



Effect of Zn and Fe Enriched FYM on Yield, Nutrient Content and Uptake by Cowpea Irrigated with Sodic Water

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A pot experiment was conducted during *kharif* 2018-19 at S.K.N. College of Agriculture, Jobner (Rajasthan) to study the "Effect of Zn and Fe enriched Farmyard manure on nutrient availability and yield of cowpea [*Vigna unguiculata* (L.)wilczek] under sodic water irrigation" to evaluate the effect of different sodic water and sources of Zn and Fe on yield, nutrient concentration and uptake by cowpea on loamy sand soil. The experiment comprising of 15 treatment combinations replicated three times, was laid out randomized block design with three levels of sodic water (2, 4 and 6 mmol L⁻¹) and five levels of sources of Zn and Fe (0, ZnSO₄.7H₂O, FeSO₄.7H₂O, Zn enriched FYM, Fe enriched FYM) as variables. The total and number of nodules per plant, nodule index, pods per plant and seeds per pod were counted at stage and harvesting respectively. Results revealed that under 6 mmol L⁻¹ Residual sodium carbonate of irrigation water, the seed and straw yield of, nutrient concentration and uptake viz., P, K, Zn and Fe in seed and straw decreased significantly with all levels of sodic water and maximum reduction was recorded with the application of 6 mmol L⁻¹ of sodic water, while N in seed and straw, protein content in seed increased significantly. The application of Zn enriched FYM increased seed and straw yield, nutrient concentration and uptake viz., N, P, K, Zn and Fe in seed and straw, protein content in seed.

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1. INTRODUCTION

Pulses are gaining worldwide importance as they are the cheap source of protein in diet and have ability and soil fertility through biological nitrogen fixation as well as of ample amount of residues to the soil [1]. India is the largest producer and consumer of pulses in the world accounting for about 29 and 19 per cent of the world's area and production, respectively. The per capita availability of pulses in India is 35.5 g day⁻¹ as against the minimum requirement of 70 g day⁻¹. Cowpea [*Vigna unguiculata* (L.) Wilczek] commonly known in India as *lobia* is one of the important *kharif* pulse crops grown for vegetable, grain, forage and green manuring. This crop has great importance because of its short duration, high yielding and variety. It is a considerable promising pulse crop in farming. Unlike other legumes, cowpea is not so tolerant to sodicity. In many arid and semi-arid regions, of saline and sodic water for irrigation in the absence of appropriate soil-water-crop management often leads to the of salinity and sodicity in the soil profile which adversely the crop productivity. The quality of irrigation water plays a vital role in crop production. The use of sodic water for irrigation adversely affects of soil by influencing the uptake of nutrients and many soil properties [2]. This problem becomes more aggravated when the carbonate and bicarbonate of sodic water occur in association with sodium creating the problem of residual sodium carbonate [3].

Zinc plays a vital role in chlorophyll, protein and nucleic acid and helps in nitrogen and phosphorus by plants as it acts as an activator of dehydrogenase and proteinase enzymes, directly or indirectly in carbohydrates and protein. Zinc is a constituent of tryptophan which is a precursor of auxin hormone [4]. Zinc deficiency has been reported to be the most widespread micro-nutritional disorder of the food crops in India as well as the world over. Zinc is a crucial component of the practices recommended for sodic soils reclamation. Deficiencies of Fe, Mn and Cu are much less extensive. The available Zn content of Indian soils varied from traces to 22 mg kg⁻¹ and 47 per cent of Indian soils were found to be deficient in Zn. Zn deficient soils cause low crop production leading to malnutrition in humans and livestock [5]. Continuous use of high sodic water increases the ESP and pH which decreases the availability of Zn [6]. As the soil pH, the ionic form of Zn changed to

hydroxide form, which is insoluble and unavailable to plants. Although the high RSC water can be used successfully by applying higher doses of zinc sulphate, Zinc helps in inducing alkalinity tolerance in by enhancing its efficiency in utilizing K, Ca and Mg the adverse effect of sodicity [7]. Thus, reducing of Na/K and Na/Ca ratio in plant tissues to mitigate the adverse effect of alkalinity in is an important aspect [8]. Iron being an essential micronutrient takes part in the metabolic activities of the plant. It acts as an activator of dehydrogenase, proteolase and peptidases enzymes, directly or indirectly involved in the synthesis of carbohydrates and proteins. Iron in chloroplast reflects the presence of cytochromes for performing various photosynthetic reduction processes [3]. Zn and Fe application in the enriched form may enhance the fertilizer use efficiency and increase crop yield. However, no systematic study has been conducted on Zn and Fe-Enriched Farmyard manure in these soils irrigated with high RSC water in the region of legume crops. The productivity could be sustained through use of organic and inorganic fertilizers. The organic manures for supplement of Zn and Fe deficiency in soils has been emphasized by several workers [9]. FYM enriched zinc and iron reacts with native reserves of Zn and Fe elements and them available to plants. It has been reported that organic wastes such as presumed cattle and poultry litter and Farmyard manure with or without zinc alleviated zinc deficiency [10]. The present study was aimed at assessing the effect of Zn and Fe enriched FYM on yield, nutrient content and uptake by cowpea.

2. MATERIALS AND METHODS

Experimental Site and Soil: A pot experiment was conducted in house of Plant Physiology and samples analysis were done in the Department of Soil Science and Agricultural Chemistry, S.K.N. College of Agriculture, Jobner (Rajasthan) during the *kharif* season 2018-2019. Jobner is located at 75.28° East longitudes and 26.06° North at an altitude of 427 metres above mean sea level. This region comes under Agro Climatic Zone III-a (Semi-arid eastern plain). The climate of the region is typically semi-arid characterized by the aridity and salinity with extremes of temperature both during summer and winter. The average rainfall of this region is about 400 to 500 mm, which is mostly received between July and

September (Monsoon season). The loamy sand soil was used for experiment. The experiment comprising of 15 treatment combinations replicated three times, was laid out in randomized block design with three levels of sodic water (2, 4 and 6 mmol L⁻¹) and five levels of sources of Zn and Fe (0, ZnSO₄.7H₂O @ 12.5 mg/kg soil, FeSO₄.7H₂O @ 25 mg/kg soil, Zn enriched FYM 250 mg/kg soil, Fe enriched FYM @ 250 mg/kg soil) as variables.

Quality of Irrigation Water: The different sodic water was prepared artificially by dissolving amount of NaHCO₃, NaCl, Na₂SO₄, CaCl₂ and MgCl₂ in base water (control). The tap water (base water) was used for first irrigation in all pots and later on irrigated 6 times with water of varying RSC levels as per treatment. The composition of prepared water is given in Table 1.

Preparation of Zinc and Fe Enriched FYM: The locally available organics like farmyard manure (FYM) were used for their enrichment with Zn and Fe. The enrichment process was started 60 days before their use in cowpea. The known quantity of organics was filled in the pre-dug pits of 1.5' x 1.5' x 1.5' size. The FYM were thoroughly mixed with the solutions of ZnSO₄.7H₂O and FeSO₄.7H₂O equivalent to 25 kg Zn per ha and 50 kg Fe per ha, respectively supplied through 500 kg of FYM. The moisture percentage of FYM after mixing 70% throughout the enrichment process. The cow dung slurry @ 1% was applied as a starter inoculum of microorganisms to boost up the microbiological activities for process of composting to fix the externally added Zn and Fe through zinc sulphate and iron sulphate, respectively. The pit was covered by sheet for natural chelation during the process of composting. The mixture was turned over weekly and moisture loss was compensated during the process of enrichment. The periodical samples were taken from the pit for of water-soluble Zn and Fe content when the value of water-soluble Zn and Fe appeared to be more or less constant and the enrichment process was considered as complete. It was found that the process was almost completed within 6 to 7 weeks. After enrichment, the required quantity of zinc and Fe enriched FYM @ 250 mg/kg soil was thoroughly mixed in before sowing the crop. As per the crop production guide, the recommended dose of fertilizers (40:20:20 kg N: P₂O₅: K₂O ha⁻¹) applied as basal in the form of urea, single super phosphate and murate of potash for all the treatments. The Zinc

sulphate (ZnSO₄) and ferrous sulphate (FeSO₄) as Enriched Farm Yard Manure (EFYM) form applied as per the treatment structures.

Plant Analysis: The plant samples were first dry in open sun and then dry at 65°C until the attainment of constant weight. The oven-dried plant samples were help of a stainless-steel grinder for subsequent analysis. The chemical analysis of the plant samples was carried out by wet digesting with HNO₃:HClO₄ (4:1) di-acid mixture as per the procedure outlined by Jackson (1973). For estimation of nitrogen, phosphorus, potassium, zinc and iron content in representative samples of seed and straw taken at the time of threshing were grind to a fine powder. Nutrient content in seed and straw were estimated by using standard methods. Total N was determined using N Auto Analyzer. K was directly measured in flame photometer and P content in plant parts were measured in at 420 nm. For Zn and Fe content digested plant material was measured in AAS. The uptake of nitrogen, phosphorus, potassium, zinc and iron at harvest in seed and straw was estimated by using the following formula.

$$\text{N, P, K uptake (mg/pot)} = ((\text{Nutrient content in Seed/ straw (\%)} \times \text{yield (g/pot)}) \times 1000) / 100$$

$$\text{Zn and Fe uptake (\mu g pot}^{-1}\text{)} = ((\text{Nutrient content in seed/ straw (ppm)} \times \text{Seed/ straw yield (g pot}^{-1}\text{)}) \times 1000) / 10000$$

Statistical Analysis: The statistical analysis of the data on the final value of seed and straw yield and soil analysis for Electrical conductivity, pH, Sodium Absorption ratio, organic carbon and DTPA-Zn and Fe were done by method of analysis of variance. To compare the treatment difference, the critical difference (CD) at 5 per cent level of significance was calculated as per method described by Panse and Sukhatme [11] wherever 'F' test was found significant.

3. RESULTS AND DISCUSSION

Effect of Sodic water: The seed and straw yield of cowpea decreased significantly with increasing levels of Sodium Absorption ratio in irrigation water (Table 2). The decrease in the seed yield due to W₄ and W₆ was 16.42 and 48.77 per cent over W₂, respectively. The W₄ and W₆ decreased the straw yield to the extent of 16.50 and 49.10 per cent over W₂, respectively. Seed and straw yield of cowpea significantly decreased with

increasing of sodic. This may be explained on the basis that increasing level of sodicity of soil increased the SAR and pH of soil resulting decreased availability of N, P, K, Zn, Fe, Ca and Mg but increased the uptake of Na. The higher amount of Na may adversely affect the physiological, metabolic and enzymatic activities and utilization of photosynthates. There are several evidences that cationic (Ca, Mg, Na and K) imbalance could lead to disturbances in photosynthesis and activity of stroma enzymes [12,13]. The inability of the crop to grow under high SAR is due to the toxicity of Na itself and Ca and K frequently becomes factor for plant growth [14]. Restricted supply of Ca was reciprocated by a high Na content and was shown to affect the growth of the roots and shoots. Such a reduction in growth under Ca deficiency caused by Na accumulation was attributed to K leakage [15].

The maximum N content in seed and straw was recorded under W_6 (6 mmol L⁻¹ RSC) and it registered 13.27 and 9.40 per cent in seed and straw, it was 32.73 and 16.84 per cent higher over W_2 and W_4 , respectively. The increase in N content in with increasing level of sodic waters may be attributed to a less production of crop resulting in concentration of N. The results find support from the work of Yadav [16] and Singh et al. [17]. The W_4 and W_6 decreased the N uptake by seed to the extent of 13.50 and 42.01 per cent and in straw 5.06 and 32.41 per cent over W_2 , respectively. Similar results were reported by Doodhwal et al. [3].

The application of W_4 and W_6 decreased the P, K, Zn and Fe content in seed and straw (Table 5). The decrease in K content in seed and straw of cowpea due to sodic water might be due to the antagonistic effect of excess Na on the absorption of K [3]. A number of subsequent studies have established that increasing sodicity decreased the K and Ca concentration and increased Na concentration in tissue [18] and [19]. Zn and Fe content in grain and straw decreased significantly with increasing levels of RSC of irrigation water. It might be due to the conversion of Zn²⁺ and Fe²⁺ to its unavailable form to uptake under a sodic soil environment generated by high RSC of irrigation water. Similar results also reported by Jatav [20].

The P, K, Zn and Fe uptake decreased significantly with increasing levels of sodic water (Table 5). This might be due to the fact that sodic waters had increased the ESP and pH of soil. The higher sodicity of the soil could have

decreased the mobility of P due to presence of CO₃²⁻ ions. At higher pH, the proportion of HPO₄²⁻ and PO₄³⁻ increased over H₂PO₄⁻. The OH⁻ ions, thus, decrease the availability of P to the plant. The physiological availability of P in alkali soil is a function of pH and it decreased as the pH increase over the alkaline range [21].

Protein content in seed of cowpea significantly increased with increased level of sodic water. According to Strogonov and Okinina (1961) as earlier, the N taken up by plants gets accumulated in organs as protein and is not available for plant growth leading to increased content of N, which ultimately increased the protein content with increasing levels of sodic water. The results find support from the work of Jatav [20]; Yadav [16] and Sharma [22].

Effect of Sources of Zn and Fe: The seed and straw yield of cowpea (Table 2) increased significantly with the application of Zn enriched FYM (T₃). Application of Zn enriched FYM increase the seed yield by the extent of 68.94, 16.67, 32.58 and 8.07 per cent over T₀, T₁, T₂ and T₄, respectively. An investigation of the data further showed that T₃ registered significantly higher straw yield over T₀, T₁, T₂ and T₄. Treatment T₃ showed an increase of 78.40, 16.67, 32.58 and 7.97 per cent in straw yield over T₀, T₁, T₂ and T₄, respectively. Application of Zn enriched FYM enhanced the seed yield and straw yield over control. The significance difference in seed yield under the influence of FYM and Zn was largely a function of improved growth and the consequent increase in different yield attributes. Further, FYM increases the activities of nitrogen fixation bacteria and increased of humification. Humic acid in FYM enhanced the availability of both native and added in soil and thus plant growths, yield attributes and yield increased. Similar results were also reported by Meena et al., [23], Yadav et al. [24] and Bandiwaddar et al. [25]. The higher seed and straw yield arising from Zn enriched FYM further substantiated by the significant and the gradual release and steady supply of nutrients from FYM throughout the growth and development of plants maintained the photosynthetic efficiency and production of metabolites at higher level and later on the translocation of photosynthetic to various sinks resulting into higher seed and straw yield. Similar findings were also reported by Prihar [26], Kumawat [27], Patel et al. [28] and Kanwar and Sharma [29].

The N, P, K, and Zn content in seed and straw of cowpea increased significantly with the application of Zn enriched FYM (Table 5). The Fe content in seed and straw increased significantly with the application of Fe enriched FYM. The significant increase in nutrient content in plant ascribed to the beneficial role of FYM in mineralization of native as well as nutrients in soil

through added fertilizers in addition of its own nutrient content which enhanced the available nutrients pool of soil. The favourable conditions for microbial as well as chemical activities due to addition of FYM augmented the mineralization of nutrients and ultimately the available nutrient pool of the soil led to higher uptake of nutrient by plant [30]. These results are in agreement with

Table 1. Composition of irrigation water

RSC mmol L ⁻¹	EC (dSm ⁻¹)	SAR	Ionic composition (mmol L ⁻¹)						
			Na ⁺	Ca ²⁺	Mg ²⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻
2.0 Base water	1.31	8.2	10.0	1.5	1.5	1.0	4.0	6.5	1.5
4.0	3.14	16.7	26.4	2.5	2.5	2.0	7.0	11.4	11.0
6.0	3.14	16.7	26.4	2.5	2.5	2.0	9.0	10.5	9.9

Table 2. Effect of different sodic water and sources of Zn and Fe on seed and straw yield of cowpea

Treatments	Seed yield (g/pot)	Straw (g/pot)
Sodic water (RSC-mmol/L)		
W ₂	8.65	15.03
W ₄	7.23	12.55
W ₆	4.43	7.65
SEm _±	0.12	0.24
CD (P= 0.05)	0.35	0.68
Sources of Zn and Fe		
T ₀ (control)	4.83	8.01
T ₁ (ZnSO ₄ ·7H ₂ O)	7.08	11.39
T ₂ (FeSO ₄ ·7H ₂ O)	6.23	10.20
T ₃ (Zn enriched FYM)	8.16	15.20
T ₄ (Fe enriched FYM)	7.55	13.90
SEm _±	0.16	0.31
CD (P= 0.05)	0.46	0.88

Table 3. Interactive effect of sodic water and sources of Zn and Fe on seed yield (g/pot) of cowpea

Treatment	T ₀	T ₁	T ₂	T ₃	T ₄
W ₂	6.17	9.05	7.96	10.43	9.65
W ₄	5.16	7.56	6.65	8.71	8.06
W ₆	3.16	4.63	4.08	5.34	4.94
	SEm _±	0.29			
	CD (P= 0.05)	0.84			

Table 4. Interactive effect of sodic water and sources of Zn and Fe on straw yield (g/pot) of cowpea

Treatment	T ₀	T ₁	T ₂	T ₃	T ₄
W ₂	10.25	14.58	13.05	19.45	17.79
W ₄	8.56	12.17	10.90	16.24	14.85
W ₆	5.22	7.42	6.64	9.90	9.05
	SEm _±	0.53			
	CD (P= 0.05)	1.52			

Table 5. Effect of different sodic water and sources of Zn and Fe on zinc and iron content and uptake in seed and straw of cowpea

Treatments	Iron content (ppm)		Iron uptake ($\mu\text{g}/\text{pot}$)		Zinc content (ppm)		Zinc uptake ($\mu\text{g}/\text{pot}$)	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Sodic water (RSC-mmol/L)								
W ₂	99.21	112.31	25.61	22.71	33.56	21.67	86.91	171.47
W ₄	93.83	108.71	23.51	17.43	26.31	20.35	68.70	138.59
W ₆	85.15	102.53	20.92	9.50	14.24	18.07	38.20	79.68
SEm \pm	1.75	2.05	0.45	0.34	0.53	0.38	1.28	2.68
CD (P= 0.05)	5.05	5.89	1.30	0.98	1.52	1.10	3.68	7.73
Sources of Zn and Fe								
T ₀ (control)	80.00	93.97	18.27	9.01	12.65	15.49	39.26	76.01
T ₁ (ZnSO ₄ .7H ₂ O)	89.71	103.15	22.37	16.17	23.12	19.91	64.54	118.64
T ₂ (FeSO ₄ .7H ₂ O)	91.85	107.52	21.44	13.64	19.67	18.92	58.15	110.74
T ₃ (Zn enriched FYM)	97.24	113.41	28.30	23.58	36.74	23.71	80.63	174.07
T ₄ (Fe enriched FYM)	104.85	121.20	26.37	20.33	31.34	22.12	80.44	170.11
SEm \pm	2.26	2.64	0.58	0.44	0.68	0.49	1.65	3.47
CD (P= 0.05)	6.52	7.61	1.68	1.27	1.96	1.42	4.75	9.98

those of Vasanthi and Kumarswamy (1999) and Nehra and Grewal [31] who have reported significant increase in available nutrient pool of soil with the use of vermicompost @ 5 t ha⁻¹. When the vermicompost is added to the soil, nitrogenous compounds slowly break down and make steady nutrient supply throughout period of crop, leading to higher nutrient availability to plant Rao [32] and Yadav et al., [24].

The increase in Zn content by the application of Zn enriched FYM is due to production of a host of complexing agents which form stable organometallic complexes with Zn that facilitates its efficient utilization by plant resulting in yield and its concentration [33]. Further, this was also supported by the reduced soil pH due to Zn enriched FYM application which is known to encourage solubility and availability of zinc in soil [34,35]. Higher N, P, K, Zn and Fe content with the use of organic materials have also been reported by Singh and Yadav (2006); Yadav et al., [16] and Tak et al., [36].

The protein content in cowpea increased significantly with the application of Zn enriched FYM. The favorable effect of Zn and Fe on synthesis and metabolic process augmented the production of photosynthetic and their translocation to different plant which increased the concentration of N in the seed which directly indicates the content of protein. Similar results were obtained by Ashoka et al., [37] in baby corn, Parihar et al., [38] in mustard and Tak et al., [36] in green gram.

4. CONCLUSION

Cowpea is a pulse crop role in daily diet. In arid and semi-arid of Rajasthan is having the soil sodicity limitation for this crop. experiment results, increasing RSC and pH of soil reduced the crop yield, nutrient content and uptake by plants. Whereas, application of Zn and Fe enriched FYM improved the crop yield as well as mineral nutrition of the crop. This type of study could be used for enhancing production in high sodicity agricultural fields by application of Farmyard manure enriched with Zn and Fe.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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