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Impact of zinc fortification in bread wheat (*Triticum aestivum* L.) through soil and foliar application methods

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Abstract
A field experiment entitled "Impact of Zinc Fortification in Bread Wheat (*Triticum aestivum* L.) through Soil and Foliar Application Methods" was conducted during rabi season of 2020-21 at Instructional Farm of Agronomy, Department of Agronomy, Rajasthan College of Agriculture, Udaipur (Rajasthan) to standardized zinc levels for productivity and quality of wheat and work out suitable mode of application of zinc and economically viable treatment for wheat. The experiment was laid out in factorial randomized block design with three replications. The treatments have two factors of zinc application each have four levels viz., soil application of zinc sulphate (0, 20, 25, 30 kg $ZnSO_4$ ha^{-1}) and foliar spray (water spray, spray of 0.5% $ZnSO_4$ at tillering, early heading and tillering + early heading).
Results revealed that the basal application of zinc sulphate has significantly improved the maximum effective tillers in 0.5 metre row length (54.73), number of grains ear^{-1} (47.00), weight of grains ear^{-1} (1.91 g), ear length (7.74 cm) and test weight (42.52 g) and grain (5440 kg ha^{-1}), straw (7077 ha^{-1}) and biological yield (12517 kg ha^{-1}) was recorded with the application of $ZnSO_4$ 30 kg ha^{-1}, which was remained at par with the application of $ZnSO_4$ 25 kg ha^{-1}. Foliar spray of zinc sulphate at tillering + early heading stages has significantly improved the maximum effective tillers in 0.5 metre row length (55.44), number of grains ear^{-1} (46.04), weight of grains ear^{-1} (1.77 g), ear length (7.42 cm) and test weight (41.73 g), grain (5526 kg ha^{-1}), straw (6852 kg ha^{-1}) and biological yield (12378 kg ha^{-1}) was obtained with the foliar spray of 0.5% $ZnSO_4$ at tillering + early heading, which was remained at par with the foliar spray of 0.5% $ZnSO_4$ at early heading.

Keywords: zinc fortification, bread wheat, soil and foliar application methods

Introduction
Wheat (*Triticum aestivum* L.) is belonging to grass family *i.e*., Gramineae and known as staple food of millions of people. This important cereal crop would provide foodstuffs and nutrition to majority of world's population *i.e.*, about two third. Wheat is unanimously known as '*King of Cereals*' because of its wider adaptability and higher productivity. Wheat grain contains 8 to 12 per cent protein *viz*., glutein which is accountable for functional activities of wheat flour like binding quality and this characteristic very vital for bakeries. Apart from protein, wheat grains have carbohydrates, fat soluble vitamins *i.e*. A, D, E and K and water-soluble niacin and thiamine, fatty acids like linolenic and archidonic acids and the essential amino acids *viz*., phenyl alanine, methionine, threonine, leucine, isoleucine and valine. Wheat crop is well comparable with other important cereals in terms of its nutritive value. Crop required, balanced nutrition in the form of macro and micro nutrients for successfully completion of their life cycle *i.e*., vegetative and reproductive phases, respectively. Nitrogen required in ample amount and it is the most scare element in the category of macro nutrients and in respect of micro elements, zinc is most abundant element now a day worldwide. Zinc is an essential element for growth and development of crop, an imperative constituent of carbonic-anhydrase and aldolase stimulator in carbon metabolism (Tsonev and Lidon, 2012) [15].
Bio-fortification is a progression by that the nutrient density of food crops are increased by means of agronomic practices, conventional breeding methods or bio-technology. The bio-fortification differs from ordinary fortification because it focuses on making plant foods more nutritious as the plants are growing, rather than having nutrients added to the foods when they are being processed. This is an important improvement on ordinary fortification when it comes to providing nutrients for the rural poor, who rarely have access to commercially fortified foods. As such, bio-fortification is seen as an upcoming strategy for dealing with deficiencies

of micro nutrients in low and middle-income countries. The current global challenge of mineral mal nutrition is avoidable with bio-fortification techniques if properly and timely adopted (Das *et al*., 2019) [3]. Zn mediated agronomic bio-fortification of cereals proved useful for enriching the micronutrient content in the edible parts (Kumar *et al.*, 2020) [7] and thus, helped overcome hidden hunger caused due to Zn micronutrient deficiency to some extent besides rectifying the deficiency in dietary intake. Keeping the above facts an experiment entitled "Impact of Zinc Fortification in Bread Wheat (*Triticum aestivum* L.) through Soil and Foliar Application Methods" was planned and conducted during *rabi* 2020-21.

Material and Methods

The present investigation entitled "Impact of Zinc Fortification in Bread Wheat (*Triticum aestivum* L.) through Soil and Foliar Application Methods" was carried out during *rabi* 2020-21, at Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan). The site is located at 24˚35' N latitude and 74˚42' E longitude in the South-Eastern part of Rajasthan, at an altitude of 579.5 metres above mean sea level and belongs to agro-climatic zone IVa*i.e.*, Sub-Humid Southern Plain and Aravalli Hills of Rajasthan. The region's annual average rainfall is 637 mm, most of which receives from South-West monsoon accounting for the bulk of this (80-85%) from July to September. The maximum and minimum temperatures during the crop growth period ranged between 22.49 ºC to 33.34 ºC and 3.77 ºC to 15.26 ºC, maximum and minimum relative humidity ranged between 54.43 to 90.57 and 18.27 to 52.14 per cent, respectively. The total rainfall received during the cropping season was 12.60 mm and evaporation was ranged between 2.57 to 7.93 mm day^{-1}. The treatments have two factors of zinc application each have four levels *viz.*, soil application of zinc sulphate 0, 20, 25, 30 kg $ZnSO_4$ ha^{-1} (Z_1, Z_2, Z_3, Z_4) and foliar spray water spray (F_1), spray of 0.5% $ZnSO_4$ at tillering (F_2), early heading (F_3) and tillering + early heading(F_4).

Four levels of zinc sulphate *viz.*, 0, 20, 25 and 30 kg ha^{-1} (Fwas used for soil application and supplied through zinc sulphate ($ZnSO_4$) fertilizer at the time of sowing as per the treatment recommendations. As per the treatments foliar application of 0.5 per cent zinc sulphate were used for the foliar application and sprayed at tillering and heading stages.

After palco, the field was prepared by tractor drawn disc-harrow afterward cross cultivator and planking was done to obtain a fine seed bed. The plots were demarcated and prepared according the layout along with irrigation channels. Raj 4079 wheat variety was released from Rajasthan Agriculture Research Institute, Durgapura (Rajasthan) in year 2011. This wheat variety recommended for timely sown irrigated condition. This variety have tolerance resistance against heat and highly responsive to fertility status also have good texture, test weight and excellent for chapati making. Wheat variety Raj 4079 was sown uniformly on November 10th, 2020 by using seed rate of 100 kg ha^{-1} at inter row spacing of 20.0 cm. Seeds were weighed separately for each plot in small packets for sowing in order to achieve a uniform plant stand. Sowing was performed in furrows by hand, followed by irrigation. The recommended dose of fertilizer for zone IVa was 120, 80 and 60 kg NPK ha^{-1} for timely sown and fully irrigated wheat crop. Half of nitrogen and full phosphorus and potash were applied at the time of sowing and zinc was applied as per the treatments. As nitrogen, phosphorus, potassium, and zinc sources, urea, DAP, MOP and $ZnSO_4.7H_2O$ were used. The wheat crop required 5-6 irrigations as per their critical growth stages and during investigation irrigation given to the crop as per its critical crop growth stage *viz*., CRI (21 DAS, it is most critical stage for wheat), tillering (40-45 DAS), late jointing (60-65 DAS), flowering (80-85 DAS), milking (100-105 DAS) and dough stage (115-120DAS). For control of complex weed flora in experimental plot, ready mix of post emergence herbicide *i.e*., Total (Trade name) Sulfosulfuron 30 g + metsulfuron 2 g was dissolved in 500 litres of water ha^{-1} and sprayed with the help of knapsack sprayer fitted who have flat fan nozzle at 32 DAS. The crop was manually harvested with the help of sickle when the crop reached its maturity (124 DAS). In every plot boarder crop was harvested first, removed it than after main crop stands in net plot was harvested, tied and tagged in bundles. The bundles were weighed after proper drying (2-3 days sun light) to assess the biological yield by treatment. The electric thresher was used for threshing of crop, threshing of crop done plot wise and their produce *i.e*., grain collected in cloth bags separately. The collected grain/ produce was winnowed, cleaned and then weighed on electric balance to record grain yield kg plot-1 after that this was converted into hectare.

Results and Discussion

Effect of Soil Application of Zinc Sulphate

Yield, yield attributes and economics

The basal application of zinc sulphate has significantly increased the yield and yield contributing parameters of bread wheat. The results revealed that the increasing dose of zinc sulphate from zero to 30 kg ha^{-1} has significantly increased the number of effective tillers, number of grains ear^{-1}, weight of grains ear^{-1}, ear length and test weight. Data from results show that the maximum effective tillers in 0.5 metre row length (11.40), number of grains ear^{-1} (47.00), weight of grains ear^{-1} (1.91 g), ear length (7.74 cm) and test weight (42.52 g) was found with the application of $ZnSO_4$ 30 kg ha^{-1}, which was remained statistically at par with the application of $ZnSO_4$ 25 kg ha^{-1}. The significantly higher grain, straw and biological yield 5440, 7077 and 12517 kg ha^{-1}, respectively was obtained with the application of $ZnSO_4$ 30 kg ha^{-1}, which was statistically similar to the application of $ZnSO_4$ 25 kg ha^{-1}. The maximum gross return (₹135756 ha^{-1}), net return (₹104944 ha^{-1}) and benefit cost ratio (3.40) was received with the basal application of $ZnSO_4$ 30 kg ha^{-1}, which were statistically similar to the basal application of $ZnSO_4$ 25 kg ha^{-1}. The maximum nitrogen content (2.0 and 0.49 %), potassium (0.371 and 1.677 %) and zinc (34.26 and 30.55 %) of grain and straw recorded with the basal application of $ZnSO_4$ 30 kg ha^{-1} and maximum uptake of nitrogen (108.87, 34.54 and 143.41 kg ha^{-1}), phosphorus (23.24, 10.32 and 33.55 kg ha^{-1}), potassium (20.25, 118.74 and 138.99 kg ha^{-1}) and zinc (187.02, 216.47 and 403.49 g ha^{-1}) by grain, straw and total by crop were recorded with the basal application of $ZnSO_4$ 30 kg ha^{-1}, which was remained at par with the basal application of $ZnSO_4$ 25 kg ha^{-1}.

The increasing dose of zinc had positive effect on various plant growth parameters *viz*., leaf area, plant height, number of effective tillers. The improve growth parameters resulted upsurge the yield attributing characters *i.e*., number of grains ear^{-1}, ear length and test weight and also improve biological and straw yield. The apparent mechanism for achieving these improvements was the increase in above parameters, providing an improved resource generating base for the crop *i.e.*, an improved carbohydrate source. The consequence of this improved source was the improvement in overall biomass and consequently improvements in yield components of the crop. Improvements in effective tillers and number of grains ear^{-1} are important aspects to achieve more grains unit^{-1} land area. These results are closely in conformity with findings of Firdous *et al.* (2018) [6] and Arif *et al.* (2019) [1].

Effect of foliar application of zinc sulphate

Yield, yield attributes and economics

The foliar spray of zinc sulphate has significantly increased the yield and yield contributing parameters of bread wheat. The results show 0.5% foliar spray of zinc sulphate has significantly increased the effective tillers, number of grains ear^{-1}, weight of grains ear^{-1}, ear length and test weight. The results show that the maximum effective tillers in 0.5 metre row length (11.97), number of grains ear^{-1} (46.04), weight of grains ear^{-1} (1.77 g), ear length (7.42 cm) and test weight (41.73 g) was obtained with the foliar spray of 0.5% $ZnSO_4$ at tillering + early heading, which was remained statistically at par with the foliar spray of 0.5% $ZnSO_4$ at early heading. The significantly higher grain, straw and biological yield 5526, 6852 and 12378 kg ha^{-1}, respectively was obtained with the foliar spray of 0.5% $ZnSO_4$ at tillering early heading, which was statistically similar to the foliar spray of 0.5% $ZnSO_4$ at early heading. The foliar spray of zinc sulphate 0.5% $ZnSO_4$ at tillering + early heading significantly affected the gross as well as net return and benefit- cost ratio of wheat. The maximum gross return (₹ 136547 ha^{-1}) and net return (₹105060 ha^{-1}) was received with the foliar spray of 0.5% $ZnSO_4$ at tillering + early heading, which were statistically similar to the foliar spray of 0.5% $ZnSO_4$ at early heading. The maximum benefit- cost ratio (3.33) was obtained with the foliar spray of 0.5% $ZnSO_4$ at early heading. The maximum nitrogen content (1.98 and 0.48 %), potassium (0.366 and 1.665 %) and zinc (34.23 and 30.53 %) of grain and straw and uptake of nitrogen (109.65, 32.90 and 142.55 kg ha^{-1}), phosphorus (23.95 and 34.21 kg ha^{-1}), potassium (20.28, 114.16 and 134.44 kg ha^{-1}) and zinc (190.58, 210.22 and 400.80 g ha^{-1}) by grain, straw and total by crop along with was recorded with the foliar spray of 0.5% $ZnSO_4$ at tillering + early heading. Application of zinc has synergistic effect of adding nitrogen to the crop. Increasing basal doses of zinc had significantly increased the concentration of nitrogen, potassium and zinc in the grain and straw. Similar results have been reported by Yilmaz *et al.* (1997) [16], Seilsepour (2007) [13] and El-Majid *et al.* (2000) [5]. This might be due to the increased grain and straw yield of wheat crop and reduced cost of cultivation and good market price of produce. This is close in conformity with the findings of Shivay *et al.*, (2008) [14], Meena *et al.*, (2017) [10], Firdous *et al.*, (2018) [6] and Arif *et al.*, (2019) [1].

Table 1: Effect of soil and foliar application of zinc on yield attributes, yield and economics of bread wheat

Treatments	Yield attributes					Yield (kg ha^{-1})			Economics		
	Number of effective tillers at harvest	Number of grains ear^{-1}	Weight of grains ear^{-1}	Ear length (cm)	Test weight (g)	Grain	Straw	Biological	Gross return (₹ha^{-1})	Net return (₹ha^{-1})	B-C ratio
Basal Application of $ZnSO_4$ (kg ha^{-1})											
Z_1	47.98	42.92	1.28	6.70	38.47	4041	4944	8985	99590	69378	2.29
Z_2	52.23	44.33	1.65	7.17	39.83	4949	6474	11423	123647	93035	3.03
Z_3	53.14	45.98	1.83	7.60	41.24	5427	6922	12350	134870	104158	3.39
Z_4	54.73	47.00	1.91	7.74	42.52	5440	7077	12517	135756	104944	3.40
SEm±	0.87	0.47	0.03	0.05	0.32	103	156	176	2056	2056	0.07
CD (p = 0.05)	2.51	1.36	0.09	0.15	0.92	298	449	508	5937	5937	0.19
Foliar Application of $ZnSO_4$ (0.5 %)											
F_1	48.78	43.73	1.57	7.17	39.02	4198	5947	10145	106696	77009	2.59
F_2	51.48	44.81	1.64	7.38	40.46	4780	6210	10980	119240	88653	2.90
F_3	52.37	45.65	1.68	7.24	40.84	5354	6409	11763	131379	100792	3.29
F_4	55.44	46.04	1.77	7.42	41.73	5526	6852	12378	136547	105060	3.33
SEm±	0.87	0.47	0.03	0.05	0.32	103	156	176	2056	2056	0.07
CD (p = 0.05)	2.51	1.36	0.09	0.15	0.92	298	449	508	5937	5937	0.19

Table 2: Effect of soil and foliar application of zinc on nutrient content of bread wheat

Treatments	Nutrient content (%)						Nutrient content (ppm)	
	Nitrogen		Phosphorus		Potassium		Zinc	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Basal Application of Zinc (kg ha^{-1})								
Z_1	1.942	0.461	0.451	0.160	0.352	1.614	29.60	25.78
Z_2	1.966	0.482	0.445	0.158	0.357	1.629	33.82	30.01
Z_3	1.969	0.485	0.435	0.152	0.364	1.657	33.90	30.21
Z_4	1.997	0.488	0.427	0.146	0.371	1.677	34.26	30.55
SEm±	0.013	0.003	0.002	0.002	0.003	0.012	0.32	0.30
CD (p = 0.05)	0.037	0.008	0.007	0.004	0.009	0.034	0.93	0.87
Foliar Application of $ZnSO_4$ (0.5 %)								
F_1	1.958	0.471	0.445	0.158	0.351	1.608	30.70	26.85
F_2	1.961	0.484	0.441	0.156	0.362	1.650	33.19	29.38
F_3	1.974	0.482	0.438	0.153	0.365	1.654	33.45	29.78
F_4	1.981	0.479	0.434	0.150	0.366	1.665	34.23	30.53
SEm±	0.013	0.003	0.002	0.002	0.003	0.012	0.32	0.30
CD (p = 0.05)	NS	0.008	0.007	0.004	0.009	0.034	0.93	0.87

Table 3: Effect of soil and foliar application of zinc on nutrient uptake of bread wheat

Treatments	Nutrient uptake (kg ha^{-1})									Nutrient uptake (g ha^{-1})		
	Nitrogen			Potassium (kg ha^{-1})			Potassium (kg ha^{-1})			Zinc (g ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Basal Application of Zinc (kg ha^{-1})												
Z_1	78.47	22.80	101.28	18.20	7.91	26.11	14.23	79.86	94.09	119.76	128.02	247.78
Z_2	97.40	31.21	128.61	22.02	10.23	32.25	17.69	105.54	123.23	168.18	194.69	362.87
Z_3	106.84	33.62	140.46	23.58	10.56	34.14	19.79	114.84	134.63	184.65	209.69	394.34
Z_4	108.87	34.54	143.41	23.24	10.32	33.55	20.25	118.74	138.99	187.02	216.47	403.49
SEm±	2.20	0.79	2.18	0.44	0.25	0.48	0.42	2.79	2.80	3.28	5.29	6.01
CD (p = 0.05)	6.37	2.29	6.30	1.28	0.72	1.39	1.22	8.06	8.08	9.47	15.27	17.35
Foliar Application of $ZnSO_4$ (0.5 %)												
F_1	82.23	28.11	110.33	18.65	9.35	27.99	14.74	95.88	110.62	129.28	161.35	290.63
F_2	93.86	30.17	124.03	21.02	9.63	30.65	17.32	102.59	119.91	159.35	184.14	343.49
F_3	105.86	30.99	136.85	23.43	9.77	33.19	19.62	106.34	125.95	180.40	193.16	373.57
F_4	109.65	32.90	142.55	23.95	10.27	34.21	20.28	114.16	134.44	190.58	210.22	400.80
SEm±	2.20	0.79	2.18	0.44	0.25	0.48	0.42	2.79	2.80	3.28	5.29	6.01
CD (p = 0.05)	6.37	2.29	6.30	1.28	NS	1.39	1.22	8.06	8.08	9.47	15.27	17.35

Conclusion
On the basis of one year field research findings, it can be concluded that bread wheat crop should be fortified with zinc fertilizer. For this the crop must be supplied with 25 kg $ZnSO_4$ ha^{-1} as basal soil application and one foliar spray of 0.5 per cent ZnSO4 at early heading stage to get maximum grain yield, net return and B-C ratio However, to arrive at final recommendation further experimentation on same line is needed.

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