

Original Research Article

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Effect of FYM and Zinc Application on Soil Nutrient availability, Soil enzyme activity and Nutrient Content and yield of Barley under Irrigation with Different Residual Sodium Carbonate Waters

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ABSTRACT

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Field experiment was conducted to work out the effect of different residual sodium carbonate (RSC) waters, FYM and zinc fertilization on soil nutrient availability, soil enzyme activity, nutrient content and yield of Barley on loamy sand soil during rabi seasons of 2013-14 and 2014-15. The treatments were: Three levels of RSC waters (control, 5 and 10 mmol L⁻¹), two levels of FYM (control and 15 t ha⁻¹) in main plot and four levels of zinc (control, 15, 30 and 45 kg ZnSO₄ ha⁻¹) in sub-plot. Result revealed that under irrigation with high RSC (10 mmol L⁻¹) of irrigation water the soil available N, P₂O₅ and K₂O content, soil enzyme activity, nutrient content viz., P, K, Ca, Mg and Zn and yield of grain and straw of barley was decreased significantly. Application of 15 t FYM ha⁻¹ showed significant improvement in soil available N, P₂O₅, K₂O, soil dehydrogenase enzyme activity at different months, nutrient content (N, P, K, Ca, Mg and Zn) and grain and straw yield of barley. The increasing level of Zn significantly increased the N, K, Zn, Ca, Mg content as well as grain and straw yield of barley at harvest, while, while, P, Na concentration in grain and straw were decreased significantly.

Introduction

In many parts of arid and semi-arid regions, ground water which is often of poor quality is used as a major source of irrigation. The continuous use of such water for irrigation creates salinity or sodicity in the soil. The soil degradation due to salinity and sodicity problems has affected larger areas of fertile tracts, particularly in arid and semi-arid regions of country and caused significant losses to crop productivity (Yadav, 2003). At present about 6.73 million hectare (Mha) salt affected soils exist in India. Out of which 2.96

Mha are saline and remaining 3.77 Mha are characterized as sodic soils (Anonymous, 2016). As regards to underground water quality in Rajasthan state, only 16% is good, 16% marginal and 68% is of poor quality, whereas, under poor quality water category, distribution of saline, sodic and saline sodic waters are about 16, 35 and 49%, respectively (Sen, 2003).

The role of FYM in promoting reclamation of sodic soils through improvement of soil physical conditions, greater mobilization of

native Ca, reduction in pH and enhancement of biological activities is well known. All this could be achieved through use of technology and inputs. The organic supplementations not only meet the nutrient requirements of plant but also sustain microbial activity, catalyzing crop production. Organic manures also, catalyzing mitigate the adverse effect of alkalinity which develops due to use of high RSC irrigation water, by means of increasing aeration, permeability and infiltration rate of soil (Abbas and Fadul, 2013).

Soil enzymatic activity are typically concentrated in the top few centimetres of soil (Murphy *et al.*, 1998) changes in chemistry near the surface (such as increased salinity or sodicity) could greatly affect soil enzymatic activity. The nutrient transformation processes in soil are governed by enzymatic activity, which plays an important role in the initial stages of oxidation of organic matter of the soil. It also helps in improving soil structure, which is required for sustaining crop productivity as well as soil health.

In India, Zinc is now considered the fourth most important yield-limiting nutrient after nitrogen, phosphorus and potassium, respectively (Arunachalam *et al.*, 2013). Zinc deficiency in soils of India is likely to increase from 49 to 63 % by the year 2025 as most of the marginal soils brought under cultivation are showing zinc deficiency (Singh, 2006). Continuous use of high RSC water increases the ESP and pH of soil which decreases the availability of Zn. As the soil pH increase, the ionic form of Zn is 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 (Shukla and Mukhi, 1980), however,

no systematic study has been conducted on application of zinc to soils irrigated with high RSC water in the region. The present investigation was, therefore, undertaken to study the effect of FYM and zinc application on soil properties, build-up of microbial biomass and yield of barley under irrigation with varying levels of RSC water.

Materials and Methods

The experiment was conducted at the Agronomy Farm, Sri Karan Narendra Agriculture College, Jobner during rabi 2013-2014 and 2014-15. The site is situated at 26°05 N latitude and 75°28 E longitude at an altitude of 427 m above mean sea level. The region falls under agroclimatic zone of Rajasthan zone III-A (semi arid eastern plain). The experimental soil (0.0-0.15 m depth) had pHs 8.10, ECe 2.56 dS m⁻¹, organic carbon 1.80 g kg⁻¹, available N 133.60 kg ha⁻¹, available P 9.48 kg ha⁻¹, available K 159.15 kg ha⁻¹ and available Zn 0.38 ppm. The experiment was laid out in a split block design with 24 treatment combinations of three levels of RSC waters, two levels of FYM and four levels of ZnSO₄ with four replications. The RSC waters were synthesized by dissolving required quantities of NaCl, Na₂SO₄, NaHCO₃, CaCl₂ and MgSO₄ in base water of 2.5 mmol L⁻¹. To check the lateral movement of water and salts, buffer strips around each irrigation channel were kept. The RSC water levels were 2.5 (base water), 5.0 and 10.0 mmol L⁻¹. Nitrogen was applied as per recommended dose of 100 kg N ha⁻¹. The farmyard manure was applied @ 15 t ha⁻¹. The farmyard manure contained 16.40% total carbon, 0.55% N, 0.25% P, 0.51% K and had a C:N ratio of 29.7. The FYM was applied 15 days before sowing of crop. Half of N as per treatment through urea was applied as basal. The remaining half dose of N was applied before first irrigation. Grain and straw yield were

recorded at harvest, after complete drying the produce of individual plot was weighed before threshing and the weight recorded as biological yield. After recording the biological yield, the material was threshed manually and winnowed. The clean grains obtained from individual plots were weighed and the weight recorded as grain yield. Straw yield was obtained by subtracting the grain yield from biological yield. The grain and straw yield recorded under each plot were converted into quintals per hectare. Soil samples (0-15 cm) were collected before sowing and after harvesting of the crop from net plots for the study of chemical and biological properties viz. available N, P₂O₅, K₂O, dehydrogenase, alkaline phosphatase and microbial C, N and P with the help of standard methods. All the replicated data obtained from the experiments for consecutive two years of study were statistically analysed using F-test (Gomez and Gomez, 1984). Least significant difference (LSD) values at $p=0.05$ were used to determine the significance of differences between treatment means.

Results and Discussion

Available nutrient status of soil

The data presented in Table 1 reveals that the available N, P and K content of soil after harvest stage of crop decreased significantly with increasing levels of RSC in irrigation water during both the years as well as in pooled analysis. Availability of N, P and K decreased with increased levels of RSC in water could be due to high pH of soil. As soil pH increased, biological activity becomes low, which is not conducive for organic matter and its mineralization in soil. Transformations are adversely affected by high pH and sodicity. High soil pH coupled with poor physical conditions also adversely affects the transformations and availability of

nutrients in soil. The results are in close agreement with the findings of Singh *et al.*, (2005) and Yaduvanshi (2015).

Soil enzyme activity

Data given in table 2 reveal that activity of dehydrogenase enzyme were also significantly lowered with increasing level of RSC over normal water and with intervals of time, the reduced dehydrogenase activity in sodic soils due to reduction of organic matter in sodic condition and indirect effect of the structural decline of the sodic soil. Similar results were reported by Pareek and Yadav (2011).

Plant Nutrient content

Data in table 3 and 4 reveals that N and Na content in grain and straw increased significantly, while P, K, Ca, Mg and Zn content decreased significantly with increasing level of RSC in irrigation water in pooled. The increase in levels of RSC water resulted into increased concentration of Na in soil solution and on adsorbing complex which caused an increase in ESP and pHs of soil and also of marked increased in Na content in grain and straw of barley. Further, under higher sodic conditions, the activity of nitrifying bacteria lower down or checked which results into low availability of N to the plant causing stunted growth and development of plant. According to Strogonov and Okinia (1961), 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 grain and straw. Contrary, the P and K content in grain and straw decreased due to increasing levels of RSC in irrigation water. This might be due to the fact that increasing RSC water increased pH of soil.

Table.1 Effect of RSC water, FYM and Zinc levels on available N, P₂O₅ and K₂O content in soil after harvest of crop

<i>Treatments</i>	Available N (kg ha ⁻¹)			Available P ₂ O ₅ (kg ha ⁻¹)			Available K ₂ O (kg ha ⁻¹)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RSC levels									
W ₁ (2.5 mmol L ⁻¹)	136.46	136.84	136.65	20.38	20.38	20.38	230.93	230.94	230.94
W ₂ (5 mmol L ⁻¹)	133.12	133.50	133.31	19.26	19.26	19.26	229.19	229.19	229.19
W ₃ (10 mmol L ⁻¹)	125.12	125.50	125.31	15.29	15.30	15.29	223.60	223.61	223.60
SEm _±	0.67	0.71	0.49	0.11	0.19	0.11	1.15	1.47	0.93
CD (P=0.05)	2.03	2.13	1.41	0.32	0.58	0.32	3.45	4.43	2.69
FYM levels									
F ₀ (Control)	129.30	129.68	129.49	17.39	17.39	17.39	224.19	224.20	224.20
F ₁ (15 t ha ⁻¹)	133.83	134.21	134.02	19.23	19.24	19.24	231.62	231.63	231.63
SEm _±	0.55	0.58	0.40	0.09	0.16	0.09	0.94	1.20	0.76
CD (P=0.05)	1.65	1.74	1.15	0.26	0.47	0.26	2.82	3.62	2.20
Zinc levels									
Zn ₀ (Control)	132.26	132.42	132.34	18.17	18.18	18.17	225.78	225.93	225.86
Zn ₁₅ (15 kg ZnSO ₄ ha ⁻¹)	132.21	132.26	132.23	18.30	18.20	18.25	228.01	228.02	228.02
Zn ₃₀ (30 kg ZnSO ₄ ha ⁻¹)	131.23	131.85	131.54	18.30	18.43	18.36	228.62	228.63	228.62
Zn ₄₅ (45 kg ZnSO ₄ ha ⁻¹)	130.56	131.26	130.91	18.48	18.44	18.46	229.21	229.08	229.15
SEm _±	0.82	0.77	0.56	0.11	0.12	0.08	1.44	0.98	0.87
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non significant at 5% level of significance

Table.2 Effect of organic manures, moisture regimes and salinity levels on soil dehydrogenase activity (pKat kg⁻¹ soil) at different month

Treatments	2013-14 (month after sowing)				2014-15 (month after sowing)			
	I	II	III	IV	I	II	III	IV
RSC levels								
W ₁ (2.5 mmol L ⁻¹)	18.43	17.50	15.96	15.14	18.63	17.56	15.92	15.22
W ₂ (5 mmol L ⁻¹)	17.36	16.15	15.52	14.79	17.50	16.16	15.86	14.89
W ₃ (10 mmol L ⁻¹)	14.58	13.11	11.92	10.86	14.66	13.12	12.14	10.96
SEm _±	0.09	0.11	0.08	0.07	0.12	0.11	0.09	0.08
CD (P=0.05)	0.26	0.33	0.24	0.22	0.38	0.33	0.26	0.23
FYM levels								
F ₀ (Control)	15.83	14.81	13.63	12.67	15.97	14.86	13.85	12.76
F ₁ (15 t ha ⁻¹)	17.75	16.35	15.31	14.52	17.90	16.37	15.43	14.62
SEm _±	0.07	0.09	0.06	0.06	0.10	0.09	0.07	0.06
CD (P=0.05)	0.22	0.27	0.19	0.18	0.31	0.27	0.21	0.19
Zinc levels								
Zn ₀ (Control)	16.69	15.35	14.42	13.46	16.81	15.52	14.56	13.67
Zn ₁₅ (15 kg ZnSO ₄ ha ⁻¹)	16.70	15.53	14.47	13.60	16.82	15.53	14.64	13.68
Zn ₃₀ (30 kg ZnSO ₄ ha ⁻¹)	16.81	15.72	14.49	13.66	17.01	15.69	14.66	13.69
Zn ₄₅ (45 kg ZnSO ₄ ha ⁻¹)	16.97	15.74	14.51	13.67	17.09	15.73	14.70	13.72
SEm _±	0.11	0.13	0.09	0.10	0.13	0.12	0.10	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table.3 Effect of RSC water, FYM and Zinc levels on N, P, K content (%) in grain and straw after harvest

<i>Treatments</i>	N content (%) Pooled		P content (%) Pooled		K content (%) Pooled	
	grain	Straw	grain	Straw	grain	Straw
RSC levels						
W ₁ (2.5 mmol L ⁻¹)	0.364	0.232	0.159	0.089	0.249	0.542
W ₂ (5 mmol L ⁻¹)	0.339	0.200	0.148	0.079	0.267	0.663
W ₃ (10 mmol L ⁻¹)	0.315	0.172	0.140	0.069	0.317	0.745
SEm±	0.001	0.001	0.001	0.000	0.002	0.003
CD (P=0.05)	0.004	0.003	0.002	0.001	0.005	0.009
FYM levels						
F ₀ (Control)	0.332	0.197	0.147	0.078	0.281	0.662
F ₁ (15 t ha ⁻¹)	0.347	0.207	0.151	0.080	0.273	0.638
SEm±	0.001	0.001	0.001	0.000	0.001	0.003
CD (P=0.05)	0.003	0.002	0.002	0.001	0.004	0.007
Zinc levels						
Zn ₀ (Control)	0.329	0.195	0.144	0.076	0.287	0.677
Zn ₁₅ (15 kg ZnSO ₄ ha ⁻¹)	0.337	0.200	0.148	0.078	0.281	0.658
Zn ₃₀ (30 kg ZnSO ₄ ha ⁻¹)	0.345	0.205	0.152	0.081	0.274	0.636
Zn ₄₅ (45 kg ZnSO ₄ ha ⁻¹)	0.346	0.206	0.153	0.082	0.268	0.630
SEm±	0.002	0.232	0.001	0.000	0.001	0.003
CD (P=0.05)	0.005	0.200	0.002	0.001	0.004	0.009

NS = Non significant at 5% level of significance

Table.4 Effect of RSC water, FYM and Zinc levels on Ca, Mg, Na, Zn content (%) in grain and straw after harvest

<i>Treatments</i>	Ca content (%)		Mg content (%) Pooled		Na content (%)		Zn content (%)	
	Pooled		grain	Straw	Pooled		Pooled	
	grain	Straw	grain	Straw	grain	Straw	grain	Straw
RSC levels								
W ₁ (2.5 mmol L ⁻¹)	0.364	0.232	0.159	0.089	0.249	0.542	44.58	34.08
W ₂ (5 mmol L ⁻¹)	0.339	0.200	0.148	0.079	0.267	0.663	44.32	34.11
W ₃ (10 mmol L ⁻¹)	0.315	0.172	0.140	0.069	0.317	0.745	43.16	32.70
SEm _±	0.001	0.001	0.001	0.000	0.002	0.003	0.19	0.15
CD (P=0.05)	0.004	0.003	0.002	0.001	0.005	0.009	0.55	0.43
FYM levels								
F ₀ (Control)	0.332	0.197	0.147	0.078	0.281	0.662	43.50	33.12
F ₁ (15 t ha ⁻¹)	0.347	0.207	0.151	0.080	0.273	0.638	44.53	34.14
SEm _±	0.001	0.001	0.001	0.000	0.001	0.003	0.15	0.12
CD (P=0.05)	0.003	0.002	0.002	0.001	0.004	0.007	0.45	0.35
Zinc levels								
Zn ₀ (Control)	0.329	0.195	0.144	0.076	0.287	0.677	43.05	33.13
Zn ₁₅ (15 kg ZnSO ₄ ha ⁻¹)	0.337	0.200	0.148	0.078	0.281	0.658	43.72	33.30
Zn ₃₀ (30 kg ZnSO ₄ ha ⁻¹)	0.345	0.205	0.152	0.081	0.274	0.636	44.55	33.96
Zn ₄₅ (45 kg ZnSO ₄ ha ⁻¹)	0.346	0.206	0.153	0.082	0.268	0.630	44.75	34.13
SEm _±	0.002	0.232	0.001	0.000	0.001	0.003	0.20	0.15
CD (P=0.05)	0.005	0.200	0.002	0.001	0.004	0.009	0.56	0.42

NS = Non significant at 5% level of significance

Table.5 Effect of RSC water, FYM and Zinc levels on grain and straw yield (q ha⁻¹) of barley

Treatments	Grain yield			Straw yield		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RSC levels						
0	44.84	46.45	45.64	65.56	66.36	65.96
5	43.87	45.49	44.68	64.82	65.89	65.35
10	37.05	38.81	37.93	58.31	59.03	58.67
SEm±	0.61	0.71	0.47	0.93	0.94	0.66
CD (p=0.05)	1.84	2.15	1.35	2.80	2.83	1.91
FYM levels						
0	40.36	42.10	41.23	61.34	62.14	61.74
15	43.49	45.07	44.28	64.45	65.37	64.91
SEm±	0.50	0.58	0.38	0.76	0.77	0.54
CD (p=0.05)	1.50	1.75	1.11	2.29	2.31	1.56
Zinc levels						
0	40.52	42.13	41.32	59.94	60.92	60.43
15	41.55	43.19	42.37	61.70	62.42	62.06
30	42.64	44.56	43.60	64.81	65.76	65.29
45	42.99	44.46	43.72	65.13	65.93	65.53
SEm±	0.49	0.61	0.39	0.90	0.75	0.58
CD (p=0.05)	1.37	1.73	1.09	2.53	2.12	1.63

The resulted higher sodicity of the soil could have decreased the mobility of P due to presence of Na. At higher pH, the proportions of HPO_4^{2-} and PO_4^{3-} have increased over H_2PO_4^- . The presence of OH^- ions, the availability of P to the plant is reduced. The physiological availability of P in alkali soil is a fraction of pH and it decreases as the pH increase over the alkaline range (Pratt and Thorne, 1948 and Sauchelli, 1965). Further, the decrease in content of K in grain and straw of barley as influenced by various levels of exchangeable sodium, increased Na saturation of soil was accompanied by an extensive depletion of K in plant (Moustafa *et al.*, 1966). This can be explained on the basis of hypothesis of Heimann (1958) who was of the view that Na-K relationship may be synergistic or antagonistic depending upon the ratio between them. The decrease in K content in grain and straw of barley with an increase in RSC in irrigation water was also reported by Singh *et al.*, (2005) and Mahmood (2011). The Ca and Mg content of both grain and straw decreased significantly with increasing levels of RSC in irrigation water. This may be due to the fact that the increase in Na concentration, either in soil solution or on adsorbing complex owing to precipitation of Ca and Mg into sparingly soluble CaCO_3 and MgCO_3 , thus, decreases its availability to crop plants. The increasing levels of RSC in irrigation water decreased the Zn in grain and straw, might be due to the fact that increased alkali concentration decreased in the Zn content may be ascribed to the conversion of Zn^{2+} to its unavailable form under sodic environment generated by high RSC water. Similar findings were also reported by, Yadav (1999), Jatav (2000) and Yadav (2001) and Jakhar *et al.*, (2013).

The N, P, K, Ca, Mg and Zn content in grain and straw of barley increased significantly, whereas Na content in grain and straw decreased significantly with application of

FYM @ 15 t ha⁻¹ in pooled analysis (Table 3 to 4). The higher content of nutrients in grain and straw of barley may be attributed to increased available nutrient status of soil due to application of FYM. The improvement in properties of soil as observed in the present study (Table 2) coupled with steady and slow release of macro and micro nutrients during microbial decomposition of FYM increased the available nutrient pool of soil. As stated earlier, under higher availability of nutrients, the plants absorbed nutrients liberally without any hindrance which resulted in improved photosynthesis, production of assimilates and their efficient partitioning into different sinks resulting into higher nutrient content of grain and straw. The decrease in Na content of grain and straw was a consequence of lesser availability of Na in soil solution due to reduction in ESP under increased application of FYM which resulted in decreased absorption by plants and ultimately the content. The decrease in Na concentration in grain and straw of barley have also been reported by Poonia and Bhumbra (1974). The findings of the present investigation get support from the results of Singh and Singh (2001), Sharma and Sharma (2002) and Mann *et al.*, (2006), who also reported that increase nutrients in grain and straw of barley, may be attributed to increase available nutrient status of soil due to application of FYM under irrigation with high sodic water. The N, K, Ca, Mg and Zn content in grain and straw of barley increased significantly with increasing level of zinc upto 30 kg ZnSO_4 ha⁻¹ in pooled analysis (Table 3 to 4). The P and Na content decreased significantly with increasing level of zinc in pooled analysis. The significant response of barley to zinc is due to low status of Zn availability in experimented soil and alkalinity of soil. The low magnitude of response at higher level of Zn is due to increase in availability of Zn at higher level leading to toxic effect of this dose on the adsorption of various nutrients

which is supported by lower concentration of P and higher concentration of Zn in grain and straw. This appears to have caused nutrient imbalance in plant system. The beneficial role of Zn in increasing CEC of roots helped in increasing adsorption of nutrients from the soil. Further, the beneficial role of Zn in chlorophyll formation, regulating auxin concentration and its stimulatory effect on most of physiological and metabolic process of plant, might have helped to plants in absorption of greater amount of nutrients from the soil. Thus, the favourable effect of Zn on photosynthesis and metabolic process augmented the production of photosynthates and their translocation to different plant parts including grain which ultimately increased the concentration of nutrients in the grain. The reduction in the concentration of P owing to application of Zn might be due to antagonism relationship of Zn and P (Olsen, 1972). The increased concentration of Zn created hindrance in absorption and translocation of P from the roots to the above plant parts (Damodhar Reddy and Yadav, 1994). Ca and Mg concentration in grain and straw increased with increasing level of Zn. The Na content in grain and straw decreased with the application of increasing level of Zn, this may be due to the fact that on the exchangeable complex, the Na will be replaced by Zn which results into more absorption of Zn than Na by plants. This led to the lower concentration of Na in grain and straw.

Yield

The grain and straw yield of barley decreased significantly with increase in level of RSC in irrigation water during both the years and also when data were pool (Table 5). This may be explained on the basis that increasing RSC in irrigation water increased the ESP and pH of soil resulting into decreased availability of N, P, K, Ca and Mg but increased the content of Na which is toxic to plant. The higher amount

of Na may adversely affect the physiological, metabolic and enzymatic activities and utilization of photosynthates in plant, resulting into poor root development and plant growth and ultimate decrease in yield of barley (Bajwa *et al.*, 1982).

The application of 15 t FYM ha⁻¹ substantially increased the grain and straw yield of barley over control in both the years (Table 5). The increase in yield due to addition of FYM might be the result of overall improvement in soil physicochemical properties of sodic soil due to decrease in pH, EC, and ESP; and increase in saturated hydraulic conductivity and cation exchange capacity. The higher nutrient availability and congenial environment for their uptake favoured greater synthesis of carbohydrates and their efficient portioning into different sinks including reproductive structures which ultimately brought about significant improvement in yield (Abbas and Fadul, 2013). Similar results were also reported by Ghosh and Singh (2003) and Thakur *et al.*, (2011).

The increasing level of Zn application upto 30 kg ZnSO₄ ha⁻¹ significantly increased grain and straw yield during both the years and in pooled analysis (Table 5). The favourable influence of applied Zn on these characters may be explained to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants. Zinc is also an essential component of enzymes that are responsible for assimilation of N. It also helps in chlorophyll synthesis and plays an important role in N metabolism thereby resulting into increased uptake of N by the plants. Besides, Zn also enhances the absorption of essential nutrients by increasing the CEC of roots. The application of zinc in a soil deficient in its status, improved overall growth and development of plants and ultimately the grain and straw yield under

irrigation with high RSC water (Jakhar *et al.*, 2013). Increase in grain and straw yields due to Zn application may be attributed to the fact that the initial status of available Zn in the experimental soil (Table 5) was low and an increase in the yield was expected. These findings of present investigation are supported by Sharma *et al.*, (2002).

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