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Effect of Zinc Application on the Nutrient Content of Wheat (*Triticum aestivum* L.) Irrigated with Different Saline Waters

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Abstract: The efficiency of zinc application on the performance of wheat (*Triticum aestivum L.*) irrigated with different saline waters was studied in pot experiment on sandy clay loam soil. The experiment was laid out in CRD with four (W_0, W_1, W_2, W_3) qualities of irrigation water and four levels of zinc (0, 5, 10 and 15 mg kg^{-1} soil). High EC_{iw} significantly reduced the grain and straw yield, phosphorus, potassium and zinc contents in grain and straw, while sodium content increased. Zn application to soil had favorable effect on grain and straw yield of wheat. The Zn increased the contents of N, K, Zn significantly in both grain and straw whereas, phosphorus content was decreased significantly. The comparative reduction in grain and straw yield of wheat as well as contents of P and Zn of grain and straw was less at higher doses of zinc sulphate when the level of EC_{iw} increased in irrigation water. Hazardous effects of saline water on wheat can be mitigated to some extent by applying zinc sulphate at the rate of 15 mg Zn kg^{-1} soil.

Key words: Saline water, zinc, wheat, yield.

Salt affected soils adversely affect the livelihood security of the people in more than 100 countries, occupying about 831 Mha across the Globe. Out of the total (831 Mha) salt affected soils, 397 Mha (47.8%) are saline, while 434 Mha (52.2%) are sodic in nature. In the Indian context, salt affected soils occupy about 6.73 Mha area affecting production and productivity across number of states. Saline and brackish groundwater also pose serious threat to land and water productivity as these constitute about 25% of the total groundwater resource of the country. Certain states like Rajasthan and Haryana having 84 and 62% of poor quality ground waters are the worst hit on this account (Salinity News, 2010). Salinity limits the water uptake of plants by reducing the osmotic potential and thus the total soil water potential (Corwin and Lesch, 2003; Sheldon *et al*., 2004). As soil dries, the concentration of salts in the soil solution increases, further decreasing the osmotic potential (Sheldon *et al*., 2004). In dryland regions with annual rainfall between 250 and 600 mm, saline subsoils having EC values between 2 and 16 dS m^{-1} can dramatically affect crop production through osmotic effects during dry periods. The combination of poor water storage and osmotic stress increase water stress of crops in such areas (Rengasamy, 2002). Salinity affects both vegetative growth and reproductive development while the more obvious effects are on the rate of leaf appearance and the number of shoots capable of producing fertile ears; the reproductive process itself can be affected (Munns and Rawson, 1999). Physiologically, many processes are affected, but the most notable are reduced cell growth and decreased leaf area, biomass and yield (Acevedo *et al*., 2005).

Wheat (*Triticum* spp.) is one of the cereals extensively grown throughout the world in more than 50 countries. In terms of production wheat occupies the prime position amongst the food crops and is next to rice. Wheat is a staple crop, but its production potential is limited by adverse environmental stress namely drought, salinity and extremes of temperature. Zinc deficiency is most widespread micronutrient deficiency worldwide (Graham *et al*., 1992; Welch *et al*., 1991). Phytoavailability of Zn in calcareous and salt affected soils is low (Khoshgoftarmanesh *et al*., 2004) hence needs to be investigated. Moreover a large number of studies have demonstrated differential Zn efficiency among wheat genotypes (Cakmak *et al*., 1997; Kalayci *et al*., 1999) in calcareous soils, but limited information is available on

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Zn efficiency on wheat genotype under saline conditions (Khoshgoftarmanesh *et al*., 2004). This study was therefore, conducted to study the performance of wheat crop fertilized with Zn and irrigated with saline water to see the effect of Zn fertilization in alleviating the deleterious effects of saline water irrigation.

Materials and Methods

The experiment was conducted in the greenhouse of the Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur, in sandy clay loam soil (Typic Ustocrepts) having pH (8.12), EC (1.8 dS m^{-1}). In soil organic carbon (0.51%) was determind according to Walkley and Black (1947) method; ESP (5.13%) and SAR (3.60) on the basis of methods given by Richards (1954); $CaCO_3$ (3.10%) by Piper (1950) and available nitrogen (279.28 kg ha^{-1}), phosphorus (26.22 kg ha^{-1}), potassium (318.52 kg ha^{-1}) and zinc (0.71 mg kg^{-1}) analyzed using standard methods given by Subbiah and Asija (1956), Olsen *et al.* (1954), Richards (1954) and Lindsay and Norvell (1978), respectively. Chemical characteristics of water were also analyzed for pH, EC, RSC and SAR using standard methods of analysis. Chemical characteristics of water used in the study are given in Table 1. The region falls under Agro-climatic zone IV-A of Rajasthan with a typical sub-tropical climate.

Table 1. Chemical characteristics of water used under study

Characteristics	Irrigation water			
	W_0	W_1	W_2	W_3
pH	7.35	7.42	7.68	7.80
EC (dS m^{-1})	2.25	4.00	8.00	12.00
RSC	1	-	-	-
SAR	6.86	7.3	8.2	9.92

The experiment was laid out in completely randomized design (CRD) with three replications. 8 kg of air dried soil was placed in lysimeter pots over washed gravel at the bottom. The treatments consisted of four levels of EC_{iw} (W_0, W_1, W_2, W_3) four levels of zinc (0, 5, 10, and 15 mg Zn kg^{-1} soil). Basal dose of N @ 60 mg N kg^{-1}, P @ 20 mg P_2O_5 kg^{-1} and K @ 15 mg K_2O kg^{-1} were applied at the time of sowing. Seven seeds of wheat (Raj-4037) were sown per pot and three seedlings in each pot were maintained after ten days of sowing. The crop was harvested at maturity. Plant and soil samples were collected after crop harvest. Plant (grain and straw) samples were rinsed with glass-distilled water and dried in hot air oven at 65°C and processed for analysis of nitrogen (Snell and Snell, 1955); sodium and potassium (Jackson, 1973); phosphorus (Jackson, 1973); calcium and magnesium (Richards, 1954) and zinc (Lindsay and Norvell, 1978).

Results and Discussion

Nutrient content of plant

Nitrogen content of grain and straw was not affected due to high EC of irrigation water. However, the application of Zn_2 and Zn_3 (10 and 15 mg Zn kg^{-1} soil) increased the nitrogen content in grain to the extent of 5.35 and 6.59%, while that in straw increased by 2.42 and 6.59%, respectively, as compared to Zn_0 (control), while Zn_1 and Zn_0 were at par in their influence on nitrogen content in grain and straw (Table 2). Nitrogen content in wheat increased with the application of zinc up to 15 mg Zn kg^{-1} soil (Table 2) since zinc is an essential component of certain enzymes of nitrogen assimilation hence application of various levels of zinc might have increased the activity of the enzymes leading to more assimilation of nitrogen by the wheat plant resulting in increased content and uptake of nitrogen. Choudhary *et al.* (1997) also observed an increase in nitrogen content of grain and straw by wheat with increasing levels of zinc.

Phosphorus content reduced with the order of 2.75, 8.53 and 14.67% in grain due to W_1, W_2 and W_3, respectively, as compared to W_0. In straw reduction was 4.83 and 10.77% due to W_2 and W_3 as compared to W_0 while W_1 and W_0 were at par in their influence on total phosphorus content (Table 2). Application of 10 and 15 mg Zn kg^{-1} soil (Zn_2 and Zn_3) decreased the phosphorus content in grain by 4.14 and 7.05% and 3.01 and 5.70% in straw, respectively, as compared to no application of zinc (Zn_0). While Zn_1 and Zn_0 were at par in their influence on phosphorus content in grain and straw (Table 2). Reduction in phosphorus availability in saline soils was suggested to be a result of ionic strength effects that reduce the activity of phosphate, the tight control of phosphorus (concentrations by sorption processes and by the low solubility of Ca-P minerals). Phosphorus content of grain and

Table 2. Effect of EC_{iw} and zinc on nitrogen, phosphorus and potassium content (%) in grain and straw of wheat

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
EC_{iw} levels						
W_0	1.843	0.6872	0.3455	0.2525	0.426	1.431
W_1	1.840	0.6860	0.3360	0.2480	0.424	1.427
W_2	1.833	0.6832	0.3160	0.2403	0.413	1.409
W_3	1.831	0.6827	0.2948	0.2253	0.399	1.383
SEm±	0.017	0.0065	0.0031	0.0023	0.004	0.008
CD at 5%	NS	NS	0.0088	0.0066	0.010	0.024
Zn levels						
Zn_0	1.773	0.6611	0.3333	0.2490	0.407	1.394
Zn_1	1.816	0.6771	0.3298	0.2448	0.413	1.411
Zn_2	1.868	0.6964	0.3195	0.2415	0.422	1.428
Zn_3	1.890	0.7047	0.3098	0.2308	0.418	1.417
SEm±	0.017	0.0065	0.0031	0.0023	0.004	0.008
CD at 5%	0.050	0.019	0.0088	0.0066	0.010	0.024

straw decreased significantly with increasing level of zinc in the soil (Table 2) probably due to their antagonistic effect on phosphorus.

Potassium content decreased significantly with higher level of EC of irrigation waters. The application of W_1 quality water decreased the potassium content in grain by 2.58 and 6.33% and in straw by 1.53 and 3.35%, respectively, as compared to W_0 (control) while W_1 and W_0 were at par in their influence on potassium content in grain and straw, while the application of zinc at levels of Zn_2 and Zn_3 (10, 15 mg Zn kg^{-1} soil) increased the potassium content of grain to the extent of 3.68 and 2.70%, while that of straw to the extent of 2.43 and 1.65%, respectively, as compared to Zn_0 (control) while Zn_1 and Zn_0 were at par in their influence on total potassium content in grain and straw. The potassium content of grain and straw as well as its uptake by wheat (Table 2) decreased with increasing level of EC_{iw} of irrigation water due to adverse effect of excessive sodium on the absorption of potassium by plant.

Calcium and magnesium contents of grain and straw were not affected with increasing levels of EC_{iw} and different doses of zinc (Table 3).

Table 3. Effect of EC_{iw} and zinc on calcium, magnesium, sodium and zinc contents in grain and straw of wheat

Treatments	Calcium (%)		Magnesium (%)		Sodium (%)		Zinc (mg kg^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
EC_{iw} levels								
W_0	0.0728	0.1742	0.0439	0.1069	0.221	0.503	34.46	23.29
W_1	0.0734	0.1754	0.0440	0.1071	0.234	0.526	33.76	22.58
W_2	0.0741	0.1759	0.0444	0.1074	0.250	0.549	32.97	21.82
W_3	0.0739	0.1762	0.0446	0.1077	0.296	0.595	32.37	20.66
SEm±	0.0006	0.0016	0.0008	0.0010	0.003	0.005	0.314	0.208
CD at 5%	NS	NS	NS	NS	0.008	0.016	0.905	0.600
Zn levels								
Zn_0	0.0748	0.1756	0.0445	0.1072	0.252	0.545	31.98	21.71
Zn_1	0.0732	0.1754	0.0440	0.1071	0.252	0.545	32.94	21.72
Zn_2	0.0729	0.1753	0.0442	0.1073	0.250	0.544	33.72	22.32
Zn_3	0.0733	0.1754	0.0443	0.1074	0.248	0.539	34.92	22.60
SEm±	0.0006	0.0016	0.0008	0.0010	0.003	0.005	0.314	0.208
CD at 5%	NS	NS	NS	NS	NS	NS	0.905	0.600

While rise in EC level of irrigation water from W_0 to W_3 significantly increased the sodium content of both grain and straw. The increase in sodium content of grain due to the application of W_1, W_2 and W_3 was 5.88, 13.12 and 33.93% and in straw 4.57, 9.14 and 18.29%, respectively, as compared to well water (W_0). Higher sodium content may be because high EC water supplied excessive quantity of soluble salts in soil which could result in increased Na content. The data further revealed that various levels of zinc had no significant influence on the accumulation of Na in grain or straw. The higher EC_{iw} of irrigation water significantly decreased the zinc content of both grain and straw. The decrease in zinc content of straw due to application of W_1, W_2 and W_3 quality irrigation water was of the order of 3.01, 6.31 and 11.29%, respectively, as compared to well water irrigation. Babaian *et al.* (2003) suggested that in saline soils, some elements such as Mg, Ca and Na have antagonistic effects with micronutrients for uptake by roots. Thus, the solubility and availability of zinc cation to plants could decrease with increase in salinity level of the soil under high EC_{iw} irrigation. The increase in zinc content of grain due to application of Zn_1, Zn_2 and Zn_3 (5, 10 and 15 mg Zn kg^{-1} soil) was 3.00, 5.44 and 9.19%, respectively, while that in straw was 0.046, 2.81 and 4.09%, respectively, as compared to control. The highest content of zinc in grain and straw was recorded under Zn_3 as 34.92 and 22.6 mg kg^{-1}, respectively.

Conclusions

The grain and straw yield as well as phosphorus, potassium and zinc contents in both grain and straw decreased, but sodium content increased with EC of irrigation water. Application of zinc to the soil has favorable effect on the grain and straw yield as well as contents of nitrogen, phosphorus, potassium, calcium, magnesium, sodium and zinc in both grain and straw increased significantly. Phosphorus content of both grain and straw decreased with increasing application of zinc to the soil. The magnitude of addition of Zn to soils and use of saline waters for crop production is of special significance. Though combined use of organic and chemical amendments depending upon the local needs and resources available must be made use of in managing soils irrigated with saline waters, but soils badly suffer from the deficiency of micronutrients like Zn, which may be mitigated by adopting suitable form and doses of these nutrients. The results of the present study showed that deleterious effects of saline water could be alleviated to some extent by making use of suitable doses (15 mg kg^{-1} soil) of Zn.

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