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Effect of Gypsum and Zinc on Performance and Nutrient Content of Wheat Crop under Sodic Water Irrigation

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Abstract

Irrigation using ground water having high residual sodium carbonate (RSC) is a serious problem as it causes soil sodification adversely affecting crop production. Gypsum application is frequently advised to counteract the negative effects of sodic water on soil. With the intensive cropping of high yielding varieties of rice and wheat in the state, deficiency of zinc in rice and manganese in wheat emerged as threats to sustaining high level of food grain production. Therefore, the present investigation was conducted to evaluate the effect of gypsum and zinc on growth, yield and nutrient content of wheat (*Triticum aestivum*) under sodic water irrigation. The experiment was conducted under field conditions during *Rabi* 2021-22 at farmers' field in Mahendergarh district of Haryana. The experiment was laid out in a randomized block design with three replications. The treatments comprised four levels of gypsum [0 kg ha^{-1} (G_0), 50 kg ha^{-1}(G_{50}), 75 kg ha^{-1}(G_{75}) and 100 kg ha^{-1} (G_{100})] and four levels of zinc (0, 5, 10 and 25 kg Zn ha^{-1}). The results revealed that different levels of gypsum and zinc application had significant effect on growth, yield and nutrient content in grain of wheat. Among different levels of gypsum, application of 100 kg gypsum ha^{-1}recorded the highest yield attributes, grain yield and nutrient content in wheat. The highest value of these parameters was recorded with 25 kg Zn ha^{-1} among different zinc treatments. From the present study it was concluded that application of gypsum to 100% neutralization of RSC of irrigation water and zinc at 25 kg ha^{-1} was found optimum in situations where irrigation water is sodic and soil is deficient in zinc.

Key words: Grain yield, Gypsum, Nutrient content, Residual sodium carbonate, Sodification, Zinc

Introduction

In India, wheat (*Triticum aestivum*) is widely grown crop and a significant source of staple food. India is the world's second largest producer of wheat with is cultivated on 31.36 million hectares (Mha) producing 107.86 million tones and productivity of 3440 kg ha^{-1} (USDA, 2021).Major increase in the productivity of wheat has been observed in the Northern states such as Haryana, Punjab and Uttar Pradesh.

Salt-affected soils are important ecological entity in India and around 6.7 Mha area is affected in different climatic regions (NRSA, 1996). Out of this, 3.77 Mha area is sodic and 2.95 Mha area are saline. Soil degradation resulting from sodicity is a major obstacle for optimal utilization of land resources. The 3.78 Mha soils in India and 0.18 Mha soils in Haryana are affected by sodicity (Anonymous, 2018). Out of total cultivated area of 3.62 Mha, 1.24Mha is canal irrigated, 1.65 Mha is irrigated by tube wells which often contain water of dubious quality (Anonymous, 2011), 0.73 Mha is non irrigated area. In the state, 37% of water is of good quality, 8% normal and 55% is of poor quality. Out of this poor-quality water, 11% is saline, 18% is alkali and 26% as saline-alkali (Manchanda, 1976). Most of the ground water is having high residual sodium carbonate (RSC) which is a serious problem. Amongst various categories of poor-quality water, alkali (sodic) water has greater irrigation potential by virtue of their low salinity load and in amenability for reclamation especially in semi-arid and arid region of North-West India where their occurrence in ground water is around 30-54% (Minhas and Bajwa, 2001). Scarcity of good quality water in these regions often forces the farmers to use available poor-quality water for irrigation. Sodic water is characterized by their low EC (<4 dS m^{-1}), high SAR and high RSC which constitute most important source of supplemental irrigation provided they are used carefully. Such waters are found in vast areas of Rewari, Jhajjar, Bhiwani, Mahendergarh, Gurgaon, Sirsa, Kaithal, Hisar and Fatehabad districts of Haryana. Use of sodic waters for irrigation as such causes soil sodification. Sodic soils are mainly characterized by presence of excessive sodium ions (Na^+) in soil solution and in the exchange phase up to the levels, which can adversely affect the physical, chemical, and biological properties of soils (Rietz and Haynes, 2003; Ferreras *et al.,* 2006). High RSC irrigation water is characterized by low total salt concentration. The prolonged use of such water immobilizes soluble calcium and magnesium in the soil by precipitating them as carbonates. The increased ESP resulting from their long-term use, break down soil structure due to swelling and dispersion of clay particles. By combining the necessary amount of gypsum with sodic water, it is possible to profitably use sodic irrigation water. The amount of gypsum needed will largely depend on the RSC in the sodic water, as well as the type of soil to be irrigated, crops to be grown, and the amount of annual precipitation received. Gypsum is frequently advised to counteract the negative effects of sodic water. The effect of salinity and sodicity on physical and chemical properties of soil under field crops is well documented (Choudhary *et al*., 2007). Due to its affordability, gypsum is the most often utilized amendment for reclaiming sodic soil. Among various micronutrients, zinc is one of the important elements for plant growth and it activates many enzymes which are involved in metabolic processes and biochemical pathways. It acts as a functional, structural, or regulatory co-factor for many enzymes and has key role in DNA transcription. It influences the formation of chlorophyll and auxins which resulted in formation of the growth promoting compounds (Nijra and Nabwami, 2015). Zinc plays an outstanding role in synthesis of chlorophyll and protein, and regulates inter absorption. Moreover, it is also concerned with carbohydrate metabolism and activation of various enzymes. Zinc application recommendation in soils depends upon crop, soil type, pH and other nutrient status. Its deficiency in sodic soils is quite common due to excessive sodium ions, high pH, carbonate and bicarbonate ions. It also helps in inducing alkalinity tolerance in crops by enhancing crops efficiently to utilize K and Ca. Thus, it reduces the Na/K and Na/Ca ratio in plant tissues to mitigate the adverse effect of alkalinity in crop which is an important aspect (Mishra, 2001; Singh, 2009). The hypothesis of the present study was that gypsum can neutralize RSC of irrigation water along with zinc application which might result in higher wheat productivity and nutritional quality. The objective of the present study was to find optimum dose of gypsum to 100% neutralize RSC of irrigation water along with zinc application to get higher wheat yield and nutrient content in grain.

Material and Methods

A field experiment was conducted during *Rabi* 2021-22 at farmers' field in Mahendergarh district of Haryana (28.19° N, longitude 76.59° E and 266 m above mean sea level). The experimental site was dry sub-humid with normal rainfall of about 577 mm. The total precipitation received during the crop growth period was 73.83 mm. The mean maximum and minimum temperature varied between 26.90°C and 11.06°C, respectively. The experiment was laid out in randomised block design under 16 treatments with three replications. Wheat was grown under sodic water irrigation having RSC (5.2 meq l^{-1}) with four levels of gypsum and Zn were applied. The treatment without gypsum (G_0) was control and G_{50}, G_{75} and G_{100} (of required dose) were applied for neutralization of RSC and Zn_0, Zn_5, Zn_{10} and Zn_{25} kg Zn was applied per hectare with recommended dose of N, P and K. The plant samples were collected at harvest stage of crop from each treated plots of the layout. Samples were dried, ground and digested in a di-acid mixture using sulphuric and perchloric acid in 4:1 ratio. The digested samples were filtered and stored in plastic bottles with proper labelling for further analysis. The surface soil samples from 0-15 cm were collected randomly from selected plots all over the experimental field before superimposing the

Table 1. Initial physico-chemical properties of experimental site

Soil parameters	Value
pH	9.15
EC (dS m^{-1})	0.35
Organic carbon (%)	0.30
Bulk density (g cm^{-3})	1.56
Exchangeable sodium percentage (ESP)	45.30
Cation exchange capacity (cmol(+) kg^{-1})	8.01
Available nitrogen (kg ha^{-1})	110.25
Available phosphorous (kg ha^{-1})	10.1
Available potassium (kg ha^{-1})	165.5
Available sulphur (kg ha^{-1})	38.60
Available calcium (kg ha^{-1})	46.8
Available zinc (mg kg^{-1})	0.65

Table 2. Irrigation water analysis used in experimental site

Parameters	Value
pH	8.7
EC (dS m^{-1})	3.2
Ca^{2+}(meq L^{-1})	2.3
Mg^{2+}(meq L^{-1})	2.5
HCO_3^{-1}(meq L^{-1})	8.5
CO_3^{2-} (meq L^{-1})	1.5
RSC (meq L^{-1})	5.2
Na^+ (meq L^{-1})	15.8
K^+ (meq L^{-1})	14.3
Zn^{2+} (ppm)	0.02

treatments. The composite soil sample was prepared and analysed for its various chemical properties. The initial properties before start of the experiment from 0-15 cm depth is given below.

The calculated amount of gypsum and zinc sulphate and RDF was applied through Urea, DAP and MOP. All the fertilizer doses were applied at the time of sowing. N fertilizer is applied in split doses.

The plant samples were collected at harvest stage of crop from each treated plots of the layout. Samples were dried, ground and digested in a di-acid mixture using sulphuric and perchloric acid in a ratio of 4:1. The digested samples were filtered and stored in plastic bottles with proper labelling for further analysis. Total nitrogen in the digested plant material was determined by colorimetric method using Nessler's reagent as described by Lindner (1944). Total phosphorus in the plant sample was determined by Vanado-molybdophosphoric acid, yellow color method as proposed by Koenig and Johnson (1942). Potassium in the acid digest of plant samples was determined by using flame photometer. The acid digest of plant samples was titrated with standard EDTA using calcon indicator in the presence of NaOH solution to estimate total calcium. Sulphur in the HNO_3-$HClO_4$ digest of the plant was determined by precipitation of sulphate as barium sulphate with the addition of $BaCl_2$ salt (turbidimetric method).The Zn of plant samples were determined by using plant digestion obtained from digestion by HNO_3 and $HClO_4$ with the help of Atomic Absorption Spectrophotometer as described by Lindsay and Norvell (1978).

Statistical analysis

Statistical analysis of data collected during the study was done by applying the technique of analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1985). All the statistical analysis was carried out using OPSTAT statistical software. The critical differences for all the parameters were calculated to compare the treatment means. Least Critical Difference was calculated with the help of standard error for the differences of two means and tabulated value of 't' at 5 per cent level of significance and at error degree of freedom.

Least Significant Difference (LSD) = SE (d × t) at 5% probability at error degrees of freedom.

Results and Discussion

The effect of gypsum and Zn application on yield attributes i.e., number of tillers/m.r.l., number of grains per spike, test weight and grain yield was found to be significant (Table 3 & 4).

Among different gypsum levels, application of 100 kg gypsum (G_{100}) recorded maximum number of tillers/m.r.l. (104.37), number of grains/spike (47.83), test weight (40.26 g) and grain yield of wheat (3918 kg ha^{-1}) followed by G_{75} and the minimum in G_0.Likewise, among different Zn levels, Zn_{25} recorded maximum tillers/m.r.l. (103.30), number of grains/spike (42.58), test weight (40.90 g) and grain yield of wheat (33.08 kg ha^{-1}) followed by Zn_{10} and the lowest in $Zn_{05.}$

Table 3. Effect of gypsum and zinc application on yield attributes of wheat under sodic water irrigation

Gypsum level	Level of Zn (kg ha^{-1})									
	Number of tiller (per m.r.l.)					Number of grains per spike				
	Control	05	10	25	Mean	Control	05	10	25	Mean
G_0	83.63	86.00	90.33	95.50	88.87	32.33	34.00	35.33	37.00	34.67
G_{50}	92.37	96.00	98.10	101.17	96.91	37.67	39.33	40.33	40.00	39.33
G_{75}	95.00	98.10	100.47	105.20	99.69	41.00	42.33	43.33	44.33	42.75
G_{100}	98.33	101.63	106.17	111.33	104.37	46.67	47.33	48.33	49.00	47.83
Mean	92.33	95.43	98.77	103.30		39.42	40.75	41.83	42.58	
LSD ($p \leq 0.05$)	Gypsum level (G)=0.67					Gypsum Level (G)=2.86				
	Level of Zn= 0.67					Level of Zn= NS				
	G × Zn= 1.33					G × Zn= NS				

Table 4. Effect of gypsum and zinc application on test weight and grain yield of wheat under sodic water irrigation

Gypsum level	Level of Zn (kg ha^{-1})									
	Test weight (g)					Grain yield (q ha^{-1})				
	Control	05	10	25	Mean	Control	05	10	25	Mean
G_0	33.23	35.40	37.23	39.50	36.34	12.38	13.37	18.37	20.50	16.15
G_{50}	34.47	36.30	38.60	40.07	37.36	19.27	23.40	29.37	32.30	26.08
G_{75}	35.23	37.43	39.60	41.03	38.33	29.37	30.30	32.37	35.23	31.82
G_{100}	37.07	39.57	41.40	43.00	40.26	33.53	37.60	41.33	44.27	39.18
Mean	35.00	37.18	39.21	40.90		23.64	26.17	30.36	33.08	
LSD ($p \leq 0.05$)	Gypsum level (G) = 1.64					Gypsum Level (G)= 0.81				
	Level of Zn = 1.64					Level of Zn = 0.81				
	G × Zn = NS					G × Zn = 1.61				

1q=100 kg

The interaction effect of gypsum and Zn application was significant on the number of tillers/m.r.l. and grain yield while non-significant for number of grains/spike and test weight. Maximum number of tillers/m.r.l. (111.33) and highest grain yield (44.27 q ha^{-1}) was recorded in $G_{100}Zn_{25}$ while the lowest in G_0Zn_0.

Improvement in the soil properties such as pH, EC and ESP due to addition of gypsum favours seedling emergence, increased number of fertile spikelet and plant height and better metabolic activities of plant (Rasouli *et al.,* 2013). The nutritional imbalance caused by excess Na^+ ions is not favorable for plant growth, root development, cell division and cell elongation (Naga *et al.,* 2005; Choudhary *et al.*, 2014).Zinc plays a role in increasing the CEC of roots, regulating the auxin concentration. The physiological and metabolic activities of plants enhanced due to Zn application and this increases the plant population, plant height and effective tillers. Similar findings were reported by Naga *et al.* (2005), Jakhar *et al.* (2013).

The grain yield increased significantly yield due to gypsum application upto 100 kg ha^{-1} (G_{100}). Moreover gypsum application improved the soil physical properties by decreasing the sodicity effects caused by excessive Na^+ ions present in high RSC water, increasing the plant biomass and rhizosphere environment. Similar findings have also been reported byRasouli *et al.* (2013), Adkine *et al*. (2017), Chhabra *et al.*(1987), Minhas *et al.* (1998). Similarly, the test weight and grain yield increased significantly with increasing levels of zinc. It was due to zinc application increases the level of growth hormone such as auxin. Zinc plays a vital role in plant nutrition, photosynthesis and sugar translocation. It has role in biosynthesis of indole acetic acid and especially due to role in primordial for reproductive parts and partitioning

Table 5. Effect of gypsum and zinc application on N and P content in grain of wheat under sodic water irrig**ation**

Gypsum level	Level of Zn (kg ha^{-1})									
	N content (%)					P content (%)				
	Control	05	10	25	Mean	Control	05	10	25	Mean
G_0	2.17	2.22	2.27	2.30	2.24	0.26	0.28	0.31	0.33	0.29
G_{50}	2.25	2.30	2.34	2.37	2.31	0.31	0.32	0.36	0.39	0.35
G_{75}	2.30	2.36	2.39	2.42	2.37	0.36	0.38	0.40	0.42	0.39
G_{100}	2.35	2.38	2.41	2.42	2.39	0.41	0.41	0.43	0.44	0.42
Mean	2.27	2.32	2.35	2.38		0.33	0.35	0.38	0.40	
LSD ($p \leq 0.05$)	Gypsum level (G) = 0.02					Gypsum Level (G) = 0.01				
	Level of Zn = 0.02					Level of Zn = 0.01				
	G× Zn = NS					G× Zn = NS				

of photosynthesis towards them which resulted in better flowering and fruiting (Adkine *et al.*, 2017; Naga *et al.,* 2005; Dogra *et al.,* 2016; Jakhar *et al.,* 2013).

The interaction effect of gypsum and zinc was found significant in number of tillers (per meter of row length) and grain yield of wheat. The behaviour of interaction of gypsum and zinc sulphate at different levels showed that they add to the effect of each other in increasing the number of tillers and grain yield. They complement each other. This type of behaviour of gypsum and zinc interactions in increasing seed and straw yield have been reported by Adkine *et al.* (2017) and Chhabra *et al.* (1987) also.

The yield of crop is related with the amount of nutrient taken up the crop i.e. the amount of nutrient taken up per unit of grain production determines the achievable yields since essential nutrients are involved in the metabolism of plants. The effect of gypsum and Zn application significantly influenced the N, P, K, Ca, S and Zn content (%) in wheat grain (Tables 5, 6 and 7). Among gypsum treatments, G_{100} resulted in the highest N (2.39%), P (0.42%), K (1.49%), Ca (2.97%), S (0.17%) and Zn (32.01%) content in grain followed by G_{75} while the lowest nutrient content was observed in G_0 (control). Likewise, among different levels of Zn, application of 25 kg Zn/ha (Zn_{25}) resulted in highest N (2.38%), P (0.40%), K (1.37%), Ca (2.54%), S (0.17%) and Zn (29.90%) content in grain followed by Zn_{10} while the lowest under control. The interaction effect of gypsum and Zn application on N, P, K, Ca, S and Zn content in grain was found to be non-significant.

Application of gypsum influenced physical, chemical and biological properties of soil, resulting in decrease in soil pH, ESP. The physical properties influence the release of nutrients in available form, the availability of nutrients leading to their absorption. Gypsum acted as a source of

Table 6. Effect of gypsum and zinc application on K and Ca content in grain of wheat under sodic water irrigation

Gypsum level	Level of Zn (kg ha^{-1})									
	K content (%)					Ca content (%)				
	Control	05	10	25	Mean	Control	05	10	25	Mean
G_0	0.67	0.67	1.10	1.27	0.93	1.73	1.97	2.00	2.10	1.95
G_{50}	1.30	1.35	1.35	1.38	1.35	1.90	2.43	2.17	2.20	2.18
G_{75}	1.40	1.40	1.39	1.42	1.40	2.20	2.67	2.67	2.80	2.58
G_{100}	1.40	1.39	1.41	1.41	1.49	2.97	3.00	2.83	3.07	2.97
Mean	1.19	1.21	1.31	1.37		2.20	2.52	2.42	2.54	
LSD ($p \leq 0.05$)	Gypsum level (G) = 0.07					Gypsum Level (G) = 0.25				
	Level of Zn = 0.07					Level of Zn = 0.25				
	G× Zn = NS					G × Zn = NS				

Table 7. Effect of gypsum and zinc application on S and Zn content in grain of wheat under sodic water irrigation

Gypsum level	Level of Zn (kg ha^{-1})									
	S content (%)					Zn content (%)				
	Control	05	10	25	Mean	Control	05	10	25	Mean
G_0	0.08	0.09	0.10	0.11	0.10	25.13	26.47	26.86	27.56	26.50
G_{50}	0.10	0.13	0.15	0.17	0.14	27.66	28.28	27.88	28.62	28.11
G_{75}	0.13	0.14	0.17	0.19	0.16	29.57	29.61	30.47	31.05	30.18
G_{100}	0.14	0.17	0.18	0.19	0.17	31.54	31.74	32.40	32.36	32.01
Mean	0.11	0.13	0.15	0.17		28.48	29.03	29.40	29.90	
LSD ($p \leq 0.05$)	Gypsum level (G) = 0.01 Level of Zn = 0.01 G × Zn = NS					Gypsum Level (G) = 0.80 Level of Zn = 0.80 G× Zn = NS				

Table 8. Effect of Gypsum and Zinc application on available Zn in soil after harvest of wheat

Gypsum Level	Level of Zn (kg ha^{-1})				Mean
	Control	05	10	25	
G_0	0.50	0.68	0.72	0.79	0.67
G_{50}	0.68	0.92	0.83	0.98	0.85
G_{75}	0.86	1.28	1.40	1.30	1.21
G_{100}	1.02	1.58	1.65	1.67	1.48
Mean	0.77	1.11	1.15	1.18	
LSD ($p \leq 0.05$)	Gypsum Level (G)= 0.16 Level of Zinc (Zn)= 0.16 G × Zn= NS				

sulphur seems to improve nutritional environment both in rhizosphere and plant system. The increased availability of nutrients in root zone increase metabolic activity at cellular level and thus, increases the uptake of nutrients. The results obtained are in accordance with the results reported by Adkine *et al*. (2017), Rasouli *et al.* (2013), Naga *et al.* (2005), Chhabra *et al.* (1987), Kumar *et al.* (2012).

The Zn_{25} treatment recorded significantly higher Zn content and uptake in grain as compared to control (Zn_0). This might be due to the increasing pattern of grain yield with graded levels of fertilizers or may be due to the dilution effect. The role of zinc in increasing in CEC of roots influence increasing absorption of nutrients, chlorophyll formation regulating the auxin concentration and its stimulatory effect on physiological and metabolic process of plant enhance absorption of nutrients. The favourable influence of zinc on photosynthesis and metabolic process augment the production of photosynthates and their translocation to different plant part which increase nutrient content in seed and straw, similar result reported byNaga *et al.* (2005), Yaduvanshi and Sharma (2007), Dwivedi *et al.* (2001).

The interaction effect of gypsum and zinc was found to be significant in nutrient content in grain of wheat, maximum level of interaction was observed at $G_{100}Zn_{25}$ due to improvement in nutritional environment in rhizosphere and plant system increasing absorption of nutrients and translocation to different plant part. Similar results reported by Adkine *et al*. (2017), Dwivedi *et al.* (2001).

Available Zn in soil after harvest of wheat crop increased significantly with addition of gypsum, the maximum was recorded in the treatment G100 (1.48 mg kg^{-1}) as compared to G0 (0.67 mg kg^{-1}), due to the more favourable condition of the soil by improvement in the physical condition in the soil by addition of gypsum. Zinc application also shows increased in available Zn in the Zn25 (1.18 mg kg^{-1}) treatments as compared to Zn0 (39.88 mg kg^{-1}). This significant increase in available Zn status was due to the direct application of Zinc sulphate in soil, similar findings were reported by Adkine *et al*. (2017), Meena *et al.* (2006).

Conclusion

The high RSC water can cause alkalinity problems and reduce soil permeability. The resultant manifestation of physical stresses from the deteriorated soil structure includes the water stagnation and anoxia from poor infiltration and hydraulic conductivity, tillage problems from the hard-setting of dispersed soils, impairment of germination with surface crusts, etc. Therefore, low RSC water is safer for irrigation as it maintains soil structure and nutrient availability. The results of this study also suggests that 100% neutralization of RSC of irrigation water through gypsum and zinc application (25 kg/ha) was found optimum in term of productivity and nutritional quality of wheat irrigated with sodic water. However, further research can be done to explore the long-term effects of gypsum and zinc applications on soil properties, crop productivity, and nutrient dynamics, alternative soil amendments, performance of different crops with application of gypsum and zinc irrigated with sodic water, integrated nutrient management with integration of organic and inorganic sources with gypsum and zinc to enhance nutrient availability and soil structure, to study change in soil biological properties with the application of gypsum and zinc.

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