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Agronomic fortification in wheat (*Triticum aestivum* L.) with zinc

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Abstract
Zinc is one of the essential plant micronutrient and its importance for crop productivity is similar to that of major nutrients. Intensive agriculture coupled with the continuous use of N, P, K fertilizers have remarkably increased the production but simultaneously brought about problems related to micronutrient deficiencies, particularly that of Zn in soil. Zinc deficiency is major risk factor to crop production and human health. A field experiment was conducted during Rabi Season of 2018-19 at Research Plot of Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi. The experiment was laid out in a randomized block design with six treatment combinations and three replications. Treatment includes T_0 = Control (RDF), T_1 = RDF + $ZnSO_4$ @ 25 kg ha^{-1}, T_2= RDF + $ZnSO_4$ @ 50 kg ha^{-1}, T_3= RDF+ T_1 + 3 FS @ 0.5% $ZnSO_4$ at PF, HS and MS, T_4 = T_2 + 2 FS @ 0.5% $ZnSO_4$ at PF and MS, T_5= RDF + $ZnSO_4$ @ 5kg ha^{-1} + F S @ 0.5% at HS. FS= Foliar Spray, PF= Pre Flowering Stage, HS=Heading Stage, MS= Milking stage, RDF= Recommended Dose of Fertilizer. Important growth parameter (plant height and number of tillers) at different growth stages and dry matter yield (grain and straw) was determined. Application of Zn significantly affected the plant height, number of tillers, grain and straw yields over control (without Zn). Maximum was registered in the treatment T_4 ($ZnSO_4$ @ 50 kg ha^{-1} and 2 FS @ 0.5% $ZnSO_4$ at PF and MS). All the treatments have significant positive effect over control in case of nutrient content in plant. The minimum nutrient content and its uptake were recorded with T_0 and the maximum under the treatment T_4. Application of Zn also increased the availability of nitrogen, phosphorus and potassium in post harvest soil.

Keywords: Wheat yield, NPK & Zn content and uptake, Available NPK

1. Introduction
The state of Uttar Pradesh in North India is covers an area of 24.09 m ha and has 16.81 m ha of cultivated area, constituting 70 per cent of the total geographical area. The irrigated area is 73 % and cropping intensity is 153 %. Present agricultural system depend upon mining of plant nutrients by adoption of intensive tillage, use of high yielding varieties imbalanced use of organic and inorganic sources of nutrients, less recycling of crop residues into the soil, soil erosion and un judicious use of irrigation water. Zinc is one of the essential plant micronutrient and its importance for crop productivity is similar to that of major nutrients. Intensive agriculture coupled with the continuous use of N, P, K fertilizers has remarkably increased the production but simultaneously brought about problems related to micronutrient deficiencies, particularly that of Zn in soil. In India, analysis of over 2,50,000 soil sample from 20 states show that 48 % soils are Zn deficient with DTPA- Zn values below 0.6 mg kg^{-1} (Singh, 2009) [14]. Shukla *et al*. (2014) [13] reported that about 43% soils in India are potentially Zn deficient. Zinc application to Zn deficient soil has been found to boost the growth of plants and yield of crops to a great extent. Bio-fortification is a recent approach aimed at increasing the bio-available nutrients, such as Fe and zinc, in the staple crops rather than using fortificants or supplements (Waters and Sankaran, 2011) [21] (White and Broadley, 2009) [22]. Being the major staple, wheat contributes more than two-thirds of Fe and almost one-third of calcium required by adult in low socio-economic groups of the population in northern India. Therefore, the composition and nutritional quality of wheat grain has significant impact on human health and well-being, especially in the developing world. Hence the present study initiated to investigate the agronomic fortification in wheat (*Triticum aestivum* L.) with zinc.

2. Materials and Methods
Field experiment was conducted in Rabi Season of 2018-19 at the research plot of Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi. The experiment was carried out in Randomized Block Design (RBD) with six treatments and three replications. Treatments includes T_0 = Control (RDF), T_1 = RDF + $ZnSO_4$ @ 25 kg ha^{-1},

T_2= RDF + $ZnSO_4$@ 50 kg ha^{-1}, T_3= RDF+ T_1 + 3 FS @ 0.5% $ZnSO_4$ at PF, HS and MS, T_4= T_2 + 2 FS @ 0.5% $ZnSO_4$ at PF and DS, T_5= RDF + $ZnSO_4$ @ 75 kg ha^{-1} + FS @ 0.5% at HS. FS= Foliar Spray, PF= Pre Flowering Stage, HS=Heading Stage, MS= Milking stage. Recommended doses of fertilizer (RDF) viz; nitrogen, phosphorus and potassium @ 120, 60 and 60 kg ha^{-1} respectively were applied. Half dose of nitrogen and full doses of phosphorus and potassium were applied as a basal dose at the time of sowing. Rest amount of N was applied in two equal splits, first at tillering and second at ear head initiation stage as top dressing. Zn was applied as per treatments requirement as basal dose before sowing and as foliar spray at various growth stages. The wheat variety PBW343 was used as test crop and sown @ 100 kg ha^{-1} with a spacing of 20×15cm row × plant. Response of wheat to applied treatments was evaluated in terms of growth attributes, dry matter yield, and nutrient content as well as nutrient uptake.

The soil pH and EC were determined in a soil water suspension (1:2.5) the help of glass electrode pH and TDS meter. The soil samples were analyzed for organic carbon (Walkley and Black, 1934) [20], available N (Subbiah and Asija, 1956) [18], available P (Olsen, 1954) [10], available K (Jackson, 1973) [6] and DTPA extractable Zn (Lindsay and Norvell, 1978) [7]. Straw and grain samples were first dried in air and then in an electrical oven at 60 ^{0}C. Powdered samples were digested in di-acid mixture (3:1 of HNO_3: $HClO_4$) and analysed for Zn by atomic absorption spectrophotometer. The processed straw and grain samples were digested in sulphuric-selenium- salicylic acid and H_2O_2 system (Novozamsky *et al*., 1983) [9] and stored in plastic bottles for estimation of nitrogen and phosphorus (Tandon, 1993) [19]. Potassium content was determined flame-photo metrically (Jackson, 1973) [6]. The important initial soil characteristics of the experimental soil were as pH 7.20, E.C, 0.25 dS m-^{1} and organic carbon 0.36 %. Available N, P, K (kg ha^{-1}) and Zinc (ppm) were 235.8, 13.30, 206.2 and 0.45, respectively.

3. Results and Discussion

3.1 Plant height and number of tillers

The data presented in Table-1 indicates that the plant height and number of tillers under various treatments ranged from 71 to 75.33 cm and 3.33 and 5.50. Results clearly indicates that application of Zn (soil applied alone and in combination of foliar spray at different growth stages) significantly increased the growth parameters viz; plant height and number of tillers when compared with no zinc application. Minimum plant height and number of tillers were recorded with the treatment T_0 (control) whereas maximum with T_4 (application of $ZnSO_4$ @ 50 kg ha^{-1} and two foliar spray @ 0.5% $ZnSO_4$ at pre flowering stage and milking stage in combination of nitrogen, phosphorus and potassium). Singh (2012) [16], Parmar *et al*. (2016) [11] and Balai (2017) [2] reported significant increase in growth parameters in various crops due to application of zinc in general and foliar application in particular. T_4 was found to be significantly superior over all the treatments. This enhancement with T_4 in plant growth due to zinc application in booting stage indicates the importance of zinc in nitrogen and phosphorus utilization by plants. Zn recovery was considerably higher with soil + foliar application compared to soil application only. This could also be due to fact that Zn application in soil enhanced Zn concentration in the plant which is associated with RNA and ribosome induction which in turn might have accelerated in protein synthesis. Similar results are quoted by Sonune *et al*. (2001) [17] who reported increased conversion of N to protein compound and build - up of free amino acids and amides in the plant with Zn application.

3.2 Grain and straw yield

Data presented in Table-1 shows that soil alone and with foliar applied zinc at different stages of crop growth significantly and positively affected the grain and straw yield. Maximum grain and straw yield was recorded with T_4 when zinc was applied as foliar spray @ 0.5% $ZnSO_4$ at pre flowering and milking stages along with soil application @ 50 kg ha^{-1}. This might be due to role of Zn in physiological processes such as enzymes activation involved in membrane integrity, chlorophyll formation, stomata regulation and starch utilization, while enhanced accumulation of assimilate in grain which results in heavier grains. Maralian (2009) [8] showed that foliar application of Zn increased grain yield of wheat. Cakmak (2008) [3] reported the highest increase in grain yield with soil and soil +foliar application of Zn. Haslett *et al.* (2001) [5] also reported an increase in biomass by Zn application in soil without or with foliar sprays in wheat.

3.3 Nutrient content and uptake

Table 2 and 3 shows that application of soil applied zinc alone and combined with foliar spray significantly increased the nutrient content and uptake (N, P, K and Zn) by grain and straw as compared to without zinc application. Maximum content and uptake (N, P, K and Zn) by grain and straw were found with the treatment T_4 ($ZnSO_4$ @ 50 kg ha^{-1} and two foliar spray @ 0.5% $ZnSO_4$ at pre flowering and milking stages in combination of nitrogen, phosphorus and potassium) followed by T_5, T_3, T_2, T_1 and T_0. T_4 was found to be significantly superior over all the treatments. The Zn uptake was significantly influenced by the increasing level of Zn. The increased uptake may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to grain is more than to stem and leaves thereby leading to higher grain yield which was reflected in the Zn uptake. Cakmak (2008) [3] and Cakmak *et al*. (2010) [4] reported increased Zn content in wheat grain with the soil and foliar application of $ZnSO_4$ by about 3-5 fold. Similarly, Phattarakul *et el.* (2012) [12] also documented higher Zn content in brown wheat by 25 and 32 per cent by foliar and foliar + soil Zn application as compared to control, respectively. Abbas *et al.* (2018) [1] reported that total uptake of Zn and Fe, increased by applying Zn up to 8 kg ha^{-1} of wheat. This could be ascribed to balanced nutrition to crop at proper rate and time.

Table 1: Effect of treatments on growth attributes and yield of wheat crop

Treatment	Plant height (cm)	Number of tillers per plant	Grain (q ha^{-1})	Straw (q ha^{-1})
T_0 = Control (RDF)	71.00	3.33	27.08	31.66
T_1= RDF + Zinc Sulphate @25 kg ha^{-1}	71.76	3.66	27.11	40.83
T_2= RDF + Zinc Sulphate @50 kg ha^{-1}	73.08	3.75	30.75	43.33
T_3= RDF+ T_1 + 3 FS @ 0.5% $ZnSO_4$ at PF, HS and MS	73.25	3.91	30.80	44.16
T_4 = T_2 + 2 FS @ 0.5% $ZnSO_4$ PF & DS	75.33	5.50	32.50	46.66
T_5= RDF + Zinc Sulphate@75kg ha^{-1} + F S @ 0.5% at HS	73.58	4.00	30.83	45.83
SEm±	0.3114	0.2604	0.8876	1.5138
CD (P=0.05)	0.6937	0.5801	1.9775	3.7227

Table 2: Effect of treatments on N, P, K and Zn content in straw and grain of wheat

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (ppm)	
	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
T_0 = Control (RDF)	0.19	1.51	0.12	0.33	0.42	0.06	22	14.5
T_1 = RDF + Zinc Sulphate @25 kg ha^{-1}	0.25	1.57	0.14	0.42	0.57	0.11	24	16
T_2= RDF + Zinc Sulphate @50 kg ha^{-1}	0.33	1.65	0.21	0.47	0.66	0.13	26	16.5
T_3= RDF+ T_1 + 3 FS @ 0.5% $ZnSO_4$ at PF, HS and MS	0.35	1.66	0.22	0.51	0.75	0.16	27	17.2
T_4 = T_2 + 2 FS @ 0.5% $ZnSO_4$ PF and DS	0.43	1.78	0.27	0.63	0.87	0.24	31	18.2
T_5= RDF + Zinc Sulphate@75kg ha^{-1} + F S @ 0.5% at HS	0.41	1.70	0.25	0.57	0.81	0.18	29	17.5
SEm±	0.0266	0.0323	0.0043	0.0037	0.0079	0.0025	0.6055	0.5309
CD (P=0.05)	0.0592	0.0719	0.0095	0.0082	0.0176	0.0055	1.3490	1.1828

Table 3: Effect of treatments on N, P, K and Zn uptake by straw and grain of wheat crop

Treatment	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})			Zinc (g ha^{-1})		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
T_0 = Control (RDF)	40.89	6.01	46.90	3.79	8.93	12.73	13.29	1.62	14.91	696.52	392.66	1089.18
T_1 = RDF + Zinc Sulphate @25 kg ha^{-1}	42.56	10.2	52.77	5.71	11.38	17.10	23.27	2.98	26.25	979.92	433.76	1413.68
T_2= RDF + Zinc Sulphate @50 kg ha^{-1}	50.73	14.29	65.04	9.09	14.45	23.55	28.29	3.99	32.58	1126.58	507.3	1633.88
T_3= RDF+ T_1 + 3 FS @ 0.5% $ZnSO_4$ at PF, HS and MS	51.12	15.45	66.58	9.71	15.70	25.41	33.12	4.92	38.04	1192.32	529.7	1722.02
T_4 = T_2 + 2 FS @ 0.5% $ZnSO_4$ PF and DS	57.85	20.06	77.91	12.59	20.47	33.07	40.59	7.8	48.39	1446.46	591.5	2037.96
T_5=RDF+Zincsulphate@75kg ha^{-1} + F S @ 0.5% at HS	52.41	18.79	71.20	11.45	17.57	29.03	37.12	5.54	42.66	1329.07	539.5	1868.57
SEm±	0.3152	0.2357	0.2981	0.4714	0.3162	0.7889	0.1381	0.2074	0.2439	0.5932	0.6325	0.2985
CD (P=0.05)	0.9932	0.7427	0.9395	1.4854	0.9965	2.4858	0.4352	0.6536	0.7686	1.8691	1.9929	0.9406

4. Conclusion

It can be concluded from the present study that adequate Zn availability during vegetative growth phase is important for wheat. Wheat favorably responded to applied Zn in different combination and doses. Application of $ZnSO_4$ @ 50 kg ha^{-1} and two foliar sprays @ 0.5% $ZnSO_4$ at pre flowering stage (PF) and milking stage (MS) in combination of nitrogen, phosphorus and potassium was found to be the best treatment regarding growth, yield and zinc content of wheat.

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