



Effect of zinc fertilization on growth, yield attributes and yield of wheat (*Triticum aestivum*) crop under irrigated mollisol

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ABSTRACT

A field experiment was conducted during *rabi* 2017-18 and 2018-19 to investigate the effects of different methods of zinc fertilization on growth parameters, yield attributes and yield of wheat (*Triticum aestivum* L.). The experiment was laid-out in a randomized complete block design with 12 treatments and 3 replications. Seed priming as well as soil application was effective in improving emergence count of wheat over control. Soil application of zinc sulphate heptahydrate @ 25 kg/ha could improve growth parameters, yield attributes and yield of wheat while nutripriming and foliar application failed to do so. The study suggested that soil application method alone or in combination with other application methods like nutripriming or foliar application can provide yield advantage of 10-15% over no zinc application. Considering the fact that combination of other application methods with soil application could not improve yield over soil application alone significantly, hence; soil application of 25 kg ZnSO₄·7H₂O alone can be recommended for achieving higher grain yield under irrigated mollisol.

Key words: Foliar, Nutripriming, Soil application, Wheat, Yield, Zinc

Intensive agriculture, lower addition of organic matter to soil, use of high analysis fertilizers etc. have given way to micronutrient deficiency in Indian agriculture. More than 50% of the area has been reported to be deficient in zinc (Shivay *et al.* 2008). Zinc deficiency often limits the productivity of cereals, though the response to the nutrient often varies with crop and even with variety.

Zinc plays many important roles in the growth and development of crops. Zinc plays multiple roles like protein synthesis, carbohydrate, lipids and nucleic acid metabolism and gene expression and regulation (Chang *et al.* 2005). Zinc is also an important part of enzymes like carbonic anhydrase, superoxide dismutase, alcohol dehydrogenase and RNA polymerase as well as cofactor of all six classes of enzymes, i.e. hydrolases, ligases, lysases, isomerases, oxidoreductases and transferases (Broadley *et al.* 2007, Maret 2013).

Considering important role played by zinc in plant and its deficiency in Indian soil, application of zinc holds a great significance. Zinc can be applied to crops through different

application methods, i.e. soil application, seed priming (or nutripriming), foliar application or by any combination of application methods. Different methods of zinc application are expected to bring different result in terms of improving yield and grain zinc concentration.

Soil application of zinc is a common method of zinc application. However, soil application of zinc is limited by different factors like pH, organic matter, redox potential of soil etc. in addition to this, zinc also interacts with phosphorus and its availability to plant is affected by concentration of zinc (Marschner 1993).

Foliar application provides many advantages like: Low fertilizer requirement, no fixation of nutrient in soil, less cost etc. In foliar method of application nutrient solution is applied to the foliage of plant and thus nutrients are not subjected to fixation.

Seed priming is also another low cost option of zinc application to crop. Primed seeds usually have better and synchronized germination owing to less imbibition period and build up of germination enhancing metabolites (Farooq *et al.* 2006). Micronutrient application through seed treatment improves stand establishment, advances phenological events and increases yield and micronutrient content in grain. In some instances, seed treatments are non-beneficial; however, the negative effects are rare (Farooq *et al.* 2012).

As different application methods as well as their combination are expected to show different response, hence;

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a field experiment was conducted to study the response of different zinc fertilization methods.

MATERIALS AND METHODS

A field experiment was conducted during *rabi*, 2017-18 and 2018-19 at Norman E. Borloug crop research center, G B Pant University of Agriculture and Technology, Pantnagar. The research centre lies in the *Tarai* belt, 30 km southern end of foothills of Shivalik range of Himalayas at 29°N latitude and 79.3°E longitude and an altitude of 243.83 m above the mean sea level. The experimental site had pH 7, organic carbon 0.70%, available nitrogen 267.5 kg/ha, available phosphorus 21.9 kg/ha, available potassium 170.3 kg/ha and available zinc 0.57 mg/kg. For the experiment wheat variety UP 2784 was grown. The experiment consisted of 12 treatments, each with 3 replications. The treatments are; T1: control, T2: soil application @ 25 kg ZnSO₄·7H₂O (SA), T3: Nutri priming with 0.3% ZnSO₄·7H₂O (NP), T4: T2+T3 (SA+NP), T5: foliar application of 0.5% ZnSO₄·7H₂O (FZS), T6: Foliar application of 0.5% ZnSO₄·7H₂O + 1% urea (FZU), T7: T2+T5 (SA+FZS), T8: T3+T5 (NP+FZS), T9: T4+T5 (SA+NP+FZS), T10: T2+T6 (SA+FZU), T11: T3+T6 (NP+FZU) and T12: T4+T6 (SA+NP+FZU). Symbols that has been used for different treatments is written in the parentheses. The details zinc application has been given in the following paragraph.

The experimental wheat crop was fertilized uniformly with 150:60:40 kg/ha of N, P₂O₅ and K₂O, respectively. Half of the nitrogen and full amount of phosphorous and potassium were applied at the time of sowing as basal. Remaining half of the nitrogen was top dressed in two equal splits, first at CRI stage and second split at second irrigation of the crop. Zinc was applied to crop as per the treatments as follow. Soil zinc was applied as basal. For soil application, 25 kg ZnSO₄·7H₂O was applied. For nutripriming, seeds were soaked in 0.3% ZnSO₄·7H₂O solution for six hr. After soaking for six hr, seeds were dried to original moisture content. For foliar application of zinc sulphate heptahydrate (alone or in combination with 1% urea as per treatment), was sprayed at heading and early milk stage. Combination of different application methods were applied as per treatments.

Emergence count was taken at 10 DAS and expressed per m² basis. For measurement of height, with a meter scale from the base of the plant to the tip of spike was measured. For estimation of dry weight plant sample was dried at 70±2 °C till constant weight was obtained. Dry matter was expressed as g/m². Tiller number was taken from sampling area and expressed as number per m². The number of spikes was counted from the observation area of two meter row length marked for shoot count and was expressed as number of spikes per meter square. Length of ten spikes was measured in cm and average was considered as spike length and expressed as cm per spike. The sampled spikes were manually threshed and number of total grains was counted manually. The number of grains per spike was computed by taking the average of all 10 spikes. The

number of the total grains from the sampled spikes was counted manually and the grain weight of thousand grains was computed and expressed in grams (g).

After harvesting, threshing, cleaning and drying, the grain yield from net plot was taken and expressed as t/ha basis. Likewise, straw yield was recorded by subtracting grain yield from the total biomass yield. Yield was expressed in t/ha. Harvest index was calculated by dividing economic yield with biological yield. Gross and net returns were calculated based on the grain and straw yield and the prevailing market prices of basmati rice in respective seasons. Benefit: cost ratio was calculated by dividing the net returns from total cost of cultivation. The data obtained from this study for 2 years were analyzed statistically using the F-test, as per the procedure given by Gomez and Gomez (1984). CD values at (P=0.05) were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Growth and yield attributes

Emergence count: Emergence count varied significantly with treatments. The treatments where seed priming (nutri priming) or soil application of zinc was done, showed significantly higher emergence count over control. Foliar application of zinc at this stage had no effect, as foliar application of zinc was scheduled at heading and early milk stage. However, no significant difference in emergence count between seed, soil as well as their combined application was observed. Data on both the years of study suggested similar result. Better germination in primed seeds might be due to less imbibition period and build up of germination enhancing metabolites (Farooq 2006).

Plant height: Plant height varied significantly across treatments. Seed priming could not improve plant height significantly above control. Treatments where soil application of zinc was done, alone or in combination with other application methods, showed significant increase in height over control. All those treatments where there was no soil application of zinc sulphate could not improve plant height over control. Zinc acts as a cofactor and activates different hormones like auxin which is required for growth and development of plants. Hence, deficiency of zinc results in leaf distortion and shortening of internode (Begum et al. 2016). Thus, application of zinc plays an important role improving plant height.

Tiller count: Treatments where soil application of zinc was done (either alone or in combination with other application) showed significant increase in tiller count over control while rest of the treatments were at par with control. Tiller count is very important as most of the effective tillers contributes towards yield. The tiller count (tillers/m²) in the first year of study varied from 321 to 374 while that in second year varied from 330 to 379. All the treatments where zinc was applied through soil application (SA, SA+NP, SA+FZS, SA+FZU, SA+NP+FZS, SA+NP+FZU) significantly improved tiller count though there was no

significant difference between tiller count among these treatments. Combination of other application method(s) with soil application could not bring any significant difference suggesting that soil application was responsible for improvement of tiller count in these treatments. Shaheen et al. (2007) reported that the numbers of tillers were significantly increased due to application of zinc. Increase in tiller count due to soil application of zinc was also reported by Khan et al. (2008).

Dry matter accumulation: As dry matter accumulation is very essential for getting higher yield, hence soil application of zinc can play an important role in this regard. Like other growth parameters soil application was effective in improving dry matter accumulation. Narwal et al. (2010) found that soil application plays a role in improving grain yield rather than improving micronutrient content. The increase in dry weight due to zinc application might be due to higher photosynthesis due to zinc application. Zinc being an integral part of carbonic anhydrase which is required for activity of Rubisco, the carbon dioxide acceptor in C_3 plants plays an important role in photosynthesis. In zinc deficient plants, a decrease in CO_2 assimilation can be attributed to ROS induced damage to photosynthetic apparatus and reduced Rubisco activity (Zaman et al. 2018). Considering these important roles performed by zinc in the

photosynthetic process of plant, sufficient supply of zinc to the soil is expected to enhance photosynthesis, which in turn enhances the dry matter production of the plant.

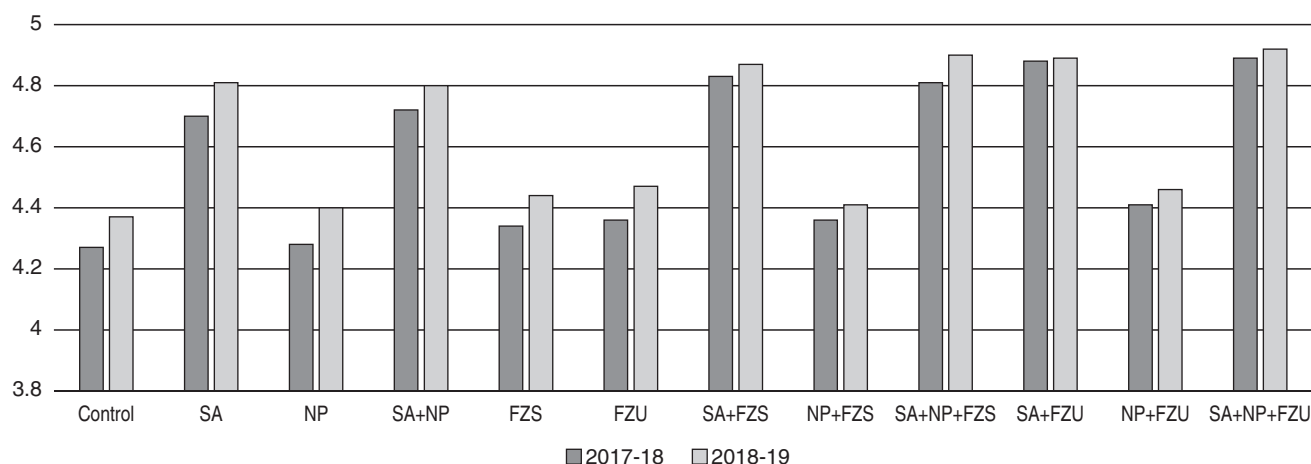
Yield attributes and yield

Number of spikes/m²: Seed priming could not bring a significant improvement in spike number above control in both the years of experiment. In control, spikes/m² was 302 and 309 in 2017-18 and 2018-19 respectively. Foliar application of zinc sulphate (FZS) or foliar application of zinc sulphate with urea (FZU) could not improve spikes/m² either. Treatments where soil application of zinc was done, alone or in combination with other application methods, i.e. SA, SA+NP, SA+FZS, SA+FZU, SA+NP+FZS and SA+NP+FZU showed significant increase in spikes/m² over other treatments. All those treatments, where there was no soil application of zinc sulphate, could not improve spikes/m² over control. Similar trend in observations was observed in both year of study. Improvement in spikes/m² due to soil zinc application has also been reported by Shaheen et al. (2007) and Khan et al. (2008).

Spike length: Spike length at harvest varied significantly. Spike length varied from 10.7 to 12.9 in 2017-18 and from 10.6 to 12.8 in 2018-19. Higher spike length was observed in treatments where zinc was applied through soil application,

Table 1 Effect of Zinc application methods on growth parameters of wheat:

Treatment	Emergence (/m ²)		Plant height (cm)		Tiller count		Dry weight (g)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Control (T ₁)	135	145	92.6	90.3	321	330	920.3	942.4
Soil application @ 25 kg ZnSO ₄ .7H ₂ O (T ₂)	147	160	102.2	99.1	361	367	973.0	998.3
Nutri priming with 0.3% ZnSO ₄ .7H ₂ O (T ₃)	146	156	93.8	92.2	326	332	929.3	951.2
Soil application @ 25 kg ZnSO ₄ .7H ₂ O + Nutri priming with 0.3% ZnSO ₄ .7H ₂ O (T ₄)	145	157	103.4	99.8	364	374	979.7	997.6
Foliar application of 0.5% ZnSO ₄ .7H ₂ O (T ₅)	138	144	92.6	91.7	325	330	922.3	947.1
Foliar application of 0.5% ZnSO ₄ .7H ₂ O + 1% urea (T ₆)	137	143	92.8	91.6	326	333	925.7	944.6
Soil application @ 25 kg ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O (T ₇)	149	157	104.3	99.3	369	375	981.7	998.3
Nutri priming with 0.3% ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O (T ₈)	146	156	92.9	93.4	327	335	931.7	960.0
Soil application @ 25 kg ZnSO ₄ .7H ₂ O + Nutri priming with 0.3% ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O (T ₉)	146	161	103.7	101.0	368	373	982.3	1001.1
Soil application @ 25 kg ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O + 1% urea (T ₁₀)	151	162	104.2	102.6	371	377	993.3	1001.7
Nutri priming with 0.3% ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O + 1% urea (T ₁₁)	144	157	92.6	93.2	330	341	933.3	961.6
Soil application @ 25 kg ZnSO ₄ .7H ₂ O + Nutri priming with 0.3% ZnSO ₄ .7H ₂ O + Foliar application of 0.5% ZnSO ₄ .7H ₂ O + 1% urea (T ₁₂)	149	161	105.4	103.4	374	379	989.0	1009.8
SEm±	2	2	2.1	1.8	9	8	13.0	11.2
CD(P=0.05)	6	5	6.0	5.3	25	24	38.0	32.7



(Control: No zinc applied, SA: Soil application of 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, NP: Nutripriming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ solution, FZS: Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, FZU: foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1% urea)

Fig 1 Effect of different zinc application methods on yield of wheat.

alone or in combination with other application method (nutri priming, or foliar or both). Nutripriming and foliar application (FZS or FZU) failed to improve spike length above control. When these treatments were applied in combination with soil application, they could not bring any

significant improvement above soil application alone (SA). It suggests that soil application was solely responsible for the improvement in spike length in those combined application methods. Increase in spike length due to soil application of zinc sulphate was also reported by Khan *et al.* (2008).

Table 2 Effect of different zinc application methods on yield attributes of wheat

Treatment	Spikes (/m ²)		Spike length (cm)		No of grains per spike		Test weight (g)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Control (T ₁)	302	309	10.7	10.6	36.6	37.7	41.5	40.5
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₂)	336	348	12.6	12.5	45.7	46.6	41.5	40.8
Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₃)	306	313	10.8	10.7	38.0	38.8	40.5	41.0
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₄)	338	346	12.7	12.6	46.0	47.2	41.1	41.9
Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₅)	301	303	10.7	10.6	38.8	39.4	41.3	40.9
Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1% urea (T ₆)	304	309	10.9	10.9	39.0	39.7	41.7	42.0
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₇)	343	350	12.8	12.7	46.7	47.3	40.6	40.0
Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₈)	306	316	10.8	10.8	40.0	40.5	41.4	40.4
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (T ₉)	344	349	12.8	12.8	47.1	48.4	41.6	41.6
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1% urea (T ₁₀)	348	348	12.9	12.8	46.3	47.8	41.3	40.8
Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1% urea (T ₁₁)	308	319	10.9	10.9	40.1	41.1	41.3	41.9
Soil application @ 25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Nutri priming with 0.3% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + Foliar application of 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1% urea (T ₁₂)	351	359	12.6	12.8	47.2	48.6	41.9	41.6
SEm±	8	8	0.2	0.2	1.5	1.2	0.5	0.7
CD(P=0.05)	24	23	0.5	0.5	4.4	3.5	NS	NS

No of grains per spike: Number of grains per spike varied significantly due to treatments. Number of grains per spike varied from 36.6 to 47.2 in 2017-18 and from 37.7 to 48.6 in 2018-19. Foliar application (FZS or FZU) as well as nutrimpriming failed to improve number of grains per spike above control. When these treatments were applied in combination with soil application, they could not bring any significant improvement above soil application alone (SA). The increase in number of grains per spike due to soil application of zinc was also reported by Khan *et al.* (2008).

Test weight: Test weight or 1000 grain weight did not vary significantly due to treatments. Test weight varied from 40.5g to 41.9g in 2017-18 and 40g to 41.9g in 2018-19 across treatments. The test weight was almost same across treatments in both the years. Though variation in grain yield per spike was observed, however no significant difference in test weight was found.

Grain yield: Seed priming, foliar application of zinc sulphate (FZS) or foliar application of zinc sulphate with urea (FZU) could not improve grain yield significantly. In both the years of experiment around 10% yield advantage was obtained with soil application of zinc alone, while combination of soil application along with nutrimpriming and/or foliar application could improve yield further. Since no combination of zinc application methods could significantly improve wheat yield over soil application alone, hence; soil application of 25 kg ZnSO₄ · 7H₂O can be recommended to farmer with the objective of higher yield. Grain yield of both the experimental years has been given in Fig 1.

The yield improvement in soil application, alone or in combination with other treatments was due to overall improvement in growth factors like tiller count, dry matter production and yield attributing factors as can be observed from Table 1 and 2. Shaheen *et al.* (2007) reported increased in grain yield due to zinc application. Narwal *et al.* (2010) also found that soil application of zinc helps in improving wheat yield.

Conclusion

The results suggested that soil application @ 25 kg/ha zinc sulphate heptahydrate was effective in improving growth parameters like tiller count, plant height and dry matter accumulation of wheat while nutrimpriming was ineffective in improving these parameters. The study suggests possible yield advantage of wheat with zinc application under irrigated mollisols; when applied through soil application method alone or in combination with other application methods. However, combination of other application methods with soil application could not improve yield over soil application alone, hence; soil application

alone can be recommended for achieving higher grain yield.

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