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Strategies to Increase Nitrogen and Zinc Use Efficiency for Climate Smart Coastal Soil Nutrient Management

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Abstract

India has an 8,129 km long coastline. A vast coastal tract faces a serious problem of soil salinity over an area of 3.1 m ha. Most of the coastal salt-affected soils were deficient in nitrogen (N) and zinc (Zn). N availability in coastal soil was lesser associated with poor mineralization by microbes with an increase in soil salinity. Low organic matter, CEC, and light texture encourage the leaching loss of applied nutrients in these soils. It is generally observed that Zn content in soil decreases with an increase in pH. The uptake of N and Zn by plants in saline soils is also affected by the presence of a high concentration of Cl^{-1} ions. A sustainable strategy to increase nutrient use efficiency in coastal salt-affected soils includes the addition of amendments and balanced use of organic, inorganic, and biological sources of nutrients. Experiments conducted in coastal saline soils which had pH 8.06, EC 2.48 dS/m, and low status of N and Zn, proved the efficacious nature of INM strategy namely 75% NPK + Azospirillum + Phosphobacterium + Zn enriched humic acid @ 20 kg/ha in significantly increasing the availability of Alkaline $KMnO_4$-N, DTPA-Zn and improving the N and Zn use efficiency. Another experiment conducted in coastal sodic soil revealed the usefulness of NPK along with 75% $ZnSO_4$ fortified coir pith/green leaf manure application in increasing Zn use efficiency. A study conducted in coastal sandy on nitrate leaching and its control showed that the application of NPK along with 40 t clay/ha + 20 kg/ha of humic acid was efficient in increasing the NH_4-N and NO_3-N (Nitrate nitrogen) content in soil and improving the N use efficiency.

Keywords

Climate smart nutrient management, Coastal soils, Strategies, Nitrogen, Zinc

Introduction

India has a coastline of 8000 km and Tamil Nadu has 1000 km. Salinity is the unique feature of the coast. High salinity, pH, low organic matter, deficiency, and leaching of nutrients are the major soil constraints that affect the nutrient use efficiency and crop productivity in coastal areas. Most of the coastal salt-affected soils were deficient in N and Zn. N availability in coastal soil was lesser associated with poor mineralization by microbes with the increase in soil salinity. Low organic matter, CEC, and light texture encourage the leaching loss of applied nutrients in these soils. The NO_3-N is soluble and moves readily with soil water becoming a potential source of groundwater pollution. The amount of NO_3-N leached into the groundwater increases with N fertilizer application rates. Rice is the dominant crop cultivated in coastal regions coinciding with the monsoon. The N use efficiency has been estimated to be 30 - 40% [1]. Zn is a key element for plant growth and human health. Zn is relatively mobile in soil and inappropriate application and unfavorable soil conditions lead to leaching loss of Zn and contamination of surface and groundwater. Further, it is generally observed that Zn content in soil decreases with an increase in pH. The uptake of N and Zn by plants in saline soils is also affected by the presence of a high concentration of Cl^{-1} ions. The retention of fertilizer nutrients depends on the clay and organic matter content of the soil. To address all the difficulties of soil applied fertilizers like fixation, immobilization, volatilization, leaching and run-off to reduce all these losses, we should think of an alternate technology such as nanotechnology to precisely detect and deliver correct quantity of nutrients and other inputs required by crops in suitable proportion that promote productivity while ensuring environmental safety.

Materials and Method

The coastal agroecosystem is characterized by saline and sandy soils. The soils show deficiencies of N and Zn associated with many soil-related constraints. Even the nutrients applied are prone to many losses like volatilization, leaching, etc. which results in very low nutrient use efficiency. To increase the nutrient use efficiency of N and Zn, a series of pot and field experiments were carried out. Experimental details and methodologies followed in the present study were furnished here. To evaluate the effect of different treatments on increasing the N use efficiency in coastal saline soil, the following treatments were studied: T1 – 100 % NPK, T2 – 75 % NPK, T3 –50 % NPK, T4 – T2 + Azospirillum + Phosphobacterium + Zn enriched FYM, T5 – T2 + Azospirillum + Phosphobacterium + Zn enriched humic acid, T6 – T3 + Azospirillum + Phosphobacterium + Zn enriched FYM, T7 – T3 + Azospirillum + Phosphobacterium + Zn enriched humic acid. The design followed was a completely randomized design with three replications. The initial pH, EC, and organic C status of soil was 8.06, 2.48 dS/m, organic C 0.36%, and available N 216.2 kg/ha, respectively. Crop rice var ADT 43 was studied. Experiment two was conducted in coastal sodic soil having an initial pH 8.14, EC 2.63 dS/m and available NPK status of 153.2, 8.9, and 186 kg/ha, respectively. The DTPA-Zn availability was 89 mg/kg. The test crop was rice var ADT 38. The treatments evaluated were T1 – Recommended level NPK, T2 – NPK + $ZnSO_4$ + $FeSO_4$ @ 25 kg/ha, T3 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 75% RL, T4 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 100% RL, T5 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 125% RL , T6 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 75% RL, T7 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 100% RL and T8 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 125% RL. A third experiment was conducted under upland conditions to increase the efficiency of Zn. The soil properties were pH 8.07, EC 2.45 dS/m, organic C 0.34%. The available N and Zn contents were low. The crop rice var ADT 43 was studied using CRD with three replications. The treatments were T1 – Recommended level NPK, T2 – NPK + $ZnSO_4$ + $FeSO_4$ @ 25 kg/ha, T3 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 75% RL, T4 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 100% R, T5 – NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 125% RL, T6 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 75% RL, T7 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 100% RL, T8 – NPK + Coir pith fortified $ZnSO_4$ + $FeSO_4$ @ 125%. At harvest soil samples were collected from all the treatments, air dried, sieved through a 2 mm sieve, and analyzed for pH, EC, organic C, NH_4-N, NO_3-N, and DTPA-Zn using the standard procedure of Jackson [2]. Grain and straw samples at harvest stages were collected from each treatment from all the experiments and the content of N and Zn were estimated in the Di-acid extract (H_2SO_4:$HClO_4$ in 4:1 ratio) [2].

Results and Discussion

Experiment I

In the present study, the application of enriched organic manure resulted in decreasing the pH and EC of the soil. Among various treatments, NPK+ Azospirillum + Phophobacterium + Zn enriched humic acid proved significantly superior in reducing the pH (7.47) and EC (1.77 dS/m). The decrease in pH and EC could be attributed to the higher production of CO_2 and organic acid during the decomposition of organic matter. The yield of rice and also Zn use efficiency increased significantly with NPK + biofertilizer + Zn enriched organic manure. Among the INM treatments, a significantly higher grain yield of 75.38 and straw yield of 93.30 g/pot was obtained with NPK + Azospirillum + Phophobacterium + Zn enriched humic acid. This could be due to the combined effect of nutrient supply, synergism, and physical and biological properties of soil [3]. The Zn use efficiency in rice under coastal saline environment also improved due to the above INM treatment. The enriched Zn with humic acid by chelation action prevented harmful reaction of Zn like precipitation and fixation under high pH which resulted in increased availability and Zn use efficiency (Table 1 and table 2).

Experiment II

The application of various fortified organics proved effi-

Table 1: Effect of INM on the physico-chemical properties and Zn availability in soil.

Treatments	pH	EC (sD/m)	Org.C (%)	DTPA-Zn (mg/kg)
T1 – 100% NPK	8.01	2.36	0.41	0.89
T2 – 75% NPK	8.02	2.41	0.37	0.84
T3 – 50% NPK	8.07	2.48	0.35	0.73
T4 – T2 + Azos + Phospho + Znenriched FYM	7.48	1.85	0.57	0.99
T5 – T2 + Azos + Phospho + Znenriched humic acid	7.47	1.77	0.60	1.02
T6 – T3 + Azos + Phospho + Znenriched FYM	7.94	2.10	0.47	0.93
T7 – T3 + Azos + Phospho + Znenriched humic acid	7.87	2.01	0.52	0.95
SEd.	002	0.022	0.013	0.009
CD (p = 0.05)	0.05	0.046	0.028	0.019

Table 2: Effect of INM on the yield and Zn use efficiency of rice.

Treatments	Grain yield (g/pot)	Straw yield (g/pot)	Zn use efficiency	
			Agronomic efficiency	Apparent Zn recovery
T1 – 100% NPK	51.82	74.79	-	-
T2 – 75% NPK	44.48	61.55	-29.36	-0.10
T3 – 50% NPK	36.45	51.00	- 61.48	-0.18
T4 – T2 + Azos + Phospho + Znenriched FYM	70.56	89.52	74.96	0.28
T5 – T2 + Azos + Phospho + Znenriched humic acid	75.38	93.30	94.24	0.40
T6 – T3 + Azos + Phospho + Znenriched FYM	62.32	80.21	42.00	0.11
T7 – T3 + Azos + Phospho + Znenriched humic acid	66.59	84.15	59.08	0.20
SEd.	1.22	1.46	2.63	0.01
CD (p = 0.05)	2.48	2.99	5.25	0.03

cient in reducing the pH and EC of coastal saline soil. Among all the treatments, T5, NPK + green leaf fortified $ZnSO_4$ + $FeSO_4$ @ 125% recommended level and T4, NPK green leaf @ 100% level rated on par in reducing the pH of soil. At harvest these treatments recorded a pH value of (8.24 and 8.21) and EC of (1.23 and 1.42 dS/m), respectively. The organic C content of the soil significantly increased over control due to the addition of various fortified organic manures. The lowest organic C content was observed in the control treatment 0.32%. The highest organic C content was recorded with the treatment T5, green manure fortified micronutrients @ 125% RL which recorded 0.45% and this was at par with treatment T4, green manure fortified micronutrients @ 100% RL. Coir pith fortified organics also increased the organic C content in the coastal saline soil as compared to control. The application of micronutrients as chemical fertilizers and also as fortified organic manures to coastal saline soil significantly increased the DTPA-Zn content. Among the various fortified organic manures, the highest DTPA-Zn content of 1.07 mg/kg was recorded with T5, NPK + green manure fortified $ZnSO_4$ + $FeSO_4$ @ 125% recommended level however it rated on par with the treatment T4. The result from the field investigation clearly indicated the significant influence of various micronutrient fortified organics on significantly improving the Zn use efficiency and rice production in the coastal saline soil. The highest grain and straw yield of 5410 and 8198 kg/ha was registered with treatment T5, NPK + green leaf manure fortified $ZnSO_4$ + $FeSO_4$ @ 125% recommended level. This yield compared with treatment T4, which recorded a grain yield of 5388 kg/ha and straw yield of 7927 kg/ha, respectively. Increase in grain yield might be attributed to improvement in metallo-enzymes system regulatory function and growth promoting auxin production [4]. The treatment, T4 also recorded a significantly higher Zn use efficiency of 53.44% agronomic efficiency and apparent Zn recovery (3.00) (Table 3 and table 4). The Zn fortified organic manure chelated the Zn ion and increased the availability in soil and its efficiency as reported by Veeranagappa et al. [5].

Experiment III

The present study clearly indicated the usefulness of clay and organic amendment in reducing the pH and EC of soil. The treatment, T7 - NPK + 40 t clay/ha + Humic acid @ 20 kg/ha rated best in reducing the pH (7.69) and EC (1.82 dS/m) of soil. The organic acid and also the buffering action produced by the amendments clay and organic manure have resulted in decreased pH and salinity [6]. One of the objectives proposed in the present study includes the improvement of N availability and N use efficiency in coastal sandy soil. The treatment clay addition @ 40 t/ha along with humic acid @ 20 t/ha significantly increased the availability of NH_4-N (48.26 mg/kg) and NO_3-N (36.33 mg/kg) in soil. This treatment also accounted for increased agronomic efficiency (25.95) and apparent N recovery (0.88). This was followed by 20 t clay + humic acid treatment. The increased availability of N might be due to increased CEC with clay and humic acid treatment. Earlier Croker et al. [7] reported addition of 40 t clay/ha increased CEC by approximately 3-fold. Wahab et al. [8] explained the presence of phenolic, carboxylic and hydroxyl groups in humic acid retained more N and hence increased the availability. The increased N availability resulted in improved N use efficiency and increased yield of grain (54.73 g/pot) and straw (76.86 g/

Table 3: Effect of micronutrients fortified organic manure on the physico-chemical properties and DTPA-Zn content of soil.

Treatments	pH	EC (dS/m)	Org.C (%)	DTPA-Zn (mg/kg)
T1 – Recommended level NPK	8.70	1.97	0.32	0.77
T2 – NPK + $ZnSO_4$ + $FeSO_4$ @ 25 Kg/ha	8.98	1.84	0.37	0.91
T3 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 75% RL	8.28	1.49	0.44	0.97
T4 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 100% RL	8.24	1.42	0.43	1.07
T5 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 125% RL	8.21	1.23	0.45	1.09
T6 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 75% RL	8.34	1.66	0.39	0.95
T7 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 100% RL	8.32	1.64	0.40	1.02
T8 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 125% RL	8.31	1.61	0.41	1.04
SEd	0.38	0.05	0.02	0.01
CD (p = 0.05)	0.77	0.10	0.05	0.03

Table 4: Effect of micronutrients fortified organic manures on the grain and straw yield of rice (kg/ha).

Treatments	Grain yield (g/pot)	Straw yield (g/pot)	Zn use efficiency	
			Agronomic efficiency	Apparent Zn recovery
T1 – Recommended level NPK	4058	5882	-	-
T2 – NPK + $ZnSO_4$ + $FeSO_4$ @ 25 Kg/ha	4642	6820	23.36	0.98
T3 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 75% RL	5021	7378	38.52	1.99
T4 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 100% RL	5388	7927	53.44	3.00
T5 – NPK + GM Forti.$ZnSO_4$ + $FeSO_4$ @ 125% RL	5410	8198	54.08	3.04
T6 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 75% RL	4857	7297	31.96	1.57
T7 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 100% RL	5160	7648	44.08	2.00
T8 – NPK + Coir pith Forti.$ZnSO_4$ + $FeSO_4$ @ 125% RL	5095	7703	41.48	2.02
SEd	128	200	3.16	0.12
CD (p = 0.05)	256	401	6.35	0.23

Table 5: Effect of clay and organic amendments on the physico-chemical properties and N availability in coastal sandy soil.

Treatments	Grain yield (g/pot)	Haulm yield (g/pot)	N use efficiency	
			Agronomic efficiency	Apparent N recovery (%)
T1 – Control	39.16	50.01	-	-
T2 – NPK + 20 t clay/ha	44.02	56.31	0.81	0.18
T3 – NPK + 40 t clay/ha	46.34	58.94	11.97	0.28
T4 – NPK + 20 t clay/ha + FYM@ 12.5 t/ha	47.30	63.89	13.57	0.40
T5 – NPK + 40 t clay/ha + FYM@ 12.5 t/ha	50.42	71.03	18.77	0.63
T6 – NPK + 20 t clay/ha + Humic acid@ 20 kg/ha	48.61	67.57	15.75	0.52
T7 – NPK + 40 t clay/ha + Humic acid@ 20 kg/ha	54.73	76.86	25.95	0.88
SEd	.073	1.45	0.63	0.04
CD (p = 0.05)	1.56	3.10	1.28	0.08

Table 6: Effect of clay and organic amendments on the physico-chemical properties and Zn use efficiency in coastal sandy soil.

Treatments	pH	EC (dS/m)	Org.C (%)	NH_4^+-N (mg/kg)	NO_3-N (mg/kg)
T1 – Control	8.06	2.38	0.30	39.96	24.74
T2 – NPK + 20 t clay/ha	7.95	2.28	0.35	51.77	27.32
T3 – NPK + 40 t clay/ha	7.90	2.24	038	55.92	29.89
T4 – NPK + 20 t clay/ha + FYM@ 12.5 t/ha	7.81	2.07	0.44	42.37	31.28
T5 – NPK + 40 t clay/ha + FYM@ 12.5 t/ha	7.74	1.93	0.47	46.31	34.16
T6 – NPK + 20 t clay/ha + Humic acid@ 20 kg/ha	7.78	1.98	0.49	43.14	32.62
T7 – NPK + 40 t clay/ha + Humic acid@ 20 kg/ha	7.69	1.82	0.51	48.26	36.33
SEd	0.02	0.03	0.01	0.96	0.073
CD (p = 0.05)	0.04	0.07	0.02	1.94	1.47

pot) under this treatment. The improved fertilizer N efficiency was associated with an increase in cation exchange capacity (Table 5 and table 6). Similar results of clay incorporation on yield improvement were reported by Noble et al. [9].

Conclusion

The present study clearly indicated the usefulness of the strategies such as application of 75 % NPK + Azospirillum + Phophobacterium + Zn enriched humic acid @ 20 kg/ha/application of micronutrient fortified organic manure i.e., NPK + GM fortified $ZnSO_4$ + $FeSO_4$ @ 100% RL in significantly increasing the Zn use efficiency and yield of rice under wetlands. For coastal sandy soils, NPK + 40 t clay/ha + Humic acid @ 20 kg/ha was more efficient in increasing the N use efficiency and yield of black gram.

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None.

Conflict of Interest

None.

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