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RESEARCH ARTICLE

Effect of Amendments, Zinc Solubilizing Bacteria and Zinc Sulphate on Physicochemical Properties and Zinc Availability in Sodic Soil

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ABSTRACT

Excess sodium levels of sodic soil can adversely affect soil structure and disturb the availability of nutrients for plant growth. Micronutrients particularly zinc exhibit low levels of solubility in sodic soils which may results in Zn deficiency in rice. Different attempts have been made to increase the solubility of zinc in sodic soils. Hence an incubation study was conducted to understand the availability of soil Zn due to the application of amendments, zinc sulfate and zinc solubilizing bacteria. The soil samples were collected at 15, 30 and 45 days after incubation. The results revealed that the application of amendments significantly reduced the pH, ESP and increased the OC, EC of incubated soil. The exchangeable cations viz., Ca, Mg, K increased and exchangeable Na content was decreased by the application of amendments. DTPA-Zn increased at 15 days after incubation (DAI) in ZnSO4 alone applied treatments and it was drastically reduced to the initial level with the advancement of the incubation period. However, in amendments and zinc sulfate combinedly applied treatments, the DTPA- Zn level increased at 15 DAI and almost maintained throughout the incubation period. Increased DTPA- Zn was observed in zinc solubilizing bacteria alone applied treatments. The application of amendments and ZnSO4 significantly influenced the distribution of different fractions of Zn in soil. They found in order of a WSEX-Zn < OM-Zn <AFeOX-Zn <CFeOX-Zn <MnOX-Zn < RES-Zn fractions. The results of the experiment showed that the application of amendments, zinc solubilizing bacteria with zinc sulfate are required to enhance the physicochemical properties and zinc availability in sodic soil

Keywords*:Gypsum +GM, GLM, Press mud, Zinc solubilizing bacteria, Zn fractions, DTPA- Zn.*

INTRODUCTION

Sodic soils are showing poor physical and chemical properties, which impede water infiltration, water availability and ultimately affect the plant growth.In sodic soils, due to high pH, Zn gets precipitated as $Zn(OH)_2$ and hence it is unavailable to crops.Several steps have been being taken to increase the availability of Zn in sodic soils. In this way, the current experiment was conducted to study the influence of amendments, zinc solubilizing bacteria and zinc sulfate application on physico chemical properties and zinc availability in sodic soil.

MATERIALS AND METHODS

The soil used for the incubation experiment belongs to clay loam in texture. Initial soil was highly sodic (pH 10.4), low in EC (0.4 dS m^{-1}) having ESP of 33 percent. The DTPA- Zn, Fe, Mn, Cu content of the initial soil was 0.39, 3.20, 1.65, 0.68 mg kg^{-1} respectively. The initial soil contained 6.96, 5.57, 6.22, and 0.10cmol (p+) $kg^{-1}$of exchangeable Ca, Mg, Na and K respectively. The Zn fractions viz., water-soluble + exchangeable Zn (WSEX-Zn), organically bound Zn (OM-Zn), manganese oxide bound Zn (MnOX-Zn), amorphous sesquioxide bound Zn (AFeOX-Zn), crystalline sesquioxide bound Zn (CFeOX-Zn), residual Zn (RES-Zn) and total-Zn content of the initial soil was 0.32, 0.81, 0.96, 1.82, 2.19, 227 and 236 mg kg^{-1} respectively. The treatments includes T_1-control, T_2-gypsum @ 50 % GR + green manure @ 6.25 t ha^{-1}, T_3-green leaf manure @ 12.5 t ha^{-1}, T_4-press mud @ 10 t ha^{-1}, T_5-Zinc solubilizing bacteria @ 2 kg ha^{-1}, T_6-$ZnSO_4$ @ 25 kg ha^{-1}, T_7- T_2 + T_6, T_8- T_3 + T_6, T_9- T_4 + $T_6$and T_{10} -T_5 + T_6. The soil samples were collected from each treatment at 15, 30, 45 DAI and analyzed for available zinc content. The soil samples collected at 45 DAI were analyzed for physicochemical properties and Zn fractions.

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RESULTS AND DISCUSSION

Physicochemical properties of soil at 45 DAI

The application of amendments resulted ina significant decrease in soil pH (Table 1) and it ranged from 10.3 to 8.56. The reduction in soil pH on the use of gypsum with GM was attributed to the displacement of exchangeable Na by the calcium ions of gypsum and subsequent formation of sodium sulfate,which get leached out during the leaching process. The GM application after gypsum leads to a further reduction in pH by producing organic acids during decomposition leading to solubilization of native Ca. Application of organic amendments viz., GLM @ 12.5 t ha^{-1} and press mud @ 10 t ha^{-1} had an ameliorative effect and reduced the soil pH due to the liberation of CO_2 and organic acids during decomposition process and produces hydrogen ions which solubilize the $CaCO_3$ and neutralize the sodicity.

Table 1 .Effect of amendments, zinc solubilizing bacteria and zinc sulphate application on physicochemical properties of soil at 45 DAI

Treatments	pH	EC	OC	ESP	EX. Ca	Ex. Mg	Ex. Na	Ex. K
Unit	-	**dS m^{-1}**	**%**	**%**				**cmol (p+) kg $^{-1}$**
T_1	10.3	0.41	0.43	33.0	6.95	5.58	6.21	0.10
T_2	8.58	0.48	0.48	17.0	9.89	5.60	3.21	0.10
T_3	9.16	0.43	0.51	27.7	7.89	5.65	5.21	0.11
T_4	9.23	0.45	0.54	28.9	7.96	5.68	5.45	0.12
T_5	10.0	0.40	0.42	32.9	6.93	5.56	6.20	0.10
T_6	10.1	0.41	0.43	33.0	6.94	5.56	6.22	0.10
T_7	8.56	0.50	0.49	17.2	9.86	5.62	3.24	0.10
T_8	9.10	0.44	0.52	27.6	7.9	5.66	5.20	0.10
T_9	9.24	0.44	0.55	28.9	7.97	5.66	5.44	0.10
T_{10}	10.1	0.41	0.42	32.9	6.96	5.57	6.20	0.10
SE.d	0.15	0.01	0.01	0.43	0.10	0.08	0.09	0.0002
CD(0.05)	0.32	0.02	0.02	0.90	0.21	NS	0.19	NS

The highest reduction of pH was observed in gypsum+ GM followed by GLM and press mud. There was a slight increase in EC in the organic amendments applied plots and gypsum+ GM plots due to an increase in the amount of soluble salts. The highest increase in 0.5 dS m^{-1} was observed with the treatment receiving gypsum + GM + $ZnSO_4$ (T_7). There was no significant change in soil EC and pH due to the application of ZSB.

Table 2.Effect of amendments, zinc solubilizing bacteria and zinc sulphate application on Zn fractions of soil at 45 DAI

Treatments	WSEX-Zn	OM-Zn	MnOX-Zn	AFeOX-Zn	CFeOX-Zn	Residual Zn	Total Zn
T_1	0.28	0.73	3.20	1.93	2.13	227	235
T_2	0.35	1.00	3.50	1.94	2.19	229	238
T_3	0.35	1.02	3.55	2.00	2.18	229	238
T_4	0.35	0.96	3.52	2.01	2.16	230	239
T_5	0.40	1.06	3.31	2.02	2.18	227	236
T_6	0.42	0.98	3.51	2.03	2.22	231	240
T_7	0.73	1.48	3.58	2.22	2.33	231	241
T_8	0.72	1.39	3.55	2.24	2.30	231	241
T_9	0.73	1.36	3.56	2.21	2.31	231	240
T_{10}	0.62	1.28	3.55	2.11	2.28	231	241
S.E d	0.05	0.01	0.05	0.03	0.03	3	3.4
CD (0.05)	0.01	0.03	0.10	0.08	0.07	NS	NS

The application of amendments significantly increased the OC content of the soil. The highest OC content was recorded in the press mud applied plots (0.55%), followed by GLM (0.52 %) and gypsum+ GM (0.49 %) applied plots. Bokhtiar and Sakurai, (2005) also reported that the addition of FYM (or) press mud @ 15 t ha^{-1} and green manure (*Crotalaria juncea)* slightlyincreased the organic carbon status of the soil.Application of different amendments decreased the ESP with the desirable reduction was noticed in gypsum+ GM treated plots followed by GLM and press mud application over the control. The reduction in ESP was attributed to the replacement of exchangeable Naby Ca of the gypsum. The application of organic amendments also reduced the ESP from an initial level of 33 percent which may be due to increasing in exchangeable Ca and Mg ions due to solubilization by the organic acids during organic matter decomposition and supply of nutrients like K, Ca and Mg from the GLM and press mud.

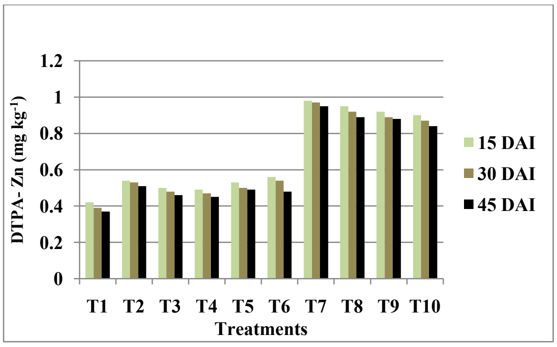

Figure 1.Effect of amendments, zinc solubilizing bacteria and zinc sulphate on available zinc content (mg kg^{-1}) of soil at different incubation periods

An increased exchangeable calcium content of 2.94, 0.94 and 1.01cmol(p+) kg^{-1}was registered over control due to the application of gypsum+ GM (T_2), GLM (T_3) and press mud (T_4) respectively. The highest Caregistered in the gypsum + GM applied treatments was mainly due to the release of Ca ions from gypsum ($CaSO_4.2H_2O$) and solubilization of native calcium on the decomposition of green manure incorporated in the fields.

Application of organic amendments also considerably increased the exchangeable Ca content. This might be due to the positive effect of organic substances on improving sodic soil. The release of CO_2 during the decomposition process decreased the precipitation of $Ca^{2+}$and CO_3^{2-} ions in $CaCO_3$form (Sekhon and Bajwa, 1993). On the other hand, the organic acids released the Ca from $CaCO_3$.

The exchangeable magnesium content showed an insignificant increase due to the application of amendments. The application of amendments showed a significant decline in the exchangeable Na content of soil. The lowest exchangeable Na content of 3.21 cmol(p+)kg^{-1} was observed in the treatment receiving gypsum+ GM followed by GLM and press mud.

While in gypsum+ GM applied plots, the 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. The present findings are in agreement with theearlier work of Moustafa (2005). Among the amendments, press mud (T_4) showed the highest exchangeable K content of 0.12 cmol(p+)kg^{-1}. The ZSB and $ZnSO_4$ did not show any variation in the physicochemical properties of soil.

DTPA-Zn

Available zinc (DTPA-Zn) is the important fraction thatwill be readily available after the application of Zn fertilizer to the soil. Application of $ZnSO_4$ significantly increased the available Zn at 15 DAI, thereafter it got declined at 45 DAI(Figure 1). An increase in available zinc at 15 DAI might be due to the high solubility of the added zinc source.Low levels of available Zn in control may be attributed to low native Zn, slow solubility of Zn from soil minerals, or strong adsorption of Zn on soil surfaces (Rieuwerts *et al*. 2006).

Thetreatments which had received $ZnSO_4$ alone released the available Zn immediately and converted to residual fraction to a large extent. The Zn has been transferred from labile to non labile pool with incubation time. This may be due to the precipitation of Zn as carbonate and bicarbonate. Although $ZnSO_4$ (25 kg ha^{-1}) was applied to all the treatments (T_6, T_7, T_8, T_9 and T_{10}) uniformly, the increase in available Zn was low in $ZnSO_4$ alone applied the treatment. Takkar and Sindhu, (1979) reported that Zn concentration in the soil solution used to be regulated by both $Zn(OH)_2$-Zn^{2+} and $ZnCO_3$-Zn^{2+} systems, during the initial periods and thereafter by $ZnCO_3$-Zn^{2+} system because of the buffering effect of the soil carbonate equilibrium. Similar findings were also observed by Mandal *et al*.(1992) who concluded that precipitation of Zn as hydroxide, carbonate and sulphide and it's adsorption on the surface of hydrous oxides of iron would be partly responsible for the decrease with time in sodic soils.

However, $ZnSO_4$ with amendments applied treatments showed a small decrease in available Zn during the incubation period. The application of amendments decreased the soil pH. The decrease in pH decreases the Zn precipitation as $Zn(OH)_2$ and hence the availability got increased.For every unit decrease in pH there may be a 100-fold increase in Zn concentration in soil solution (Lindsay, 1972). The incorporation of organic amendments might have formed organic chelates of higher stability. An increase in DTPA-Zn was observed in zinc solubilizing bacteria alone applied treatments. In the treatments without the $ZnSO_4$ application, the efficiency of zinc solubilizing bacteria was next toT_2 (gypsum + GM) in enhancing the zinc availability. The treatment gypsum + GM @ 6.25t ha^{-1}+ $ZnSO_4$ @ 25 kg ha^{-1}(T_7) registered the highest DTPA-Zn content throughout incubation period.

Zn fractions

Understanding the distribution of zinc fractions in soils (Table 2) is vital for the effective management of the Zn fertilizer resources. It is evident from the data that the distribution of different fractions of Zn in soil was significantly influenced by the application of amendments and $ZnSO_4$, found in order as WSEX-Zn < OM-Zn <AFeOX-Zn <CFeOX-Zn <MnOX-Zn < RES-Zn fractions.

Water-soluble and exchangeable Zn were the weakly-sorbed Zn species, particularly those retained on the soil surface by relatively weak electrostatic interactions and those that can be released by ion-exchange processes. The water-soluble + exchangeable Zn was the significant fraction and it would have directly contributed to the labile pool. The per cent contribution of WSEX-Zn was 0.14 to the total Zn. WSEX-Zn in $ZnSO_4$ alone applied treatments were maintained at the initial level in spite of $ZnSO_4$ addition. Since the soil is alkaline in nature, the WSEX-Zn might have been precipitated as Zn hydroxide and carbonate (residual Zn).

However in amendments and zinc sulfate combination applied treatments, the WSEX-Zn level was increased significantly. It may be attributed to the retention of Zn on organic complex and it is in conformity with the earlier reports (Hemanth Kumar and Basavaraj, 2008). It was interesting to note that the zinc solubilizing bacteria applied treatments (without zinc sulfate application T_5) the WSEX-Zn was slightly increased at 45 DAI. This must be due to the solubilizing effect of the zinc solubilizing bacteria on native zinc. However, in zinc sulfate applied treatments the zinc solubilizing bacteria have little effect on maintaining the Zn availability.

The organically bound Zn is weakly adsorbed on soil surfaces or bound by the organic matter and is thought to be potentially available. The per cent contribution of OM-Zn was only 0.34 percent to the total Zn. Application of amendments as well as zinc sulfate significantly increased the organically bound Zn content of the soil.

Higher concentrations MnOX-Zn fractions denote that their importance as the storage fractions for soil Zn, although their solubility will determine how available they are for plant uptake (Ma and Rao, 1997). The per cent contribution of MnOX-Zn to total Zn was 1.25 per cent.

The amorphous sesquioxide bound Zn (AFeOX-Zn) indicated that the ability of amorphous sesquioxide to adsorb Zn because of their high specific surface area. The per cent contribution of AFeOX-Zn to total Zn was 0.77 percent. The contribution of AFeOX-Znto available Zn is the process of mineralization (Veeranagappa *et al*., 2010). AFeOX-Zn fraction of Zn was increased with the application of amendments and $ZnSO_4$.

Crystalline sesquioxide bound Zn fraction was dominant as compared to WSEX-Zn, AFeOX-Zn and OM-Zn fractions, which might be due to the predominance of crystalline iron oxide content in the soil. The contribution of this fraction to total Zn was 0.93 per cent. CFeOX-Zn slightly increased with the application of amendments and $ZnSO_4$.

Residual Zn fraction is considered as the primary form of the native Zn and associated with soil mineral fractions. The per cent contribution of this fraction from total Zn was found to the higher than other fractions (96.2 %). The greater percentage of Zn in the residual fraction likely indicated its greater tendency to become unavailable in the soil. This is because the residual fraction represented metals that are primarily embedded in the sedimentary matrix and may not be available for remobilization except under very drastic conditions (Ma and Rao, 1997). Residual Zn was not significantly influenced by the Zn application. Total Zn is the native soil Zn which includes the available and non available pool. The application of $ZnSO_4$ was non significantly influenced the total Zn content of the soil.

CONCLUSION

The present experiment concluded that the application of amendments, zinc solubilizing bacteria with zinc sulfate is required to improve the physicochemical properties and zinc availability in sodic soil.

REFERENCES

Bokhtiar, S. M. and K. Sakurai. 2005. Integrated use of organic manure and chemical fertilizers on growth, yield and quality of sugarcane in high Ganges river flood plain soils of Bangladesh. *Commun. Soil Sci. Plant Analysis.,*36: 1823-1837.

Hemanthkumar, K. and B. Basavaraj. 2008. Zinc transformation in calcarious vertisol of Tungrabhadra command. *Karnataka J. Agric. Sci.,*21 (2): 227-230.

Lindsay, W. L. 1972. Inorganic phase equilibria of micronutrients in soils.*Micronutrients in Agriculture.,* 41-57.

Ma, L. Q. and G. N. Rao. 1997. Chemical fractionation of cadmium, copper, nickel and zinc in contaminated soils. *J. of Envi.Quality.,* **26 (1)**: 259-264.

Mandal, B., Mandal, L. N. and M. H. Ali. 1992. Chemistry of zinc availability in submerged soils in relation to zinc nutrition of rice crop. *Proceedings of the Workshop on Micronutrients.*,Bhubaneshwar, India: 22-23.

Moustafa, F. A. F. 2005. Studies on reclamation of saline sodic soils.Ph.D thesis, *Benha Univ.*, Egypt: 35-60.

Rieuwerts, J. S., Ashmore, M. R., Farago, M. E. and I. Thornton. 2006. The influence of soil characteristics on the extractability of Cd, Pb and Zn in upland and moorland soils. *Science of the total Environment.,***366(2-3)**: 864-875.

Sekhon, B. S. and M. S. Bajwa. 1993. Effect of organic matter and gypsum in controlling soil sodicity in rice-wheat-maize system irrigated with sodic waters.*Agrl. water management.*, **24(1)**:15-25.

Takkar, P.N. and B.S. Sindhu. 1979. Kinetics of zinc transformation in submerged alkaline soils in the rice growing tracts of Punjab. *J. Agric. Sci.,* **9**: 441-447.

Veeranagappa, P., Prakasha, H. C., Basavaraja, M. K. and H. Mohamed Saqeebulla. 2010. Effect of zinc enriched compost on yield and nutrient uptake of rice. *EJBS* **3 (1)**: 23-29.