International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(2): 370-377

Received: 22-01-2017
Accepted: 23-02-2017

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Effect of FYM and Zinc application on Soil Microbial Biomass, Nutrient Uptake, Sodicity tolerance and yield of Barley under Irrigation with different residual sodium carbonate waters

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Abstract
Field experiment was conducted to work out the effect of different residual sodium carbonate (RSC) waters, FYM and zinc fertilization on soil microbial biomass, nutrient uptake, sodicity tolerance 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 $ZnSO_4$ ha^{-1}) in sub-plot. Result revealed that under irrigation with high RSC (10 mmol L^{-1}) of irrigation water the soil biological activity like microbial biomass C, N and P at different months, nutrient uptake *viz.*, N, P, K, Ca, Mg, Zn, Ca/Mg ratios and yield of grain and straw of barley was decreased significantly, while, Na/K, Na+K/Ca and Na/Ca ratio of grain and straw increased significantly with increasing RSC in irrigation water. Application of 15 t FYM ha^{-1} showed significant increase in soil microbial biomass C, N and P at different months. The nutrient uptake (N, P, K, Ca, Mg and Zn), Ca/Mg ratio and yield of grain and straw of barley, increased significantly, while, Na/K, Na+K/Ca and Na/Ca ratio decreased significantly due to application of FYM @15 t ha^{-1} in grain and straw. The increasing level of Zn significantly increased the N, K, Zn, Ca, Mg uptake and yield of grain and straw of barley at harvest, while, Na/K, Na+K/Ca and Na/Ca ratios in grain and straw were decreased significantly.

Keywords: RSC water, zinc, barley, FYM, microbial biomass, nutrient uptake, sodicity tolerance

1. 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) [40]. 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) [2]. 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) [30].

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) [1].

Since the microbial community plays a critical role in regulating processes such as decomposition of organic matter and nutrient cycling, in the soil at the ecosystem level, there is a keen interest in understanding the factors that regulate its size, activity and structure (Zeller *et al.*, 2001) [41]. The importance of the size of microbial biomass is emphasised by the fact that this is the eye of the needle through which all organic material that enters the soil must pass (Jenkinson, 1977) [15].

Besides the size of microbial biomass, its functional and structural diversity has relevance as well. Functional diversity (e.g., microbial activity) is significant, because 80–90% of the processes in soil are reactions mediated by micro-organisms (Nannipieri and Badalucco, 2003) [25]. Asses-sing the composition of soil microflora gives an insight into the response of soil ecosystems to environmental changes or human impacts: healthy ecosystems are characterised by high structural diversity, and vice versa, microbial communities with a low structural diversity can hardly respond to environmental changes (Mader *et al*., 2002) [18].

In India, Zinc is now considered the fourth most important yield-limiting nutrient after nitrogen, phosphorus and potassium, respectively (Arunachalam *et al*., 2013) [3]. 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) [32], 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.

2. 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 $ZnSO_4$ with four replications. The RSC waters were synthesized by dissolving required quantities of NaCl, Na_2SO_4, $NaHCO_3$, $CaCl_2$ and $MgSO_4$ 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. Microbial biomass C, N and P were analysed following chloroform fumigation method, 50 g soil was fumigated for 24 h under vacuum in a vacuum desiccator using ethanol-free chloroform. Non-fumigated (50 g) and fumigated soils were extracted using 200 mL of 0.5 *M* K_2SO_4 and extracts were used for determining carbon (Vance *et al*., 1987) [39], nitrogen (Brookes *et al*., 1985) [6] and phosphorus (Brookes *et al*., 1982) [7]. Biomass C, N and P were computed as: Soil microbial biomass C = Fc/0.45, where, Fc = organic carbon extracted by 0.5 *M* K_2SO_4 from fumigated soil - organic carbon extracted from non-fumigated soil.

Soil microbial biomass N = Fn / 0.68 where, Fn = (flush of mineral N in fumigated soil non- fumigated soil).

Soil microbial biomass P = Pi /0.40

where, Pi = (amount of, inorganic P extracted from fumigated soil – non-fumigated soil).

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 grain obtained from individual plots were weighed and the weight recorded as grain yield.

The nutrient uptake was calculated by using the following formula:

$$\text{Nutrient uptake of N, P, K, Ca, Mg, Na by Grain/straw } ((\text{kg ha}^{-1}) = \frac{\dfrac{\text{Nutrient content} \times \text{Grain/straw yield (kg ha}^{-1})}{\text{In Grain/straw (\%)}}}{100}$$

$$\text{Nutrient uptake of Zn by Grain/straw (g ha}^{-1}) = \frac{\text{Nutrient content In Grain/straw (\%)} \times \text{Grain/straw yield (kg ha}^{-1})}{1000}$$

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.

3. Results and discussion

Microbial Biomass

Data in table 1, 2 and 3 reveals that the the amount of microbial biomass C, N and P declined with increasing RSC in irrigation water. Data further show that the microbial biomass also decreased with the advancement of the crop growth and attained the lowest value in the soil sampled after harvesting. The reduction in the microbial biomass at crop maturity and at higher level of RSC water is due to deleterious effect of sodic water on soil physico-chemical properties and organic matter content. Similar results were also reported by Pareek and Yadav (2011) [26] and Singh *et al*., (2013) [34] indicated that soil microbial biomass C, N and P decreased with increasing RSC in irrigation water. The amount of microbial biomass C, N, P increased significantly due to incorporation of FYM into the soil. In general, there was an increase in microbial growth with the addition of carbon substrate and it declined as the available carbon exhausted (Manna *et al*., 1996) [20]. Microbial, C, N, P were maximum at initial stages of crop growth under manuring with 15 t ha^{-1} FYM application and reached minimum at the later stages of crop growth. The availability of carbonaceous materials and substrates such as sugars, amino acids and organic acids in the soil from the decomposing organic materials and decay of roots under the plant canopy are important for supplying energy for microbial population (Bowen and Rovira, 1991) [5]. High soil organic carbon, more root decomposition and additional supply of N through FYM to microorganism may be reason for improving microbial biomass (Desmukh *et al*, 2015) [8]. Such increase in microbial C, N and P due to FYM were also reported by Singh *et al*., (2008) [35] and Moharana *et al*., (2014) [22]. The increase in microbial biomass C, N, P might also be due to reduction in pHs of soil on account of addition of FYM.

Nutrient uptake

Data given in table 4 and 5 reveals that a marked increase in uptake of Na in grain and straw with higher level of RSC in irrigation water, while N, P, K, Ca, Mg and Zn uptake decreased significantly with higher level of RSC in irrigation water in pooled mean. 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 and uptake in grain and straw of barley. Contrary, the P and K uptake 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. 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) [27, 28]. Further, the decrease in uptake 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) [1]. This can be explained on the basis of hypothesis of Heimann (1958) [13] who was of the view that Na-K relationship may be synergistic or antagonistic depending upon the ratio between them. The Ca and Mg uptake 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. Further, increasing RSC in irrigation water causes Na antagonism to Ca and Mg uptake in crop plants. The decreased Zn uptake in grain and straw with increasing levels of RSC in irrigation water, 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 Jakhar *et al.,* (2013) [14].

The N, P, K, Ca, Mg and Zn uptake in grain and straw of barley increased significantly, with application of FYM @ 15 t ha^{-1} in pooled analysis (Table 5). The higher uptake of these 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 with FYM application 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 uptake and content of grain and straw. The findings of the present investigation get support from the results of Sharma and Sharma (2002) [31] and Mann *et al*., (2006) [19], 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 uptake in grain and straw of barley increased significantly with increasing level of zinc upto 30 kg $ZnSO_4$ ha^{-1} in pooled analysis (Table 5). The P and Na uptake in grain and straw increased but does not reach the level of significance 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 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 uptake of nutrients in the grain.

Sodicity tolerance

Data in table 6 reveal that the Specific accumulation of Na^+ in plant tissue is toxic causing growth inhibition of plants resulted into low cytoplasmic Na^+ concentration is important for many plants growing in Na^+ affected environments. Plant cells maintain a low cytosolic Na^+ concentration presumably through Na^+ exclusion and extrusion or compartmentation inspite of higher accumulation. Barley presumably adopted some physiological mechanisms to restrict physiological interference of excess Na even in the event of excess uptake resulting in economic growth performance in sodic environment. Similar observations have also been reported by Jakhar *et al.,* (2013) [14].

The Na/K and Na+K/Ca ratios in grain and straw of barley increased significantly with increasing levels of RSC water (Table 4.40 and 4.42). This may be due to the fact that Na concentration increased with the increase in RSC of water, while the K and Ca concentration decreased in soil as well as in grain and straw. Sodicity tolerance was generally associated with efficient K regulation in shoot. The results find support from the work of Joshi *et al.,* (1980) [16].

The lower Ca/Mg and higher Na/Ca ratio in grain and straw of barley was noted with increasing levels of RSC water (Table 6). As stated earlier, the application of higher RSC water increased the concentration of Na consequently Na may inhibit the radial movement of Ca and Mg from the external solution to the root xylem by screening of cation exchange sites in the apoplast. High level of Na may adversely affect the nutritional status of plants by interfering with absorption and translocation of Ca^{2+} and Mg^{2+} resulting in salt toxicity caused by high Na/Ca and Ca/Mg ratios. The higher Na/Ca and lower Ca/Mg ratio at higher levels of RSC water showed more tolerance to sodicity. The results are also supported with the findings Naga (2013) [24] in wheat and Kumawat and Yadav (2013) [17] in fenugreek also reported higher Na/Ca and lower Ca/Mg ratio in grain and straw with increasing sodicity in soil irrigation water.

Application of FYM @ 15 t ha^{-1} narrowed the Na/K, Na+K/Ca and Na/Ca ratio in grain and straw significantly, while it increased the Ca/Mg ratio in grain and straw significantly over no application (Table 6). Thus, the application of FYM also played a beneficial role to overcome the adverse effect of different RSC water and help in induced the sodicity tolerance. The favorable influence of applied FYM on growth and yield as well as on mineral composition in grain and straw might be due to its catalytic effect on most of the physiological and metabolic process in plant.

The FYM is related to contains nutrients readily available to plant such as N, P, K, Ca, Mg, Fe, Mn, Zn and Cu etc. (Edwards and Brows, 1988) and also contain biological active substance such as plant growth regulators and enzymes (Grappolli *et al.*, 1987, and Tomati *et al.*, 1987) [12, 38], therefore, its stimulatory effect on increase in the concentration of Ca^{2+} ions and decreased in the concentration of Na ions in grain and straw, caused lower down the ratios mentioned above due to FYM application. Similar findings were also reported by (Kumawat and Yadav, 2013) [17].

Application of Zn narrowed the Na/K, Na+K/Ca and Na/Ca in grain and straw (Table 6). Application of Zn decreases Na^+ ion content and increases K^+ and Ca^{2+} ion content in plant (Saxena and Rewari, 1990) [29]. Decrease in Na/K ratio on addition of increasing doses of Zn in plants was also reported by Shukla and Prasad (1974) [33]. Elevated Ca level generated due to Zn application in present study have been found to partly mitigate the adverse effects of sodicity by reducing Na content (Mishra, 2001). The results are in close conformity with the work of Naga (2013) [24], Kumawat and Yadav (2013) [17] and Faujdar and Sharma (2014) [10].

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 7). 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 uptake 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) [4].

The application of 15 t FYM ha^{-1} substantially increased the grain and straw yield of barley over control in both the years (Table 7). 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) [1]. Similar results were also reported by Ghosh and Singh (2003) [11] and Thakur *et al*., (2011) [37].

The increasing level of Zn application upto 30 kg $ZnSO_4$ ha^{-1} significantly increased grain and straw yield during both the years and in pooled analysis (Table 7). 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) [14]. 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 7) was low and an increase in the yield was expected. These findings of present investigation are supported by Sharma *et al.*, (2002) [31].

Table 1: Effect of RSC water, FYM and Zinc levels on microbial biomass carbon (µg g^{-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})	162.02	143.04	126.93	101.16	163.68	139.22	124.36	102.06
W_2 (5 mmol L^{-1})	125.01	120.49	115.48	88.97	129.36	116.57	112.90	85.11
W_3 (10 mmol L^{-1})	109.88	101.04	95.54	75.26	108.43	96.74	92.96	77.68
SEm±	0.71	0.62	0.73	0.79	0.68	0.75	0.50	0.71
CD (P=0.05)	2.15	1.87	2.20	2.38	2.05	2.25	1.52	2.14
FYM levels								
F_0 (Control)	130.14	119.28	110.09	87.27	131.63	112.01	105.03	87.24
F_1 (15 t ha^{-1})	134.46	123.76	115.20	89.65	136.01	123.02	115.12	89.33
SEm±	0.58	0.51	0.60	0.65	0.56	0.61	0.41	0.58
CD (P=0.05)	1.76	1.53	1.80	1.94	1.68	1.84	1.24	1.74
Zinc levels								
Zn_0 (Control)	130.80	120.63	111.27	88.05	133.13	116.70	109.28	87.94
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	132.92	121.61	112.88	88.15	134.25	117.51	110.26	87.79
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	132.40	121.76	112.97	88.57	133.84	117.77	110.35	88.61
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	133.09	122.09	113.48	89.08	134.07	118.07	110.39	88.80
SEm±	0.76	0.58	0.72	0.68	0.66	0.73	0.94	0.54
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non significant at 5% level of significance

Table 2: Effect of RSC water, FYM and Zinc levels on microbial biomass nitrogen (µg g^{-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})	28.07	26.76	23.80	20.00	27.75	25.74	23.52	19.49
W_2 (5 mmol L^{-1})	25.55	23.21	20.04	19.56	24.90	22.14	20.96	19.12
W_3 (10 mmol L^{-1})	21.62	20.93	18.01	17.32	21.28	19.87	18.67	16.82
SEm±	0.13	0.13	0.15	0.09	0.12	0.12	0.12	0.10
CD (P=0.05)	0.40	0.38	0.46	0.28	0.37	0.37	0.36	0.29
FYM levels								
F_0 (Control)	24.26	22.28	19.33	18.33	23.86	21.22	19.67	17.87
F_1 (15 t ha^{-1})	25.90	24.99	21.90	19.59	25.43	23.94	22.43	19.08
SEm±	0.11	0.10	0.12	0.08	0.10	0.10	0.10	0.08
CD (P=0.05)	0.33	0.31	0.37	0.23	0.30	0.30	0.29	0.23
Zinc levels								
Zn_0 (Control)	24.91	23.58	20.44	18.88	24.46	22.54	20.89	18.41
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	24.96	23.64	20.51	18.94	24.51	22.58	20.95	18.44
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	25.17	23.65	20.66	18.95	24.80	22.60	21.10	18.45
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	25.28	23.68	20.85	19.07	24.81	22.61	21.25	18.62
SEm±	0.16	0.13	0.17	0.10	0.16	0.13	0.14	0.11
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non significant at 5% level of significance

Table 3: Effect of RSC water, FYM and Zinc levels on microbial biomass phosphorus (µg g^{-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})	12.02	11.74	9.64	7.29	12.19	11.68	9.60	7.08
W_2 (5 mmol L^{-1})	10.77	10.35	8.05	6.75	10.98	10.29	8.02	6.88
W_3 (10 mmol L^{-1})	9.01	8.74	7.56	6.56	9.03	8.26	7.48	5.66
SEm±	0.06	0.06	0.07	0.05	0.07	0.07	0.05	0.05
CD (P=0.05)	0.18	0.20	0.21	0.14	0.20	0.20	0.15	0.14
FYM levels								
F_0 (Control)	9.61	9.33	7.26	6.03	9.79	9.13	7.22	5.44
F_1 (15 t ha^{-1})	11.59	11.23	9.57	7.70	12.15	11.03	9.51	7.64
SEm±	0.05	0.05	0.06	0.04	0.05	0.05	0.04	0.04
CD (P=0.05)	0.15	0.16	0.17	0.12	0.16	0.16	0.12	0.11
Zinc levels								
Zn_0 (Control)	10.55	10.23	8.35	6.80	10.68	10.03	8.26	6.45
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	10.59	10.28	8.40	6.84	10.71	10.08	8.35	6.53
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	10.62	10.30	8.45	6.91	10.76	10.10	8.41	6.58
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	10.64	10.31	8.47	6.92	10.78	10.11	8.43	6.59
SEm±	0.07	0.08	0.07	0.06	0.08	0.08	0.05	0.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non significant at 5% level of significance

Table 4: Effect of RSC water, FYM and Zinc levels on N, P, K uptake (kg ha^{-1}) by grain and straw after harvest

Treatments	N uptake Pooled		P uptake Pooled		K uptake Pooled	
	grain	Straw	grain	Straw	grain	Straw
RSC levels						
W_1 (2.5 mmol L^{-1})	66.20	32.71	13.55	6.52	27.61	83.26
W_2 (5 mmol L^{-1})	66.46	31.80	12.87	6.38	26.80	81.55
W_3 (10 mmol L^{-1})	59.91	31.02	10.00	5.28	21.13	64.93
SEm±	0.72	0.36	0.15	0.08	0.28	0.92
CD (P=0.05)	2.07	NS	0.42	0.23	0.79	2.65
FYM levels						
F_0 (Control)	61.31	30.47	11.49	5.83	23.80	72.58
F_1 (15 t ha^{-1})	67.06	33.22	12.80	6.29	26.56	80.58
SEm±	0.58	0.30	0.12	0.06	0.22	0.75
CD (P=0.05)	1.69	0.86	0.34	0.19	0.65	2.17
Zinc levels						
Zn_0 (Control)	60.41	29.70	12.03	6.03	23.87	71.49
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	62.84	30.88	12.10	6.05	24.75	74.45
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	66.55	33.25	12.28	6.10	25.99	79.96
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	66.94	33.54	12.15	6.06	26.12	80.43
SEm±	0.69	0.31	0.12	0.06	0.26	0.71
CD (P=0.05)	1.94	0.86	NS	NS	0.74	1.98

NS = Non significant at 5% level of significance

Table 5: Effect of RSC water, FYM and Zinc levels on Ca, Mg, Na, Zn uptake (kg ha^{-1}) by grain and straw after harvest

Treatments	Ca uptake Pooled		Mg uptake Pooled		Na uptake Pooled		Zn uptake Pooled	
	grain	Straw	grain	Straw	grain	Straw	grain	Straw
RSC levels								
W_1 (2.5 mmol L^{-1})	16.66	15.38	7.25	5.90	11.35	35.82	203.46	225.35
W_2 (5 mmol L^{-1})	15.15	15.27	6.64	5.20	11.89	43.35	198.24	223.80
W_3 (10 mmol L^{-1})	11.97	12.02	5.32	4.03	12.03	43.41	163.98	190.97
SEm±	0.17	0.16	0.07	0.06	0.16	0.43	2.08	2.60
CD (P=0.05)	0.48	0.45	0.21	0.18	0.46	1.24	6.01	7.50
FYM levels								
F_0 (Control)	13.75	13.55	6.10	4.86	11.51	40.58	179.77	204.95
F_1 (15 t ha^{-1})	15.43	14.89	6.71	5.22	12.00	41.15	197.35	221.80
SEm±	0.14	0.13	0.06	0.05	0.13	0.35	1.70	2.12
CD (P=0.05)	0.39	0.37	0.17	0.15	NS	NS	4.91	6.12
Zinc levels								
Zn_0 (Control)	13.67	13.18	5.99	4.61	11.77	40.63	178.25	200.58
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	14.35	13.84	6.28	4.87	11.79	40.55	185.51	206.98
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	15.13	14.87	6.64	5.30	11.85	41.26	194.63	222.02
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	15.23	15.01	6.70	5.39	11.60	41.00	195.86	223.92
SEm±	0.18	0.14	0.07	0.05	0.11	0.43	1.94	2.12
CD (P=0.05)	0.51	0.40	0.20	0.14	NS	NS	5.40	5.93

NS = Non significant at 5% level of significance

Table 6: Effect of RSC water, FYM and Zinc levels on Na/ K, Ca/ Mg, Na+ K/ Ca, Na/ Ca ratio in grain and straw after harvest

Treatments	Na/ K Pooled		Ca/ Mg Pooled		Na+ K/ Ca Pooled		Na/ Ca Pooled	
	grain	Straw	grain	Straw	grain	Straw	grain	Straw
RSC levels								
W_1 (2.5 mmol L^{-1})	0.412	0.432	2.300	2.609	2.346	7.765	0.685	2.343
W_2 (5 mmol L^{-1})	0.446	0.534	2.282	2.532	2.561	9.537	0.790	3.319
W_3 (10 mmol L^{-1})	0.572	0.673	2.255	2.502	2.776	10.840	1.009	4.360
SEm±	0.004	0.004	0.011	0.015	0.014	0.053	0.006	0.030
CD (P=0.05)	0.013	0.011	0.031	0.044	0.039	0.152	0.018	0.088
FYM levels								
F_0 (Control)	0.493	0.572	2.256	2.514	2.597	9.510	0.858	3.487
F_1 (15 t ha^{-1})	0.461	0.521	2.302	2.581	2.525	9.252	0.798	3.195
SEm±	0.004	0.003	0.009	0.012	0.011	0.043	0.005	0.025
CD (P=0.05)	0.011	0.009	0.026	0.036	0.032	0.124	0.015	0.072
Zinc levels								
Zn_0 (Control)	0.503	0.582	2.282	2.571	2.639	9.721	0.884	3.606
Zn_{15} (15 kg $ZnSO_4$ ha^{-1})	0.486	0.557	2.284	2.565	2.571	9.414	0.842	3.386
Zn_{30} (30 kg $ZnSO_4$ ha^{-1})	0.465	0.527	2.276	2.535	2.529	9.232	0.804	3.213
Zn_{45} (45 kg $ZnSO_4$ ha^{-1})	0.453	0.520	2.273	2.521	2.505	9.156	0.783	3.159
SEm±	0.003	0.004	0.012	0.016	0.015	0.052	0.005	0.029
CD (P=0.05)	0.009	0.011	NS	NS	0.041	0.144	0.015	0.080

NS = Non significant at 5% level of significance

Table 7: 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

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