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Effect of zinc application on growth, yield and grain quality of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted during *Rabi* season of 2019-20 in Western section of Birsa Agricultural University Farm, Kanke, Ranchi to assess the effect of Zinc application on growth and yield of wheat. The treatments consisted of different zinc fertilization practices which include the following: T_1 (control), T_2 (FYM @ 10 ton/ha), T_3 (Soil application @ 12.5 kg $ZnSO_4.7H_2O$/ha), T_4 (Soil application @ 25 kg $ZnSO_4.7H_2O$/ha), T_5 (Soil application @ 37.5 kg $ZnSO_4.7H_2O$/ha), T_6 (Foliar application of 0.5% $ZnSO_4.7H_2O$/ha at heading and milking stage), T_7 (Soil application @ 12.5 kg $ZnSO_4.7H_2O$/ha+Foliar application of 0.5% $ZnSO_4.7H_2O$/ha), T_8 (Soil application @ 25 kg $ZnSO_4.7H_2O$/ha +Foliar application of 0.5% $ZnSO_4.7H_2O$/ha at heading and milking stage), and T_9 (soil application @ 37.5 kg $ZnSO_4.7H_2O$/ha +Foliar application of 0.5% $ZnSO_4.7H_2O$/ha at heading and milking stage). Results revealed that maximum increase in growth parameters and yield and yield attributes of wheat *viz*: plant height (cm), number of tillers/m^2, leaf area index and spike length (cm), number of spikelets/spike (18.22), grains/spike (33.80, grain yield (5.09 ton^{-1}) and biological yield (12.7ton^{-1}) as compared to control or RDF+10 ton FYM/ha.

Keywords: Zinc fertilization, foliar zinc application, soil zinc application

Introduction

Wheat (*Triticum aestivum* L.) one of the most important cereal crops in the world. It is grown under different agro-climatic conditions and it occupies 220.29-million- hectare (mha) area with the production of 780.59 million tones and productivity of 3390 kg ha^{-1}. India is the second largest producer of wheat in the world after China. In India, wheat cultivated in area of with the production 109.52 million tones and productivity of 3464 kg ha^{-1} (Anonymus 2022-23) [2]. Productivity of wheat (1800 kg/ha) in Jharkhand is still less than the national average which remains a serious thought on crop improvement and management process. Wheat is considered to be a major staple food in many countries of the world. Despite its lower zinc content (20 mg/kg) in grain, the consumption by the target groups is increasing at a higher rate, which further elevated nutritional related problems. Zinc contributes to the human health and any deficient noticed leads to affect the immune system that has a major impact on health leading to many other diseases, even to the extent of mortality. Thus, agronomic biofortification at critical stages by using Zinc as foliar application will play a critical role in providing a complimentary effect in grains. Almost 50% of the agricultural lands around the world are Zn deficient for cereal productivity Catmak *et al.*, (2010) [4]. Biofortification is the process of increasing the content and bioavailability of essential nutrients in crops during plant growth through genetic and agronomic pathways Bouis and Welch (2011) [3]. Agronomic biofortification involves the practices of fertilization that increase the nutrient content in grains. Micronutrients Zn very essential for normal plant growth and development of wheat crops Fageria (2007) [6]. Agronomic biofortification is achieved through micronutrient fertilizer application to the foliar application directly to the leaves of the crop to improve the growth and yield in wheat crop. Biofortification is mainly focused on starchy staple crops wheat because they dominate diets worldwide especially among groups vulnerable to micronutrient deficiencies and provide a feasible means of reaching malnourished populations with limited access to diverse diets, supplements, and commercially fortified foods [Saltzman and Ekin, (2013) [15].

Keeping these views in mind the research was conducted to optimize the use by application of different mode of application of Zinc to increased grain yield and Zinc content in grains.

Material and Methods

A field experiment was conducted in Western section of Birsa Agricultural University Farm, Kanke, Ranchi (23˚17' N latitude, 85˚10' E longitude and 625.22m above mean sea level) Jharkhand in the *rabi* season during 2019-20 and 2020-21. The soil was clay loam with 32.4% sand, 30.3% silt and 37.3% clay. The soil was slightly acidic in reaction (pH 5.8), low in organic carbon (0.45%) and available nitrogen (225 kg/ha), medium in available phosphorus (15.4 kg/ha) and in potassium (186.6 kg/ha). The experimental plot was provided with assured irrigation facility having uniform topography and proper drainage. The experiment was laid under RBD in three replications. Net plot size was 6.0 m x 2.0 m. Row to row distance for wheat was 20 cm. Seed rate used was 100 kg/ha. Recommended dose of fertilizer (N, P and K) was 150:60:40 (kg/ha). Wheat variety 'DBW 187' was used in the investigation. Full dose of phosphorus as DAP (18%N +46% P_2O_5) and potash as muriate of potash (60% K_2O) was applied at the time of sowing of wheat crop. Nitrogen was applied through urea (46% N) in 3 splits as per the recommended practice, in which half was applied at the sowing of wheat. Remaining half of N was top dressed equally after first and second irrigation. Wheat was sown in lines by opening the furrows with the help of Dutch hoe. The experiment was conducted in randomized block design having nine treatments with three replications. Recommended dose of fertilizer was applied in all of the treatments. For weed control, herbicide was used and hand weeding was done. For chemical weed control herbicide 2, 4-D @ 0.5 kg a.i/ha was applied as post emergence. The crop was grown under irrigated condition but only two irrigations were applied due to timely rainfall, one at CRI stage and another at boot stage to maintain optimum soil moisture for crop growth. Data on growth parameter, yield attribute characters, grain yield and straw yield were recorded at different growth stages. The protein content in the seed was determined by multiplying the nitrogen content in the seed by a factor of 6.25, as specified by AOAC (1960) [1]. The data were analysed by using the Analysis of Variance Technique for randomized block design (RBD) as per the procedure described by Gomez and Gomez. (1984) [7]. The treatment means were compared at 5% level of significance.

Table 1: Treatment details along with the symbol used

Tr. No.	Treatments
T_1	Control (RDF+No $ZnSO_4.7H_2O$)
T_2	RDF+FYM @ 10 t/ha
T_3	RDF+12.5 kg/ha $ZnSO_4.7H_2O$)
T_4	RDF+25 kg/ha $ZnSO_4.7H_2O$
T_5	RDF+37.5 kg/ha$ZnSO_4.7H_2O$
T_6	RDF+0.5% foliar spray of $ZnSO_4.7H_2O$ at heading and early milking stage
T_7	RDF+12.5 kg/ha$ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$ at heading and early milking stage
T_8	RDF+25 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$ at heading and early milking stage
T_9	RDF+37.5 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$ at heading and early milking stage

Result and Discussion

Effect on Growth characters

Data at maturity highest plant height(103.26cm), was recorded with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$, which was higher than control treatment and RDF+0.5% foliar spray of $ZnSO_4.7H_2O$ but at par with rest of the treatments. At 75 days after sowing LAI was significantly higher (4.62) than control treatment, and RDF+0.5% foliar spray of $ZnSO_4.7H_2O$, with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$but was at par with rest of the treatments. At maturity highest number of tillers/m^2 (394) was recorded with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$, which was at par with rest of the treatments, except control treatment, and RDF+0.5% foliar spray of $ZnSO_4.7H_2O$ and RDF+12.5 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$. The lowest number of tillers/m^2 (340) was recorded due to control treatment. Dry matter accumulation at maturity showed significantly higher dry matter accumulation as 1240 g/m^2 for RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ as compared to control treatment and RDF+0.5% foliar spray of $ZnSO_4.7H_2O$ but at par with rest treatments. Data showed that at the interval of 100 DAS to maturity, significantly higher crop growth rate (10.05 g/m^2/day) was observed with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ and was at par with RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$, RDF+37.5 kg ha^{-1} $ZnSO_4.7H_2O$, RDF+12.5 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$andRDF+37.5 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$. Plant height, number of tillers m^{-2}, leaf area index, dry matter accumulation, and the crop growth rate are all significant indicators of crop performance**.** The application of zinc sulphate heptahydrate significantly influenced the plant height, number of tillers, leaf area index, crop growth rate and dry matter accumulation. Soil application alone or combination of soil application with foliar application significantly increased all the growth characters. However, the foliar application of zinc alone could not bring any significant increase in the growth characters, owing to its late application during the reproductive stage of wheat crop. Increase in plant height might be because, Zinc act as a cofactor and activates different hormones like auxin which is required for growth and development of plants. Zinc is a precursor of tryptophan which helps in the biosynthesis of Auxin. Likewise, increase in leaf area index, tillers m^{-2} and crop growth rate, might be due to adequate supply of zinc during crop growth, which plays an important role in chlorophyll biosynthesis, maintenance of photosynthetic activity and biosynthesis of auxin Prahraj *et al*. (2020) [13] and Hassan *et al*. (2019) [8]**.** Application of zinc increased plant height, total tillers per m^2 and leaf area index indicating higher chlorophilic area improving photosynthesis efficiency of plant which in turn resulted in higher dry matter accumulation per m^2. The increase in dry matter accumulation due to zinc application might also be due to higher photosynthesis. Zinc being an important component of carbonic anhydrase, which is essential for the activity of Rubisco, the carbon dioxide acceptor in C_3 plants, it plays a crucial role in photosynthesis. Because zinc plays such a crucial part in plant photosynthesis, a sufficient supply of zinc in the soil is expected to boost photosynthesis rates, which will increase plant dry matter accumulation Prahraj *et al*. (2020) [13]and Chaure *et al*. (2019) [5]**.** Crop growth rate (CGR) showed a continuously increasing trend throughout the vegetative stage this might be due to better vegetative growth at all the stages thus improving the crop growth rate as reported by Nadim *et al*. (2012) [12]**.**

Effect on yield attributes and yield

Data pertaining to yield attributing characters namely spikes/m^2, spikelet/spike, grains/spike, spike length, spike weight, test weight and grain yield were significant and presented in Table 2 &3.It is evident from the data that the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ gave the maximum spike/m^2(390), Spikelets/spike(18.22), Grains/spike(33.80), Spike length(9.46cm) and Spike weight (1.47g) were found significantly higher with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ as compared to control and RDF+12.5 kg ha^{-1} $ZnSO_4.7H_2O$ but at par with the rest of the treatments Grain yield across treatments varied from 44to50.86qha^{-1}.Significantly higher grain yield (50.86q/ha), straw yield(76.29 q/ha) and biological yield (127.15q/ha) was observed with the application of RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$as compared to control and RDF+0.5% foliar spray of $ZnSO_4.7H_2O$ but at par with the rest of the treatments under investigation. Soil application of zinc sulphate heptahydrate substantially increased the number of productive tillers owing to increase in the translocation of photosynthates, enzymatic activation and improvement in auxin metabolism. Zinc application considerably influenced yield traits like spike/m^2 was reported by Hassan *et al*. (2019) [8]. Soil application of zinc alone or in combination with foliar application recorded significantly higher yield attributes than those treatments where zinc was not applied. However, soil application of zinc in combination with foliar application recorded maximum yield attributes. This might be due to better nutrient translocation during reproductive and grain filling stages and increasing rate of photosynthesis. The application of Zn through different methods considerably influenced the yield traits. Maximum spikelet and grains per spike were recorded with soil application and lowest was noted with control Hassan *et al*. (2019) [8].Improvement in yield attributes was also reported by Khan *et al*. (2008) [9]. The increase in yield from soil application, whether used alone or in combination with other treatments, was attributed to an overall improvement in growth factors such as tiller count, dry matter production, and so on. Additionally, these treatments resulted in an increase in yield attributing characters over control. Yield is determined by the amount of photosynthetic surface available and the plant's photosynthetic efficiency. In light of role of zinc in photosynthesis, it is reasonable to conclude that zinc plays a significant role in plant photosynthesis and yield**.** Improvement in yield due to zinc application was also reported by Khan *et al*. (2008) [9] and Ranjbar & Bahmaniar (2007) [14]. As grain yield and straw yield was higher in treatments where zinc was applied through soil application alone or in combination with foliar application, hence biological yield also followed the same trend as that of grain and straw yield. Chaure *et al*. (2019) [5] and Kumar *et al*. (2019) [11] reported that soil application of zinc significantly recorded highest wheat grain, straw yield and biological yields.

Effect on quality parameters

The data of the protein content in grains as influenced by different treatments were significant and are presented in Table 4. The highest percentage of protein content in grain (12.43%) was recorded under treatment receiving T_8: RDF+25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ (at flowering & milking stages) which was at par with T_5, T_6, T_7, and T_9 treatments. The lowest percentage of protein content in grain (10.75%) was recorded under control (T_1). Such effects of Zn application on protein content in grain might be due to the fact that Zn increased the N-metabolism, which enhanced the accumulation of amino acids and drastically increased the rate of protein synthesis and consequently, the grain protein content. The more or less similar results were also found by Zeidan *et al*., (2010) [16] and Keram *et al*., (2014) [10]. The data on protein yield (kg/ha) as affected by different treatments were significant and are presented in Table 4. The highest value of protein yield (632.18kg/ha) was recorded under the application of RDF along 25 kg ha^{-1} $ZnSO_4.7H_2O$+0.5% foliar spray of $ZnSO_4.7H_2O$ (at flowering & milking stages) (T_8) which was at par with T_9 treatments but significantly higher than rest of the treatments.

Table 1: Growth parameters of wheat as affected by different zinc application method.

Treatments	Plant height(cm) at maturity	Crop growth rate (g/m^2/day)	Dry matter/m^2 (g) at maturity	LAI at 75 DAS	Tillers/m^2 at maturity
T1 Control (RDF+No $ZnSO_4.7H_2O$)	94.60	7.15	989.02	4.02	340
T2 (RDF+FYM@ 10 t/ha)	99.46	6.58	1130.20	4.06	366
T3 (RDF+12.5 kg/ha $ZnSO_4.7H_2O$)	97.33	7.10	1120.10	4.16	348
T4 (RDF+25 kg/ha $ZnSO_4.7H_2O$)	97.66	8.70	1200.00	4.20	390
T5 (RDF+37.5 kg/ha$ZnSO_4.7H_2O$)	98.33	9.84	1210.40	4.30	365
T6(RDF+0.5% foliar spray of $ZnSO_4.7H_2O$)	92.24	7.03	988.21	4.04	343
T7(RDF+12.5 kg/ha$ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$)	98.46	8.00	1160.40	4.50	346
T8(RDF+25 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	103.26	10.05	1240.00	4.62	394
T9(RDF+37.5 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	100.02	8.38	1190.30	4.43	385
SEm±	2.41	0.83	58.47	0.19	14.26
CD (P=0.05)	7.21	2.52	176.42	0.57	42.75

Table 2: Yield attributes of wheat as affected by different zinc application method.

Treatment	Yield attributes					
	Spikes/m2	Spikelet/ Spike	Grains/spike	Spike length (cm)	Spike weight (g)	Test weight (g)
T1 Control (RDF+No $ZnSO_4.7H_2O$)	334	15.21	30.2	7.46	0.90	41.60
T2 (RDF+FYM @ 10 t/ha)	362	16.36	32.8	8.24	1.15	41.48
T3 (RDF+12.5 kg/ha $ZnSO_4.7H_2O$)	343	15.01	32.2	7.65	0.95	41.62
T4 (RDF+25 kg/ha $ZnSO_4.7H_2O$)	386	16.48	32.7	8.43	1.19	41.54
T5 (RDF+37.5 kg/ha$ZnSO_4.7H_2O$)	360	17.06	33.3	9.02	1.25	42.37
T6(RDF+0.5% foliar spray of $ZnSO_4.7H_2O$)	338	16.52	32.1	8.32	1.09	41.20
T7(RDF+12.5 kg/ha$ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$)	340	17.08	33.23	8.48	1.24	42.24
T8(RDF+25 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	390	18.22	33.8	9.46	1.47	42.44
T9(RDF+37.5 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	382	18.01	33.6	9.28	1.38	42.46
SEm±	16.76	0.81	0.95	0.38	0.04	0.91
CD (P=0.05)	50.32	2.42	2.86	1.15	0.14	NS

Note: RDF- Recommended dose of fertilizer (150:60:40 kg ha^{-1}) applied in all treatments

Table 3: Grain yield, straw yield, biological yield and harvest index of wheat as affected by different zinc application method.

Treatment	Yield			Harvest index (%)
	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	
T1 Control (RDF+No $ZnSO_4.7H_2O$)	44.00	66.00	110.00	40.00
T2 (RDF+FYM @ 10 t/ha)	46.81	70.21	117.02	40.12
T3 (RDF+12.5 kg/ha $ZnSO_4.7H_2O$)	45.97	68.95	114.92	40.14
T4 (RDF+25 kg/ha $ZnSO_4.7H_2O$)	48.98	73.47	122.45	40.14
T5 (RDF+37.5 kg/ha$ZnSO_4.7H_2O$)	49.35	74.02	123.37	40.16
T6 (RDF+0.5% foliar spray of $ZnSO_4.7H_2O$)	45.50	68.25	113.75	40.17
T7(RDF+12.5 kg/ha$ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$)	48.02	72.03	120.05	40.12
T8(RDF+25 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	50.86	76.29	127.15	40.18
T9(RDF+37.5 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	49.43	74.14	123.57	40.18
SEm±	1.66	2.42	4.19	1.55
CD (P=0.05)	4.98	7.45	12.70	NS

Note: RDF- Recommended dose of fertilizer (150:60:40 kg ha^{-1}) applied in all treatments

Table 4: Protein content and protein yield of wheat as affected by different zinc application method.

Treatment	Protein content%	Protein yield (kg/ha)
T1 Control (RDF+No $ZnSO_4.7H_2O$)	10.75	413.23
T2 (RDF+FYM @ 10 t/ha)	11.43	512.17
T3 (RDF+12.5 kg/ha $ZnSO_4.7H_2O$)	11.31	474.68
T4 (RDF+25 kg/ha $ZnSO_4.7H_2O$)	11.43	514.23
T5 (RDF+37.5 kg/ha$ZnSO_4.7H_2O$)	11.50	533.02
T6 (RDF+0.5% foliar spray of $ZnSO_4.7H_2O$)	11.87	465.30
T7(RDF+12.5 kg/ha$ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$)	12.00	516.24
T8(RDF+25 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	12.43	632.18
T9(RDF+37.5 kg/ha$ZnSO_4.7H_2O$+5% foliar spray of $ZnSO_4.7H_2O$)	12.25	605.51
S.Em±	0.32	13.71
CD (P=0.05)	0.97	41.10

Note: RDF- Recommended dose of fertilizer (150:60:40 kg ha^{-1}) applied in all treatments

Conclusion

Based on one year data mentioned above, using 100% recommended dose of fertiliser (RDF) along with 25 kg ha^{-1} $ZnSO_4.7H_2O$ +0.5% foliar spray of $ZnSO_4.7H_2O$ (at flowering & milking stages) proved most effective method for increasing the grain yield and protein content of wheat under agro climatic situation of Jharkhand.

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