

Effect of zinc management on yield, nutrient content, and acquisition of zero-tilled wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season 2018–19 and 2019–20 at Khalsa College, Amritsar, Punjab to find out the effect of soil and foliar application of $ZnSO_4 \cdot 7H_2O$ on zero till wheat. The experiment was conducted in a randomized complete block design with three replications. Treatments were control (noZn), soil application of 12.5, 25, 37.5, 50 kg/ha zinc sulfate heptahydrate ($ZnSO_4 \cdot 7H_2O$), and foliar application of 0.5% Zn as one spray at heading initiation (5% ear emergence), one spray at 100% heading (complete ear emergence) and two sprays at heading initiation and 100% heading with a recommended dose of fertilizer. Results showed that the soil application of 50 kg Zn/ha with two foliar sprays of 0.5% zinc sulfate heptahydrate at heading initiation and 100% heading produced the highest yield attributes and grain yield of wheat. Application of 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading registered ~25% higher grain yield over control. Grain Zn content (41.77ppm) percent increase was 33.9 with 50 kg Zn/ha with two foliar sprays of 0.5 % zinc at heading initiation and 100% heading over control (31.20 ppm). Likewise, application of 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading recorded the highest net returns among the Zn treatments. Overall, soil application of 50 kg Zn/ha with two foliar sprays of 0.5 % zinc at heading initiation and 100% heading improved the yield, uptake, and profitability of zero-tilled wheat in zinc-deficient soils.

Key words: Grain yield, Soil and foliar spray, Zero till wheat, Zinc

Wheat (*Triticum aestivum* L.) is the principal source of food for millions of people particularly in developing countries. However, wheat grains are often lacking in certain micronutrients like zinc (Zn), boron (B), and iron (Fe) which are essential for human health (Nadeem *et al.*, 2019). Wheat plays a crucial role in providing essential micronutrients and contributing to 70% of daily calories in third-world countries. (Cakmak, 2008). Among micronutrients, deficiency of Zn is most wide spread in wheat-growing regions. Worldwide, about 50% of cultivated soils are found deficient in bioavailable Zn (Groote *et al.*, 2021). More than two billion people worldwide are suffering from several disorders due to a deficiency of micro nutrients. However, about 1.25 billion population is at risk of Zn inadequacy (Kumssa *et al.*, 2015). The continuous cultivation of nutrients exhaustive cereal crops has endangered the productivity and sustainability of the cereal-based system due to soil degradation, excessive mineral extraction, micronutrient deficiencies, and higher production costs (Yadav *et al.*, 2024; Zulfiqar *et al.*, 2020). Applying one

nutrient can impact the absorption of others by creating different compounds in soil and plants (Yadav *et al.*, 2016). Compared to other cereals, wheat cultivars possess high sensitivity to Zn-deficiency. Thus, to attain the maximum yield potential of wheat and improve grain Zn density, micronutrient management in wheat is an area of research interest, which needs immediate attention. Agronomic biofortification of Zn involves fertilizer application by soil and foliar application (Dhillon and Ram, 2023). Soil application of zinc sulfate before sowing is the most common approach to correct Zn deficiency in crops. Foliar application of Zn seems to be an effective method of ameliorating Zn deficiency and a useful method for enhancing Zn concentration in grain. The timing of the foliar spray of micronutrients is an important factor in determining its effectiveness in increasing grain enrichment of microelements. The highest concentration of Zn in wheat grain occurs at the milking stage (Ozturk *et al.*, 2006). The increase in Zn density in grain is most likely when foliar Zn fertilizers are applied to late growth stages of wheat such as heading initiation, 100% heading, milk stage or dough stage, etc. Zero tillage (ZT) enables timely wheat sowing, saves energy, and enhances soil health and fertility. Additionally, it leads to a

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different Zn distribution in the soil compared to conventional tillage systems, with higher Zn accumulation in the rhizosphere due to residue decay (Naresh *et al.*, 2017). However, there is a lack of information on the effectiveness of various methods of applying Zn fertilizer to enhance the yield, biofortification of grain, and uptake of wheat under zero tillage systems. Therefore, a current study was conducted to determine the impact of Zn fertilization on the yield, concentration, and acquisition of Zn and macronutrients in zero-till wheat.

MATERIALS AND METHODS

Field experiment was conducted during the winter (*rabi*) season of 2018–2019 and 2019–2020 at the Research Farm of Khalsa College, Amritsar, situated at 30°-36' N latitude and 73°-54' E longitude at a mean height of 234 meters above sea level. The study site has a hot moist and semi-arid type of climate with alluvial, medium water holding capacity of soils. The mean minimum and maximum temperature recorded during the growing seasons ranged from 10.2 to 25.2 °C and 10.9 to 24.0 °C, respectively during the year 2018-19 and 2019-20. The average sunshine hours ranged from 5.1 to 6.1 hr/day. The total amount of rainfall in growing seasons was 181 and 253 mm, respectively. The soil of the field was sandy loam, with pH 7.2, EC 0.13 dS/m, organic carbon (0.31%), available nitrogen (248 kg/ha), phosphorus (17.8 kg/ha), and available potassium (275 kg/ha). The available Zn in soil was below the critical level (0.57 mg/kg). The pH was measured using 1:2 soil and water suspension, organic carbon using Walkley and Black's rapid titration method (Walkley, 1934), and available potassium using 1N ammonium acetate extractable K Method (Jackson, 1967), available nitrogen and phosphorus were determined with alkaline potassium permanganate method (Subbiah and Asija, 1956) and 0.5N sodium bicarbonate extractable method (Olsen *et al.*, 1954), respectively. The field experiment consisted of thirteen treatments, *viz.*, T₁ control (no Zn), T₂ 12.5 kg Zn/ha + 0.5% foliar spray at heading initiation, T₃ 12.5 kg Zn/ha + 0.5% foliar spray at 100% heading, T₄ 12.5 kg Zn/ha + 0.5% foliar sprays at heading initiation and 100% heading, T₅ 25 kg Zn/ha + 0.5% foliar spray at heading initiation, T₆ 25 kg Zn/ha + 0.5% foliar spray at 100% heading, T₇ 25 kg Zn/ha + 0.5% foliar sprays at heading initiation and 100% heading, T₈ 37.5 kg Zn/ha + 0.5% foliar spray at heading initiation, T₉ 37.5 kg Zn/ha + 0.5% foliar spray at 100% heading, T₁₀ 37.5 kg Zn/ha + 0.5% foliar sprays at heading initiation and 100% heading, T₁₁ 50 kg Zn/ha + 0.5% foliar spray at heading initiation, T₁₂ 50 kg Zn/ha + 0.5% foliar spray at 100% heading, T₁₃ 50 kg Zn/ha + 0.5% foliar sprays at heading initiation and 100% heading. The treatments were evaluated in random-

ized complete block design with three replications. Zn was applied as per the treatments. The soil application of Zn (ZnSO₄·7H₂O) was applied before sowing of the crop, foliar sprays of 0.5% zinc sulfate heptahydrate (21%) (dissolving in 500 liters of water per hectare during each spray) were applied at heading initiation (5 % ear emergence), 100% heading (complete ear emergence), during evening hours. Wheat variety Unnat (PBW 343) was sown in the first week of November using 100 kg seed/ha under zero-till conditions (collecting loose straw manually and without seedbed preparation) at 22.5 cm row spacing using zero till seed drill in standing rice stubbles. Nitrogen (125 kg/ha), phosphorus (62.5 kg/ha), and potassium (60 kg/ha) were applied at the recommended rates through urea, di-ammonium phosphate, and muriate of potash, respectively. Half a dose of nitrogen and a full dose of phosphorus and potassium were applied at the time of sowing with zero till seed drill. The remaining half dose was applied after the first irrigation. All other recommended packages of practices of Punjab Agricultural University were followed for the successful raising of zero till wheat. Harvested crop produce from the net plot was threshed manually by beating at a hard surface. The grain yield was recorded in kg per plot and expressed in t/ha. Macro and micro-nutrient content at different growth stages and at the time of harvesting in the plant was determined by drying the samples in the hot-air oven at 60°C ± 2° till a constant dry weight was obtained. Nitrogen content in samples was analyzed by using Kjeldahl's apparatus and expressed as a percentage. The P content was determined by using the Vanado-molybdous-phosphoric acid yellow color method (Piper, 1966). The K content was determined by using the flame photometer and was expressed as a percentage. The Zn content in wheat grain and straw was determined using Atomic Absorption Spectrophotometry (AAS). The macro and micro-nutrient uptake was computed by multiplying the nutrient content with respective plant biomass and was expressed as nutrient uptake in kg/ha. Economics was computed based on prevailing market prices of crop produce, inputs, labor, and machinery rent. The data obtained from a two-year study were analyzed statistically as per the procedure given by Gomez and Gomez (1984) using the CPCS1, software. LSD values at P=0.05 were used to determine the significance between the different treatments.

RESULTS AND DISCUSSION

Yield attributes and grain yield

Yield attributes responded significantly to the Zn treatments. Maximum numbers of effective tillers were recorded with the application of 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading, which was statistically at par with 37.5 kg Zn/ha, 25 kg Zn/

ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading and lowest was recorded in control where no Zn was applied (Table 1). Among the Zn treatments, the application of 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading resulted in a maximum number of grains per ear. Zn fertilization has been previously reported to improve yield attributing parameters of wheat like number of tillers and number of grains per ear. All methods of Zn application resulted in significantly higher ear length as compared to the control (no Zn). Among the Zn application methods, 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading produced the longest ear length spike which was significantly better than 25 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading. 1000-grain weight represents the boldness of the grain (Table 1). Application of 50 kg Zn/ha with two foliar sprays of 0.5 % Zn at heading initiation and 100% heading was superior in 1000-grain weight (47.5 g) and noticeably higher than the rest of the treatments. The application of Zn might have increased the photosynthetic efficiency due to improved enzymatic activity and thus might have increased thousand-grain weight. These results conform with the findings of Mauriya *et al.* (2015). The grain yield of zero, till responded appreciably to the soil and foliar application of Zn (Table 1.) Significant increase in the grain yield, was observed with the increasing Zn application. Higher grain yield was recorded with 50 kg Zn/ha + 0.5 % foliar spray at heading initiation and 100% heading (5.22 t/ha), which was at par with yield obtained under 37.5 kg Zn/ha + 0.5 % foliar spray at heading initiation and 100% heading, 25 kg Zn/ha + 0.5 % foliar spray at heading initiation and 100% heading and significantly superior to all other treatments. The minimum average grain yield was recorded in control (3.92 t/ha). The increase in yield and yield attributes due to Zn fertilization might be the fact that Zn plays an important role in the biosynthesis of IAA and initiation of primordia for reproductive parts. Zn is an important component and co-factor of several enzymes, cell division, and elongation, which helps plants maintain different biochemical activities for better crop growth, better physiology, more biofortified grains, and greater yield. These results conform with those of Faizal *et al.* (2021) and Dewal *et al.* (2004).

Nutrient concentration

The effect of zinc application on N, P, and K contents was found statistically identical; although a

Table 1. Effect of various zinc treatments on yield attributes, yield and economics of zero tilled wheat (pooled data of 2 years)

Treatment	Effective tillers/m ²	Ear length (cm)	Grains/ear (Nos.)	1000-grain weight (g)	Grain yield (t/ha)	Gross return (₹ x 10 ³ /ha)	Net return (₹ x 10 ³ /ha)	Additional income over control (₹/ha)
Control (no zinc) + NPK (Recommended)	284	9.2	37.9	38.2	3.93	71.13	42.44	-
12.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	318	9.6	39.7	39.6	4.06	76.74	47.80	5355
12.5 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	323	10.1	40.0	41.6	4.21	78.85	49.91	7467
12.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	331	9.4	41.4	43.6	4.36	81.23	52.29	9848
25 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	339	9.6	40.2	41.8	4.54	84.99	55.80	13351
25 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	351	10.2	42.4	47.0	4.69	87.89	58.70	16252
25 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	373	11.2	44.1	47.3	4.82	92.75	63.56	21116
37.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	344	9.8	41.1	43.1	4.67	91.89	62.45	20005
37.5 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	353	10.4	42.2	44.8	4.75	92.84	63.40	20953
37.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	372	10.7	44.4	46.9	5.11	96.81	67.36	24921
50 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	346	11.1	41.5	43.8	4.75	92.82	63.13	20684
50 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	365	11.3	42.4	45.8	4.85	94.15	64.46	22018
50 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	374	11.5	44.8	47.5	5.25	98.43	68.74	26295
SEM±	2.6	0.1	0.4	0.3	0.88	-	-	-
CD (P=0.05)	8.42	0.78	1.51	1.36	0.32	-	-	-

numerically higher value was observed with the application of 50 kg Zn/ha + 0.5 % foliar sprays at heading initiation and 100 % heading. Non-significant effects of Zn fertilizations on N,P, and K contents might be due to the application of recommended doses of N,P, and K fertilizers in all the treatments. The significant increase in N,P, and K contents with application of Zn was also reported by Singh *et al.* (2024). Zn concentration in grains and straw of zero till wheat increased significantly with different rates of Zn treatment (Table 2). The highest concentrations of Zn were recorded in grain (41.77ppm) with the application of 50 kg Zn/ha + 0.5 % foliar sprays at heading initiation and 100 % heading, which was 33.92% higher over the control (31.19 ppm). A similar trend in Zn content in straw was recorded as Zn content in grains. It was affected statistically with the various Zn treatments but it increased with all treatments over the control. The range of Zn varied from 24.52 to 18.15 mg/kg in the straw of zero till wheat. This might be attributed to the genetic potential of nutrient content and acquisition. The acquisition of nutrients by the crop depends upon the dry matter production and nutrient content in plant parts (Yadav *et al.*, 2016).

Nutrient acquisition

Total nutrient uptake (acquisition) by wheat (grain and straw) was influenced by various Zn treatments. Total N, P, K, and Zn uptake by wheat was the highest with the application of 50 kg Zn/ha + 0.5 % foliar sprays at heading initiation and 100 % heading, (163.17kg/ha, 23.47kg/ha, 15.21 kg/ha and 408.31 kg/ha) which was remarkably better than other treatments (Fig. 1). The lowest total N, P, K and Zn uptake was recorded in control, where no Zn was applied. The magnitude of increase in N, P, K, and Zn uptake with 50 kg Zn/ha + 0.5 % foliar sprays at heading initiation and 100 % heading was 49.7, 64.0 45.2, and 80.1% in wheat (grain and straw), respectively, over the control. Zn influenced the growth and grain yields of crops possibly through accelerated uptake and transport of beneficial nutrients like N, P, K, and Zn in plants. These results are following the findings of Chaudhary *et al.* (2014). Zn interacts positively with nitrogen and potassium and negatively with phosphorus in plants. The improvement in dry matter accumulation and nutrient contents ultimately led to higher uptake of nitrogen, phosphorus, potassium, and Zn (Parshad *et al.*, 2016).

Table 2. Effect of various zinc treatments on, N, P, K and Zn content of zero tilled wheat (pooled data of 2 years)

Treatments	N (%)		P (%)		P (%)		Zn (ppm)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Control (no zinc) + NPK (Recommended)	1.83	0.64	0.30	0.044	0.39	1.60	31.20	18.15
12.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	1.85	0.65	0.31	0.045	0.40	1.62	32.67	20.00
12.5 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	1.86	0.65	0.32	0.045	0.41	1.62	33.01	20.21
12.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	1.87	0.66	0.33	0.047	0.42	1.64	33.32	20.41
25 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	1.89	0.67	0.34	0.048	0.42	1.65	35.12	21.16
25 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	1.91	0.68	0.33	0.048	0.43	1.66	35.81	22.20
25 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	1.98	0.70	0.34	0.053	0.43	1.67	40.80	24.31
37.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	1.93	0.70	0.35	0.050	0.44	1.67	38.75	23.06
37.5 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	1.94	0.71	0.35	0.051	0.44	1.66	39.17	23.31
37.5 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	1.97	0.72	0.36	0.053	0.45	1.67	41.29	24.29
50 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation	1.95	0.73	0.35	0.053	0.45	1.68	39.81	23.74
50 kg Zn/ha + foliar spray of 0.5% Zn at 100% heading	1.95	0.75	0.37	0.055	0.46	1.69	40.04	23.99
50 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading	2.00	0.75	0.37	0.056	0.47	1.69	41.77	24.52
SEM±	0.03	0.05	0.0045	0.0006	0.016	0.04	0.29	0.05
CD (P=0.05)	NS*	NS	NS	NS	NS	NS	1.14	0.24

NS, non-significant

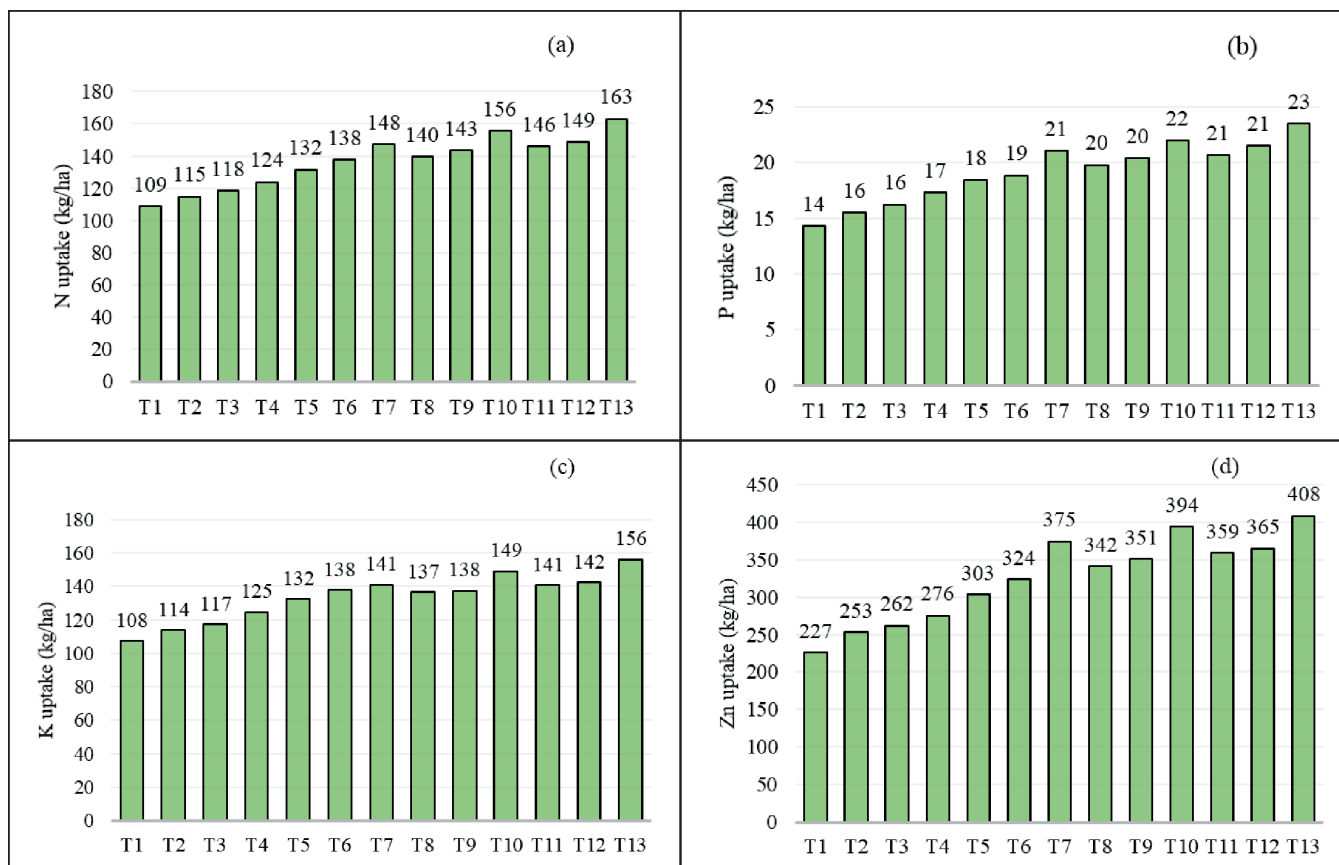


Fig. 1. Effect of various zinc treatments on N, P, K and Zn uptake of zero tilled wheat

Economics

In the current study, the net returns increased with the increase in Zn treatments over the control. Net returns among the Zn treatments varied from ₹42.44 to 68.74 $\times 10^3$ /ha. The application of 50 kg Zn/ha + foliar spray of 0.5% Zn at heading initiation and 100% heading resulted in 26.29 ₹ $\times 10^3$ /ha additional net returns over control. The increase in the grain yield leading to the higher economic return is attributable to the improved physiology of plants with the added Zn consequently enhancing the efficiency of different enzymes leading to higher yield.

Thus, it may be concluded that soil application of 50 kg Zn/ha along with two foliar sprays of Zn @ 0.5% at heading initiation and 100% heading produced ~25% higher grain yield, besides higher Zn concentration and acquisition by zero till wheat over control (no Zn). Hence, it can be recommended for quality wheat production in Punjab under zero-till conditions.

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