels of zinc sulphate *viz.,* 50, 100 and 150 per cent 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 were imposed as sub-plot treatments. Each treatment was super imposed

*Corresponding author's email: vinosiva2295@gmail.com

over recommended levels of NPK fertilizers (150:50:50 N, P_2O_5 and K_2O kg ha^{-1}) respectively. The growth and yield attributes of rice were recorded. Soil samples were analysed for pH, EC, ESP and available zinc contents. Plant samples were also analysed for Zn content and the Zn uptake was calculated for different stages.

Results and Discussion

Soil pH

Application of amendments resulted in highly significant decrease in soil pH (Table 1). The pH of the soil ranged from 9.95 to 8.34. Maximum reduction in soil pH was recorded in gypsum+ GM applied plots (8.45). The reduction in pH on application of gypsum+ GM was attributed to the displacement of exchangeable Na by the calcium ions of gypsum, which may get leached out due to the drainage provided. The addition of GM after gypsum leads to further reduction in pH by producing organic acids during decomposition, which may solubilize 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.

Table 1. Effect of amendments and zinc sulphate on pH, EC and ESP of post-harvest soil

	Control	Gypsum+ GM	GLM	Press mud	S Ed	CD(0.05)
pH	9.95	8.45	8.95	9.13	0.10	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

* Effect of zinc sulphate was non-significant.

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

M / S	Levels of $ZnSO_4$ (%)				Levels of $ZnSO_4$ (%) + Foliar Spray			Mean
	0	50	100	150	50+ FS	100 + FS	150 + FS	
AT								
Control	0.37	0.43	0.48	0.56	0.42	0.49	0.58	0.48
Gypsum+GM	0.81	0.96	1.46	1.59	0.97	1.45	1.56	1.26
GLM	0.76	0.90	1.40	1.51	0.91	1.40	1.52	1.20
Pressmud	0.72	0.88	1.38	1.46	0.87	1.39	1.47	1.17
Mean	0.67	0.79	1.18	1.28	0.79	1.18	1.28	1.03
FS								
Control	0.36	0.40	0.45	0.51	0.37	0.40	0.50	0.43
Gypsum+GM	0.76	0.91	1.36	1.46	0.92	1.35	1.45	1.17
GLM	0.74	0.86	1.21	1.42	0.88	1.20	1.43	1.11
Pressmud	0.70	0.84	1.20	1.36	0.82	1.18	1.37	1.07
Mean	0.64	0.75	1.06	1.19	0.75	1.03	1.19	0.94
HS								
Control	0.35	0.37	0.41	0.48	0.36	0.42	0.47	0.41
Gypsum+GM	0.73	0.89	1.26	1.39	0.86	1.25	1.40	1.11
GLM	0.70	0.85	1.18	1.30	0.89	1.16	1.26	1.05
Pressmud	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 x S	S x M
AT				
SE d	0.02	0.03	0.05	0.05
CD(0.05)	0.04	0.05	0.1	0.1
FS				
SE d	0.02	0.02	0.04	0.05
CD(0.05)	0.04	0.05	0.1	0.1
HS				
SE d	0.01	0.02	0.04	0.04
CD(0.05)	0.04	0.04	0.09	0.09

* AT- Active tillering Stage; FS- Flowering Stage; HS- Harvest Stage

Soil EC

In spite of higher amount of gypsum application, only slight increase in EC was observed, which might be due to very low solubility of gypsum (2.8 g. L^{-1}). Decomposition of organic materials released organic acids or acid forming compounds that could react with the sparingly soluble salts already present in the soil could have either converted them in to soluble salts or increased their solubility resulting in slight increase in EC.

Exchangeable sodium percentage

Amendments application decreased the ESP with desirable reduction being noticed in gypsum+ GM treated plots followed by GLM and press mud. 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 Na by Capresent in gypsum. The application of organic amendments also reduced the soil ESP from initial level, which may be due to the increase in exchangeable Ca and Mg ions resulting insolubilisation of the native insoluble Ca ($CaCO_3$) during decomposition of organic matter and also due to supply of nutrients like K, Ca and Mg from the GLM and press mud.

Table 3. Effect of amendments and zinc sulphate on growth parameters of rice

Treatments	Plant height (cm)	Productive tillers (Nos/ hill)	Panicle length (cm)	Filled grain percentage	Grain test weight (g)
Main plot					
Control	92.1	16.4	22.6	80	20.3
Gypsum+ GM	100.2	27.0	25.6	95	21.9
GLM	98.1	25.0	24.5	92	21.7
Pressmud	97.3	24.4	23.8	89	21.7
Mean	1.5	0.38	0.39	1.45	0.31
Sub plot (%)					
0	93.5	19.0	23.6	86	21.1
50	95.0	21.3	23.7	88	21.3
100	97.1	23.3	23.8	89	21.4
150	98.1	25.5	24.1	91	21.6
50 +FS	97.2	22.8	24.4	87	21.2
100 +FS	98.6	24.3	24.7	90	21.8
150 +FS	99.0	26.5	24.9	92	21.7
S Ed	1.72	0.43	0.45	1.67	0.36
CD(0.05)	3.45	0.88	0.90	3.35	NS

* Interaction effect of amendments and $ZnSO_4$was not significant.

	M	S	M x S	S x M
DMP at AT				
SE d	25.9	29.8	61.6	60.1
CD (0.05)	63.9	60.7	128	121
DMP at FS				
SE d	84.9	97.2	201	196
CD (0.05)	209	198	419	394
Grain yield				
SE d	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

DTPA-Zn content

DTPA-Zn significantly increased due to both amendments and zinc sulphate application at all the growth stages of rice crop (Table 2). Among the amendments, gypsum+ GM treated plots showed the highest DTPA-Zn content followed by GLM and press mud. Application of gypsum+ GM considerably decreased the soil pH. A negative correlation was observed between ESP (- 0.715) and pH (-0.953*) with DTPA-Zn. Decrease the Zn precipitation as $Zn(OH)_2$and hence, may increased. Zn is known to form relatively stable chelates with organic ligands, which their susceptibility to adsorption and fixation or precipitation. Though GLM and press mud applied treatments slightly reduced the ESP, these organic amendments considerably increased the DTPA Zn content of soil. The direct contribution of Zn from organic amendments as well as solubilization and chelation effect of organic materials might have enhanced the DTPA Zn content of soil. 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 4. Effect of amendments and zinc sulphate on yield parameters (kg ha^{-1}) of rice

M / S	Levels of $ZnSO_4$ (%)				Levels of $ZnSO_4$ (%)+ Foliar Spray			Mean
DMP at AT								
Control	675	735	784	790	719	779	792	753
Gypsum+ GM	1971	2415	2401	2513	2399	2506	2437	2377
GLM	1106	1520	2109	2107	1557	1783	2213	1771
Pressmud	983	1112	1510	2117	1210	1515	1996	1492
Mean	1184	1446	1701	1882	1471	1646	1860	1598
Control	675	735	784	790	719	779	792	753
DMP at FS								
Control	2575	2795	3256	3600	3310	3650	3757	3278
Gypsum+ GM	5250	5896	6726	6921	6541	7020	7304	6523
GLM	4873	5023	5564	5794	5720	6024	6330	5618
Pressmud	4760	4951	5416	5810	5324	5992	6013	5467
Mean	4365	4666	5241	5531	5224	5672	5851	5221
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
Pressmud	4280	4590	4900	5120	4900	5250	5290	4904
Mean	3960	4255	4545	4743	4535	4878	4993	4558
Control	2300	2550	2800	3052	2800	3082	3340	2846
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
Pressmud	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
DMP at AT				
SE d	25.9	29.8	61.6	60.1
CD (0.05)	63.9	60.7	128	121
DMP at FS				
SE d	84.9	97.2	201	196
CD (0.05)	209	198	419	394
Grain yield				
SE d	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

Growth parameters

The application of amendments to sodic soil along with $ZnSO_4$application significantly increased all the growth components of rice *viz.,* dry matter production at different stages plant height and yield components *viz.,* productive tillers, filled grains per panicle and ultimately the grain and straw yield (Table 3). The DMP at active tillering and panicle initiation varied between 675 to 2437 kg $ha^{-1}$and 2575 to 7304 kg ha^{-1}.The plant height varied from 88.8 to 102 cm. The productive tillers ranged from 13 to 30 no.$hill^{-1}$. Panicle length varied from 22 to 26.3 cm. Among the amendments, the maximum DMP (2377 kg ha^{-1}at AT and 7304 kg ha^{-1}at FS), plant height (100.2 cm), length of panicle (25.6 cm), productive tillers (27 no.$hill^{-1}$) and filled grain percentage (95) were recorded in the treatment gypsum+ GM followed by GLM and

Table 5. Effect of amendments and zinc sulphate on Zn uptake (g kg^{-1}) of rice at different growth stage

M /S	Levels of $ZnSO_4$ (%)				Levels of $ZnSO_4$ (%)+ Foliar spray			Mean
	0	50	100	150	50 + FS	100 + FS	150 + FS	
AT								
Control	15.5	19.5	23.5	24.6	19.0	23.4	24.6	21.5
Gypsum+GM	57.1	84.0	89.0	98.7	82.29	92.7	95.0	85.6
GLM	32.0	50.1	76.9	81.75	52.94	66.2	85.2	63.6
Pressmud	28.4	36.7	54.5	80.7	41.1	55.8	76.4	53.4
Mean	33.3	47.6	61.0	71.5	48.8	59.5	70.3	56.0
FS								
Control	61	82	100	115	95	121	130	101
Gypsum+GM	167	212	240	264	240	279	283	241
GLM	150	183	214	230	216	248	249	213
Pressmud	197	174	212	230	206	235	244	214
Mean	144	163	191	210	189	221	227	192
HS								
Control	95.0	118	142	163	145	178	207	150
Gypsum+GM	246	305	341	384	360	415	433	355
GLM	218	269	301	333	325	372	380	314
Pressmud	208	255	299	334	313	393	367	310
Mean	192	237	271	303	286	340	347	282

	M	S	M x S	S x M
AT				
SE d	0.82	0.94	1.94	1.89
CD (0.05)	2.02	1.91	4.04	3.81
FS				
SE d	3.12	3.57	7.38	7.2
	7.68	7.28	15.4	14.5
CD (0.05)				
HS				
SE d	4.4	4.9	10.3	10.1
CD (0.05)	11	10	22	20

* AT- Active tillering Stage; FS- Flowering Stage; HS- Harvest Stagepress mud. Significant increase in plant height was recorded due to application of different levels of zinc sulphate. The maximum DMP (1860 kg ha^{-1}at AT and 5851 kg ha^{-1}at FS), plant height (99 cm), productive tillers (26.5 cm) and panicle length (24.9 cm) was observed in the treatment receiving 150% RD of $ZnSO_4$@ basal + foliar spray and minimum was observed in the control. The effect of zinc sulphate application on the filled grain percentage was also found to be significant. The highest filled grain percentage (92) was recorded in the plots treated with 150% RD of $ZnSO_4$@ basal + foliar spray and lowest (86) in the control.

Grain and straw yield

Among the amendments, the highest yield (5511 kg ha^{-1}) was obtained in the gypsum+ GM applied treatments owing to creation of favourable micro climate, increasing the availability of essential nutrients, which in turn might have increased the yield. Next to gypsum+ GM, higher yield was noted in GLM and press mud applied treatment over the control (Table 4). The organic amendmentsnot only reclaimed the sodic soil, but also enhanced soil carbon content and biological properties. The incorporation of organic materials might have resulted in the formation organic chelates of higher stability, direct supplement of nutrients by the plant materials on decomposition and create a favourable effect for plant growth, may increase the yield. Naik and Das (2007) reported that soil application of zinc as $ZnSO_4$hadincreased the rice filled grain percentage, 1000-grain weight, number of panicles, grain and straw yield. Among the zinc sulphate application 100 % zinc sulphate as basal+ foliar spary was superior over 150 % RD$ZnSO_4$as basal application. In the treatments without any amendments (control- M_1), 100 % RD+FS (S_6) and 150 % RD+FS (S_7) were significantly different from each other. However in amendments applied treatments (M_2, M_3 and M_4) S_6 and S_7 are comparable with each other. Higher yield due to zinc fertilization is attributed to its involvement in many metallic enzyme system, regulatory functions (Sachdev1988), enhanced synthesis of carbohydrates and their transport to the site of grain production (PeddaBabu 2007). 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 (Kumawat and Yadav, 2013). The combined effect of amendments and Zinc sulphate on grain and straw yield of rice was also found to be significant. The treatments gypsum + GM + $ZnSO_4$ @ 150 % RD as basal + foliar spray (M_2S_7) recorded the highest yield, which was on par with gypsum + GM + $ZnSO_4$ @ 100 % RD as basal + foliar spray (M_2S_6).

Zinc uptake

Amendments application significantly enhanced the uptake of Zn. The highest zinc uptake was observed in gypsum + GM treated plots followed by organic amendments (Table 5). Application of amendments decreased the pH, which in turn might have decreased the Zn precipitation as $Zn(OH)_2$ and hence increasing the Zn uptake. 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. Fageria *et al*. (2011) and Ingle *et al.*(1997) reported that Zn uptake was increased with increased levels of zinc mainly due to the increase in dry matter production, yield and zinc concentration.

Conclusion

The field experiment concludes that the application of gypsum @ 50% GR + green manure @ 6.25 t ha^{-1} or press mud @ 10 t ha^{-1} or GLM 12.5 t ha^{-1} can be effectively used as an amendment for the reclamation of sodic soil. However, the gypsum+ GM exhibited its superiority over others. After sodic soil reclamation zinc sulphate application helped to increase the grain yield and zinc content of rice.While considering the quantity of $ZnSO_4$applied and grain yield of rice crop, it is recommended 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 was found to be the best for getting higher yield of rice in sodic soils. $ZnSO_4$ 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 recommended for un reclaimed sodic soil.

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