Original Research Article

EFFECT OF ZN Zn AND FE Fe ENRICHED FYM ON YIELD, NUTRIENT CONTENT AND UPTAKE BY COWPEA IRRIGATED WITH SODIC WATER

Abstract

A pot experiment was conducted during *kharif* 2018/19 2018-19 at S.K.N. College of Agriculture, Jobner (Rajasthan) to study the "Effect of Zn and Fe enriched FYM on nutrient availability and yield of cowpea *[Vigna ungiculata* (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 (*Vigna ungiculata* (L.) wilczek) on loamy sand soil. The experiment comprising of 15 treatment combinations replicated three times, was laid out in completely 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, $ZnSO_4.7H_2O$, $FeSO_4.7H_2O$, Zn enriched FYM, Fe enriched FYM) as variables. The total and effective number of nodules per plant, nodule index, pods per plant and seeds per pod were counted at pre-flowering stage and harvesting respectively. Results revealed that under 6 mmol L^{-1} RSC of irrigation water, the seed and straw yield of crop, 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 of crop, nutrient concentration and uptake viz., N, P, K, Zn and Fe in seed and straw, protein content in seed.

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Key words: Sodic water, Zn, enriched FYM, Fe enriched FYM, Seed, and Straw yield, Nodule Index

Introduction

Pulses are gaining worldwide importance as they are the cheap source of protein in human diet and have unique ability of maintaining and restoring soil fertility through biological nitrogen fixation as well as addition of ample amount of residues to the soil (Reddy and Reddy, 2010). 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 ungiculata* (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 availability of short duration, high yielding and quick growing variety. It is a considerable promising an alternative pulse crop in dry land farming. Unlike other legumes, cowpea is not so tolerant to sodicity. In many arid and semi-arid regions, use of saline and sodic water for irrigation in the absence of appropriate soil-water-crop management practices, often leads to the builds-up of salinity and sodicity in the soil profile which adversely affect the crop productivity. The quality of irrigation water plays a vital role in crop production. The use of sodic water for irrigation adversely affects productivity of soil by influencing the uptake of nutrients and many soil properties (Chauhan *et al.* 1988). 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 (Doodhwal et al. 2020).

Zinc plays a vital role in synthesis of chlorophyll, protein and nucleic acid and helps in utilization of nitrogen and phosphorus by plants as it acts as an activator of dehydrogenase and proteinase enzymes, directly or indirectly in synthesis of carbohydrates and protein. Zinc is a constituent of tryptophan which is a precursor of auxin hormone (Purushottam et al. 2018). 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 package of the practices recommended for sodic soils reclamation. Deficiencies of Fe, Mn and Cu are much less extensive than that to zinc. 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 (Kumar and Dhaliwal, 2021). Continuous use of high sodic water increases the ESP and pH of soil which decreases the availability of Zn (Meena et al. 2017). As the soil pH increase, 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 crop by enhancing its efficiency in utilizing K, Ca and Mg and decreases the adverse effect of sodicity (Raj and Raj, 2019). Thus, reducing of Na/K and Na/Ca ratio in plant tissues to mitigate the adverse effect of alkalinity in crop is an important aspect (Mishra, 2001). Iron being an essential micronutrient takes active 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 (Doodhwal et al. 2020). 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 recommendation of zinc and iron enriched FYM in these soils irrigated with high RSC water in the region for cultivation of legume crops. The productivity could be sustained through integrated use of organic and inorganic fertilizers. Use of organic manures for amelioration of zinc and iron deficiency in soils has been emphasized by several workers (Meena et al. 2014). FYM enriched zinc and iron reacts with native reserves of micro nutrient elements and render them available to plants.It has been reported that application of organic wastes such as pressmud, cattle and poultry litter and farm yard manure with or without zinc alleviated zinc deficiency (Amer et al. 2020). The present study was aimed at assessing the effect of Zn and Fe enriched FYM on yield, nutrient content and uptake by cowpea.

Materials and Methods

Experimental site and soil: A pot experiment was conducted in cage house of Department of Plant Physiology and plant samples analysis were done in Department of Soil Science and Agricultural Chemistry, S.K.N. College of Agriculture, Jobner (Rajasthan) during the *kharif* season 2018/19 2018-2019. Jobner is located at 75.28^{0} East longitudes and 26.06^{0} North latitude 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 of atmosphere and salinity of rhizosphere 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 pot experiment. The experiment comprising of 15 treatment combinations replicated three times, was laid out in completely 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, $ZnSO_4.7H_2O$ @ 12.5 mg/kg soil, $FeSO_4.7H_2O$ @ 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 required amount of $NaHCO_3$, NaCl, Na_2SO_4, $CaCl_2$ and $MgCl_2$ in base water (control). The tap water (base water) was used for first irrigation in all pots and later on crop was irrigated 6 times with water of varying RSC levels during experiment 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 $ZnSO_4.7H_2O$ and $FeSO_4.7H_2O$ 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 maintained around 70% throughout the course of enrichment process. The cow dung slurry @ 1% was applied as a starter inoculum of microorganisms to boost up the microbiological activities for enhancement of natural process of composting to fix the externally added Zn and Fe through zinc sulphate and iron sulphate, respectively. The pit was covered by polythene 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 determination 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 soil before sowing the crop.As per the crop production guide, the recommended dose of fertilizers (40:20:20 kg N: P_2O_5: K_2O ha^{-1}) were applied as basal in the form of urea, single super phosphate and murate of potash for all the treatments. The Zinc sulphate ($ZnSO_4$) and ferrous sulphate ($FeSO_4$) as Enriched Farm Yard Manure (EFYM) form applied as per the treatment structures.

Plant analysis: The plant samples were first air dried in the open sun and then oven dried at 65^0C until the attainment of constant weight. The oven dried plant samples were grinded with the help of a stainless-steel grinder for subsequent analysis. The chemical analysis of the plant samples was carried out by wet digesting with HNO_3:$HClO_4$ (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 ground to 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 spectrophotometer 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.

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

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

Statistical analysis: The statistical analysis of the data on the final value of seed and straw yield and soil analysis for EC, pH, SAR, organic carbon and DTPA-Zn and Fe were done by statistical 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 (1967) wherever 'F' test was found significant.

Result and Discussion

Effect of Sodic water: The seed and straw yield of cowpea decreased significantly with increasing levels of RSC in irrigation water (Table 2). The decrease in the seed yield due to use of W_4 and W_6 was 16.42 and 48.77 per cent over $W_{2,}$ respectively. The W_4 and W_6 decreased the straw yield to the extent of 16.50 and 49.10 per cent over $W_{2,}$ respectively. Seed and straw yield of cowpea significantly decreased with increasing level of sodic. This may be explained on the basis that increasing level of sodicity of soil increased the SAR and pH of soil resulting into decreased availability of N, P, K, Zn, Fe, Ca and Mg but increased the uptake of Na which is toxic element. The higher amount of Na may adversely affect the physiological, metabolic and enzymatic activities and utilization of photosynthates in plant. There are several evidences that cationic (Ca, Mg, Na and K) imbalance could lead to disturbances in photosynthesis and activity of stroma enzymes (Brand and Beckler, 1984; Plaut and Grieve, 1988). The inability of the crop to grow under high SAR is due to the toxicity of Na itself and Ca and K frequently becomes as limiting factor for plant growth (Dwivedi and Burrows, 1979). 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 (Ben-Hauyyim *et al*. 1987).

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 in case of straw, it was 32.73 and

16.84 per cent higher over W_2 and W_4, respectively. The increase in N content in seed with increasing level of sodic waters may be attributed to a less production of crop resulting in higher concentration of N in plant. The results find support from the work of Yadav (2001) and singh *et al*. (2005). 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. 2020.

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 by plant (Doodhwal et al. 2020). The ability of the crop to grow under high Na saturation is due to the toxic effect of Na itself and K deficiency caused by antagonistic effect between Na and K. A number of subsequent studies have established that increasing sodicity decreased the K and Ca concentration and increased Na concentration in tissue Mahmood (2011) and Garhwal *et al*. (2011). Zn and Fe content in grain and straw decreased significantly with increasing levels of RSC of irrigation water. It might be due to increased concentration of alkali and the conversion of Zn^{2+} and Fe^{2+} to its unavailable form under sodic environment generated by high RSC of irrigation water. Similar results was also reported by Jatav (2000).

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 CO_3^{2-} ions. At higher pH, the proportion of $HPO_4^{2-}$and PO_4^{3-} increased over $H_2PO_4^-$. 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 (Yadav et al. 2019).

Protein content in seed of cowpea significantly increased with increased level of sodic water. According to Strogonov and Okinina (1961) as states earlier, the N taken up by plants is not utilized and gets accumulated in organs as protein and not available for plant growth leading to increased content of N in seed which ultimately increased the protein content with increasing levels of sodic water. The results find support from the work of Jatav (2000); Yadav (2001) and Sharma (2003).

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 (T_3). 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 T_0, T_1, T_2 and T_4, respectively. An investigation of the data further showed that T_3 registered significantly higher straw yield over T_0, T_1, T_2 and T_4. Treatment T_3 showed an increase of 78.40, 16.67, 32.58 and 7.97 per cent in straw yield over T_0, T_1, T_2 and $T_{4,}$ 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 rate of humification. Humic acid in FYM enhanced the availability of both native and added micro nutrients in soil and thus plant growths, yield attributes and yield increased. Similar results were also reported by Meena *et al.,* (2006), Yadav *et al*. (2011) and Bandiwaddar *et al*. (2015). 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 (2002), Kumawat (2003), Patel *et al*. (2012) and Kanwar and Sharma (2014).

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 (Satyajeet *et al*., 2006). These results are in agreement with those of Vasanthi and Kumarswamy (1999) and Nehra and Grewal (2001) 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, long chain nitrogenous compounds slowly break down and make steady nutrient supply throughout growth period of crop, leading to higher nutrient availability to plant Rao (2003) and Yadav *et al*., (2011).

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 increase in yield and its concentration (Stevenson and Ardakani, 1972). 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 (Jahiruddin and cresser, 1993 and Sharma *et al*., 2000). 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*., (2001) and Tak *et al*., (2014).

The protein content in seed of cowpea increased significantly with the application of Zn enriched FYM. The favourable effect of Zn and FYM on synthesis and metabolic process augmented the production of photosynthates and their translocation to different plant part which increased the concentration of N in seed which directly indicates the content of protein. Similar results were obtained by Ashoka *et al*., (2009) in baby corn, Parihar *et al*., (2014) in mustard and Tak *et al*., (2014) in green gram.

Conclusion

~~Cowpea is a pulse crop which having vital role in daily diet. In arid and semi-arid part of Rajasthan is having the soil sodicity limitation for this crop. On the basis of experiment results, that I~~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 the cowpea production in high sodicity agricultural fields by application of organics enriched (FYM) form of Zn and Fe.

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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 ($ZnSO.7H_2O$)	7.08	11.39
T_2 ($FeSO4.7H_2O$	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 (µg/pot)		Zinc content (ppm)		Zinc uptake (µg/pot)	
	Seed	Straw	Seed	Seed	Straw	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±	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 ($ZnSO.7H_2O$)	89.71	103.15	22.37	16.17	23.12	19.91	64.54	118.64
T_2 ($FeSO4.7H_2O$	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±	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