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Impact of zinc fertilization on growth, yield and quality of zero till wheat (*Triticum aestivum* L.)

M. Singh^{1*} and K.S. Sandhu²¹Faculty of Agricultural and Forestry, Guru Nanak Dev University, Amritsar-143 002, India²Department of Agriculture, Khalsa College, Amritsar-143 002, India*Corresponding Author Email : mandeepsingh283@yahoo.com

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Abstract

Aim: To determine the impact of soil and foliar application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at late stages of wheat as heading initiation (5% ear formation), 100% heading (complete ear formation) and heading initiation and 100% heading along with recommended dose of fertilizer on growth, yield and quality of zero till wheat.

Methodology: The field experiment was conducted on zero till wheat. The treatments consisted of control (no Zn), soil application of 12.5, 25, 37.5, 50 kg ha⁻¹ $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ and foliar application of 0.5% Zn as one spray at heading initiation (5% ear formation), one spray at 100% heading (complete ear formation) and two sprays at heading initiation and 100% heading with recommended dose of fertilizer. These treatments were evaluated in RBD with three replications.

Results: Soil application of 50, 37.5 and 25 kg Zn ha⁻¹ with two foliar sprays of 0.5% at heading initiation (5% ear formation) and 100% heading (complete ear formation) stages gave significantly higher average grain and straw yield and Zn concentration in grain than other treatments, including control.

Interpretation: Enhanced application of Zn as soil and foliar application ameliorates soil Zn deficiency and increases protein content in grains, which might influence the quality and yield of zero tilled wheat.

Key words: Foliar spray, Grain yield, Wheat, Zinc

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Introduction

Wheat is a major cereal crop and source for dietary calorie intake, protein and micro-nutrients mostly in the developing countries, accounting 50% of the daily calories intake (Cakmak, 2008). Production of food grains is increasing year after year due to intensive cultivation of land, thereby depleting a huge amount of macronutrients along with micronutrients. Though, the requirement of micronutrients for different crops is less than the macronutrients but they play a pivotal role in influencing the yields and quality of grains. Zinc deficiency is prevalent in wheat growing areas both in temperate and tropical climates (Shivay *et al.*, 2008). As per report of Takkar (1996), about 47% of Indian soils are deficient of Zn content, which leads to decline in wheat yields in countries like India, Australia and Turkey. The soils of Punjab are also suffering from sizeable amount of Zn deficiency (22.6%), which is considerably enough to adversely affect the yield of food crop in the state (Tiwana *et al.*, 2007).

Zinc deficiency is among the top five micronutrient deficiencies severely affecting one-third of world's population, especially rural communities (Stein, 2010). Micronutrient malnutrition is a global health problem affecting more than 3 billion people world wide (Cakmak *et al.*, 2010). About 44% children less than five years of age are zinc deficient in India (Kapil and Jain, 2011). Under severely Zn deficient soils, the Zn concentration of wheat grains may be as low as 10 mg kg^{-1} , whereas the human requirement is $40\text{--}60 \text{ mg kg}^{-1}$ and the current situation for world is $10\text{--}30 \text{ mg kg}^{-1}$ (Cakmak *et al.*, 2010). Inadequate intake of food low in zinc content is a major contributor to the prevalence of zinc deficiency in humans. Zn deficiency significantly affects human health leading to reduced growth and immunity, learning deficits, mental retardation and DNA damage (Prasad, 2008).

Biofortification is the process of increasing natural content of nutrients in edible part of crop plants (Welch, 2005). The supply of minerals to the developing cereal grain originates from two sources: first as a result of direct uptake from the soil and second from remobilization of stored minerals in leaves as they senesce during grain filling stage. Agronomic biofortification of Zn involves fertilizer application by soil and foliar application. Soil application of zinc sulphate before sowing is the most common approach to correct Zn deficiency in crops (Alloway, 2008). But foliar Zn application is also used, usually at mid tillering or at early anthesis stages (Cakmak *et al.*, 2010 a). Foliar application of Zn seems to be an effective method of ameliorating Zn deficiency and a useful method for enhancing Zn concentration in grain. Moreover, the fertilizer technique is a quick and complementary strategy, which maintains and builds a pool of zinc for translocation and uptake. The timing of foliar spray of micronutrients is an important factor determining its effectiveness in increasing grain enrichment of microelements. The large increase in zinc grain concentration are most likely when foliar Zn fertilizers are applied to late growth stages of wheat as heading initiation, 100% heading, milk stage or dough stage etc. Ozturk *et al.* (2006) studied changes in grain Zn concentration in wheat and

found the highest concentration of grain Zn occurs during the milk stage of grain development. Different reports are available indicating that more than 50% of wheat around the globe is cultivated on zinc-deficient soils (Alloway, 2004; Cakmak, 2008), which further lower grain zinc content. In response to aforementioned problem, different approaches have been suggested in developing nation, where biofortification of cereals with important micronutrient is receiving a great deal of attention. Keeping in view the above, the present study was planned with soil application before sowing and foliar application at heading initiation (5% ear formation) and 100% heading (complete ear formation) with recommended fertilizer to determine their impacts on growth, yield and quality of zero till wheat.

Materials and Methods

Experimental site and weather conditions: A field experiment was conducted during Rabi season of 2018-19 and 2019-20 at the Research Farm Area of Post Graduate Department of Agriculture, Khalsa College, Amritsar. This site has hot moist and semi-arid type of climate with alluvial, medium available water holding capacity soils. The mean values of minimum and maximum temperature recorded during growing seasons of zero till wheat ranged from 10.2 to 25.2°C and 10.9 to 24.0°C , respectively. The value of minimum to maximum relative humidity during both growing seasons of wheat was 38 to 94% and 39 to 91%, respectively. The average sunshine hours during growing season of wheat ranged from 5.1 to 6.1 hr day^{-1} while total amount of rainfall was 181 and 253 mm, respectively. The soil of the field was sandy loam, having a pH 7.2, EC 0.13 dS m^{-1} , low in organic carbon (0.31%), available nitrogen (248 kg ha^{-1}), medium in phosphorus (17.8 kg ha^{-1}) and available potassium (275 kg ha^{-1}).

The available Zn in soil was below critical level (0.57 mg kg^{-1}). The pH was measured using 1:2 soil and water suspension, organic carbon by Walkley and Black's Rapid Titration Method and available potassium using with Ammonium Acetate Extractable K Method (Jackson, 1967), available nitrogen and phosphorus was determined by Alkaline Potassium Permanganate Method (Subbiah and Asija, 1956) and Sodium Bicarbonate Extractable Method (Olsen *et al.*, 1954), respectively. DTPA-extractable Zn content was determined with AAS FS 240 Model of Atomic Absorption Spectrophotometer. For estimation of Zn content in grain, 0.5 g grain sample was digested in diacid mixture of HNO_3 : HClO_4 (Page *et al.*, 1982). After proper dilution with double distilled water, the Zn content in digested materials was estimated on Atomic Absorption Spectrophotometer (Varian AAS FS 240 Model).

Experimental details: The field experiment consisted of thirteen treatments, viz T_1 - control (no Zn), T_2 - $12.5 \text{ kg Zn ha}^{-1}$ + 0.5% foliar spray at heading initiation, T_3 - $12.5 \text{ kg Zn ha}^{-1}$ + 0.5% foliar spray at 100% heading initiation, T_4 - $12.5 \text{ kg Zn ha}^{-1}$ + 0.5% foliar spray at heading initiation and 100% heading, T_5 - 25 kg Zn ha^{-1} + 0.5% foliar spray at heading initiation, T_6 - 25 kg Zn ha^{-1} + 0.5% foliar

spray at 100% heading, T_7 - 25 kg Zn ha⁻¹ + 0.5% foliar spray at heading initiation and 100% heading, T_8 -37.5 kg Zn ha⁻¹ + 0.5% foliar spray at heading initiation, T_9 - 37.5 kg Zn ha⁻¹ + 0.5% foliar spray at 100% heading, T_{10} - 37.5 kg Zn ha⁻¹ + 0.5% foliar spray at heading initiation and 100% heading, T_{11} - 50 kg Zn ha⁻¹ + 0.5% foliar spray at heading initiation, T_{12} - 50 kg Zn ha⁻¹ + 0.5% foliar spray at 100% heading, T_{13} - 50 kg Zn ha⁻¹ + 0.5% foliar spray at heading initiation and 100% heading. The treatments were evaluated in randomized block design with three replications. Zinc was applied as per the treatments, except for control.

Zinc (ZnSO₄·7H₂O) was applied before sowing of the crop, foliar sprays of 0.5% zinc sulfate heptahydrate were applied at heading initiation (5% ear formation), 100% heading (complete ear formation), initiation, and 100% heading stages of the crop vegetative growth during evening hours. During both years wheat variety of Unnat PBW 343 was sown in the first week of November using 100 kg seed ha⁻¹ under zero till conditions (without seed bed preparation) at 22.5 cm row spacing using zero till seed drill in combined harvested rice field in standing stubbles after removing the loose rice straw from the field. Nitrogen was applied @ 125 kg ha⁻¹ as urea in two splits (1/2 at the time of sowing and 1/2 after first irrigation). Phosphorus was applied @ 62.5 kg ha⁻¹ and potassium @ 30 kg ha⁻¹ as full basal dose at the time of sowing with zero till seed drill.

All the other recommended package of practices of Punjab Agricultural University was followed for successful raising of zero till wheat. Harvested crop produce from net plot was threshed manually by beating on hard surface. The grain yield was recorded in kg per plot and expressed in t ha⁻¹. Bundle weight was taken before threshing and straw weight (kg) was recorded after deducting grain weight (kg) from the bundle weight (kg), which was straw yield, expressed in t ha⁻¹. Biological yield was calculated by the sum of grain and straw yield. Zn uptake was calculated by multiplying the percent of Zn content of grain and straw with their respective yield.

Analysis of quality parameters: The grain protein content was estimated using whole grain analyzer Infratec 1241. The instrument uses the near infrared light transmitted through the grains. The results are displayed as % protein content as per calibration. The sodium dodecyl sulphate sedimentation value of whole meal samples was estimated by the method of Axford *et al.* (1979). A sample weight of 6 g and a rest period of 20 minutes were employed. Hectolitre weight was measured using the apparatus developed by the Directorate of Wheat Research, Karnal, which employs a standard container of 100 ml capacity. The grains were weighed and the hectolitre weight was expressed in kg hl⁻¹. The grain appearance score was based on the size, shape, color and luster of the grain. It was evaluated subjectively out of a maximum score of 10. Beta carotene content was determined using water saturated butanol to extract beta carotene pigment. Absorbance of the filtrate was measured at 440 nm using UV-VIS Spectrophotometer using water saturated butanol as blank. The

beta carotene content was calculated as follows: Beta carotene (ppm) = 0.0105 + 23.5366 x Optical Density (O.D.).

Statistical analysis: The data obtained from two year study were analyzed statistically as per the procedure given by Gomez and Gomez (1984) using CPCS1 software. LSD values at P=0.05 were used to determine significance between different treatments.

Results and Discussion

Grain, straw and biological yield of zero till wheat responded significantly to soil and foliar application of ZnSO₄·7H₂O at later stages (Table 1). However, the highest average grain yield, straw and biological yield was recorded with T_{13} treatment, which was at par with T_{10} and T_7 treatment. These treatments gave significantly higher grain, straw and biological yield as compared to other treatments, which was 33.16, 31.37 & 25.51, 34.95, 30.60 & 24.00 and 34.22, 30.71 & 24.81% higher than control. Therefore, T_7 treatment gave significantly similar average grain, straw and biological yield as compared to higher level of Zn treatments, so this treatment can be used to obtain higher grain and straw yield of zero till wheat in Zn deficient sandy loam soil. The results are in conformity with the findings of Narwal *et al.* (2010) who recorded the maximum increase in grain yield when ZnSO₄ of 25 kg ha⁻¹ was applied as soil application and 0.5% of ZnSO₄ as foliar spray. However, Afzal *et al.* (2017) observed the highest grain yield (6.00 t ha⁻¹) and biological yield (11.93 t ha⁻¹) with soil application of Zn before planting and foliar application at later stages of growth.

Similar findings were reported by some other workers as the highest grain and biomass yield with the addition of 20 kg Zn ha⁻¹ and foliar application of zinc (0.5%) at heading and milking stage (Vora *et al.*, 2019; Pallavi and Sudha, 2017; El-Dahshouri *et al.*, 2017). Zinc increases photosynthesis, initial growth, nitrogen fixation, which resulted in higher biological yield. Whereas, Imran and Rehim (2016) reported that combined application of Zn (soil + foliar) is more promising in improving plant growth and yield than other fertilization approaches. The increase application growth and yields of zero till wheat with application of Zn might be due to the enzymatic functions, pollination and grain development with translocation and synthesis of carbohydrates in grains due to Zn fertilization. Zn also play an important role in chlorophyll biosynthesis, maintenance of photosynthetic activity and biosynthesis of auxin, which regulates remobilization of carbohydrate to grain, providing an improved resource generating base for the crop.

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 was recorded in grain (41.77 mg kg⁻¹) with T_{13} treatment, which was 33.92% higher over the control (31.19 mg kg⁻¹). The higher concentration of Zn in grain was found with treatment T_{13} , which was at par with T_{10} and T_7 , and was 32.38 and 30.81% higher than control. Similar trend in Zn

Table 1: Effect of zinc application on yield of zero till wheat (Pooled data of two years)

Treatments	Grain yield (t ha ⁻¹)	% increase over the control	Straw yield (t ha ⁻¹)	% increase Over the control	Biological yield (t ha ⁻¹)	% increase Over the control
T ₁	3.92	-	5.75	-	9.67	-
T ₂	4.07	3.82	6.02	4.69	10.09	4.34
T ₃	4.18	6.63	6.15	6.95	10.33	6.82
T ₄	4.31	9.94	6.47	12.52	10.78	11.47
T ₅	4.51	15.05	6.84	18.95	11.35	17.37
T ₆	4.66	18.87	7.08	23.13	11.74	21.40
T ₇	4.92	25.51	7.15	24.00	12.07	24.81
T ₈	4.72	20.41	6.89	19.83	11.61	21.69
T ₉	4.80	22.45	6.99	21.56	11.79	21.92
T ₁₀	5.13	31.37	7.51	30.60	12.64	30.71
T ₁₁	4.82	22.96	7.04	22.43	11.86	22.64
T ₁₂	4.88	24.49	7.07	22.96	11.95	23.57
T ₁₃	5.22	33.16	7.76	34.95	12.98	34.22
S. Em ±	0.11	-	0.21	-	0.29	-
LSD (P=0.05)	0.32	-	0.62	-	0.92	-

Table 2: Effect of zinc application on grain quality parameters of zero till wheat (Pooled data of two years)

Treatments	Zn content in grain (mg kg ⁻¹)	% increase over the control	Zn content in straw (mg kg ⁻¹)	Total Zn uptake (g ha ⁻¹)	Protein content (%)
T ₁	31.19	0	18.15	226.62	11.49
T ₂	32.67	4.74	20.00	253.36	11.62
T ₃	33.01	5.83	20.21	262.27	11.65
T ₄	33.32	6.82	20.41	275.66	11.68
T ₅	35.12	12.60	21.16	303.12	11.84
T ₆	35.81	14.81	22.20	324.05	11.90
T ₇	40.80	30.81	24.31	374.55	12.34
T ₈	38.75	24.23	23.06	341.78	12.15
T ₉	39.17	25.58	23.30	350.88	12.21
T ₁₀	41.29	32.38	24.29	394.23	12.40
T ₁₁	39.81	27.63	23.74	359.01	12.18
T ₁₂	40.04	28.37	23.99	365.00	12.20
T ₁₃	41.77	33.92	24.52	408.31	12.53
S. Em ±	0.38	-	0.09	11.62	0.07
LSD (P=0.05)	1.14	-	0.24	33.84	0.23

concentration in straw was recorded as Zn concentration present in grains. It was affected statistically with the various Zn treatments but it increased with all treatments over the control. The range Zn varied from 24.52 to 18.15 mg kg⁻¹ in straw of zero till wheat. Similar results were recorded in the previous studies conducted by Akram *et al.* (2017); Cakmak *et al.* (2010).

In field trials, they were observed highest Zn concentration of 20 to 35 mg kg⁻¹ in different crops with the soil and foliar application of Zn. In another study, significantly higher content of zinc in wheat grain and straw was obtained with soil application of Zn SO₄ at 20 kg ha⁻¹ + foliar spray of ZnSO₄ at 0.5 %

at crown root initiation and heading stages (Vora *et al.*, 2019). While, significantly higher zinc content in straw (57.7 ppm) was recorded with soil application of ZnSO₄ at 20 kg ha⁻¹ + 0.5% foliar spray at milking and dough stages. Zn uptake was statistically more in all treatments as compared to control.

It was observed that Zn uptake by zero till wheat was same as Zn concentration in grain and straw. However, total Zn uptake was found highest (408.31 g ha⁻¹) with T₁₃ and statistically at par with T₁₀ (394.23 g ha⁻¹) and T₇ (374.55 g ha⁻¹) treatment, respectively. It was due to higher Zn concentration in the respective Zn treatments in grain and straw. The lowest total

Table 3: Effect of zinc application on grain quality parameters of zero till wheat (Pooled data of two years)

Treatments	Sedimentation value (cc)	Dry gluten (%)	Wet gluten (%)	Hectoliter weight (kg hl ⁻¹)	Grain appearance score (Max 10)	Beta carotene (PPM)
T ₁	35.2	9.42	29.55	76.9	5.1	3.46
T ₂	36.9	9.54	31.27	77.1	5.2	3.55
T ₃	38.3	9.57	31.35	77.1	5.2	3.61
T ₄	41.3	9.63	31.51	77.3	5.2	3.70
T ₅	42.6	9.66	32.58	77.4	5.4	3.77
T ₆	43.9	10.09	32.65	77.7	5.3	3.87
T ₇	50.2	10.76	33.62	79.5	5.7	4.10
T ₈	47.9	10.21	32.89	78.4	5.5	3.91
T ₉	49.0	10.49	33.04	78.5	5.5	4.01
T ₁₀	51.0	10.78	33.62	79.7	5.7	4.18
T ₁₁	49.5	10.67	33.49	79.1	5.6	4.03
T ₁₂	50.1	10.71	33.51	79.2	5.6	4.12
T ₁₃	52.2	10.83	33.82	81.1	5.8	4.23
S. Em ±	0.68	0.02	0.09	0.36	0.04	0.05
LSD (P=0.05)	2.0	0.08	0.20	1.06	0.1	0.14

uptake was recorded in control due to lower concentration of Zn in the grain and straw. Similarly, significantly high zinc uptake (475.0 g ha⁻¹) was recorded with the soil application of ZnSO₄ at 20 kg ha⁻¹ + 0.5% foliar sprays at heading and milking stages by Sabir *et al.* (2015). A significant difference in average protein content was observed among different treatments of Zn by El-Dahshouri *et al.* (2017).

The maximum average protein content (12.53%) was produced by treatment T₁₃, which was statistically at par with T₁₀ (12.40%) and T₇ (12.34%). However, the minimum mean protein content was recorded in control (11.49%) with no Zn application (Table 2). Muhammad *et al.* (2019) recorded the highest protein content with application of 125% RDN + ZnSO₄ 25 kg Zn ha⁻¹ soil application + ZnSO₄ 0.5% foliar spray, which might be due to the fact that soil and foliar application of zinc enhances nitrogen use efficiency in wheat grain and as nitrogen is the major component of amino acids, it leads to protein synthesis. Pallavi and Sudha (2017) recorded significantly highest protein content with combined soil (20 kg Zn ha⁻¹) and foliar application (0.5% through ZnSO₄·7H₂O) of Zn at heading and milking stage over control because micronutrient enhances accumulation of assimilates in grains (during the grain filling stage) leading to high protein content in seeds.

Increase in zinc dose led to concomitant increase in average protein content in wheat due to enhanced synthesis of indole acetic acid, chlorophyll formation and auxin metabolism. Cakmak *et al.* (2010) reported a close positive correlation between grain protein and Zn concentration. Akram *et al.* (2017) also reported that interaction effect of nitrogen and zinc increases the grain protein content in wheat. Various treatments of soil and foliar application of Zn significantly affected the sedimentation, dry and wet gluten content, and hectolitre

weight, grain appearance and beta carotene values (Table 3). The highest value of all quality parameters was found with T₁₃ treatment and the lowest was recorded in control plot, whereas, significantly similar values were found with T₁₀ and T₇. Similarly, Muhammad *et al.* (2019) reported higher grain appearance score and hectolitre weight with 125% RDN + ZnSO₄ 25 kg ha⁻¹ soil application + ZnSO₄ 0.5% foliar spray. The hectolitre weight and grain appearance score reflect the conditions during grain filling period of crop and as foliar application of zinc at milking and dough stage leads to bold, lustrous and attractive wheat grain, which ultimately enhances the value of hectolitre weight and grain appearance score.

The beta carotene value varied from 4.23 to 3.46 ppm in grain of zero till wheat under various treatments, however, the highest was recorded in T₁₃ and lowest in T₁ treatment, respectively. The maximum value of beta carotene (3.64 ppm) was reported by Muhammad *et al.* (2019) with the application of 125% RDN + 25 kg ha⁻¹ of ZnSO₄ as soil application + 0.5% foliar spray of ZnSO₄. The higher values of all parameters, may be due to essential role of Zn on photosynthesis, chlorophyll, metabolism of starch formation and enzyme carbonic anhydrase accelerating carbohydrate formation, accumulation of suitable carbohydrate contents (Akgun *et al.*, 2017; Soleymani *et al.*, 2012). It also activates glutamic dehydrogenase enzyme, synthesis of RNA and DNA enhancing the quality, which are the main protein components of gluten accumulated at later stages of grain filling. The effect of Zn treatment was significant on sedimentation (24.17 cc) and wet gluten content (31.56%) crude protein contents (10.56%) of bran and flour of all cultivars. Zn application increased sedimentation, wet gluten content, protein, Zn content. The quality of wheat dry and wet gluten depends on their inherent chemical composition, which have a response function in various enzymatic activities in grain.

It can be concluded from the findings of the present study, the soil and foliar application at later stages ameliorates Zn deficiency and improves the production and quality of zero till wheat. Therefore, the combined application of Zn (soil + foliar) with recommended fertilizer is more promising in improving, plant growth, yield and quality than other fertilization approaches.

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