Research Article

Evaluating the Effect of Zinc Application Methods on Growth and Yield of Wheat Cultivars

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Abstract | Zinc (Zn) deficiency is a widespread problem across the globe and it is negatively affecting the growth and productivity of the wheat crop. Therefore, a field study was conducted to determine effect of various Zn application methods on the growth and yield of wheat cultivars during the growing season 2014-2015. The study was comprised of three cultivars of wheat; Galaxy-2014, Punjab-2011 and Millat-2011 and Zn application methods; seed priming @ 0.4% Zn solution, soil application @ 40 kg $ZnSO_4$. H_2O ha^{-1} foliar spray @ 0.5% Zn solution at vegetative stage and combination of all three methods (seed priming, foliar and soil application) were used. The study was conducted in a randomized complete block design with a factorial arrangement having three replications. The combined application of Zn (seed priming, foliar and soil application) resulted in maximum leaf area index (LAI), crop growth rate (CGR), productive tillers (302.33 m^2), spike length (8.62 cm), spikelet/spike (16.66), grains/spike (39.18), thousand grain weight (40.27 g), biological (11.42 t ha^{-1}) and grain yield (5.12 t ha^{-1}), whereas the minimum LAI, CGR, tillers (261.89 m^2), spike length (7.74 cm), spikelet/spike (15.11), grains/spike (32.76), thousand grain weight (33.99 g), biological yield (10.55 t ha^{-1}) and grain yield (4.35 t ha^{-1}), were noticed in control. Among the wheat cultivars, Galaxy-2014 performed better than the Punjab-2011 and Millat-2011 in terms of growth and yield components. In conclusion, Zn application (seed priming, foliar and soil application) can be an imperative approach to improve the growth and productivity of wheat crop under semi-arid regions.

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1. Introduction

Wheat (*Triticum aestivum*) is one of the world's most imperative cereal crop and it is the most cultivated crop in Pakistan followed by sugarcane, rice, and cotton (GoP, 2020), and it as an important source of food and calories (Chattha *et al.*, 2017a; Zain *et al.*, 2017; Chatta *et al.*, 2018). The area under wheat cultivation in Pakistan is estimated at around 8825 hectares with a production of 24.34 million tonnes (GoP, 2020). Being the staple and highly consumed food, a large area is devoted to wheat cultivation and

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it is estimated that around 65% of the total cultivated area is being used for wheat cultivation. More than 80% of farmers in Pakistan cultivate the wheat crop and it has a contribution of 1.7% in national GDP (GoP, 2020).

The availability of micronutrients is considered an important factor to obtain better crop yield (Arshadullah *et al*., 2002). For both plant growth and human development, Zn is an essential nutrient (Brown *et al*., 2001). Zinc plays an imperious role in pollen viability, dry matter production (Cakmak, 2008) and stress tolerance (Hassan *et al*., 2020). Zinc is also part of structural makeup or regulatory co-factor for many enzymes involved in several essential biochemical pathways such as protein synthesis, carbohydrate metabolism, auxin regulation and genes expression (Mattiello *et al*., 2015).

Zinc deficiency occurs in almost all countries, and it is more prominent in cereal growing areas (Cakmak, 2008). In plants, Zn requirement varies with plant species and genetic characteristics, so the timing, concentration and application methods are very critical in Zn acquisition and efficiency (Chattha *et al*., 2017b; Hassan *et al*., 2019). In addition, certain factors may affect Zn availability and efficiency; for example, Zn is more available in low-pH soils and its availability reduces with increasing pH. Moreover, low soil temperature and OM (organic matter) content also contributes to Zn deficiency (Singh *et al*., 2005). Over 40% of wheat crop is cultivated in low Zn soils, which in turns produced low yield with poor grain quality (Alloway, 2008). In crops, deficiency of Zn results in many yield and nutritional losses. Besides crop production and food quality, Zn supplementation has a considerable position in human health and diet. It is involved in a wide range of human body functions including growth (cell division, height and bone development), fertility, taste, vision and immune system, and its deficiency leads to acute health problems and disorders such as dwarfism, dermatitis, decreased immunity, loss of appetite and certain infections, and in intense conditions death may occur (Das and Green, 2013). Over 30% of world's population suffering from Zn shortage and Zn deficiency is considered as a serious health and nutritional issue in worldwide (Alloway, 2004; Gunes *et al*., 2007). Increasing the value of staple grains with Zn is considered to be a good economic strategy to combat Zn deficiency (Bouis *et al*., 2011). Therefore, based on the above given discussion, the present study was conducted to determine the effect of Zn application on growth and yield of various wheat cultivars.

2. Materials and Methods

2.1 Experimental site

The proposed study was conducted during 2014-15 at Agronomic Research Farm of the University of Agriculture Faisalabad. The metrological data for crop growing season in 2014-2015 are given in (Table 1). The samples from different parts of field were taken and homogenised and analysed to measure soil physio-chemical properties by adapting the standard procedures of Homer and Pratt (1961). The soil was sandy loamy and had organic matter 0.82%, pH 7.8, electrical conductivity (EC) 1.92 dS m^{-1}, available nitrogen 0.014 %, phosphorus 4.1 (mg/kg), potassium 120 (mg/kg) and Zn contents were 39 (mg/kg).

Table 1: Metrological figures for crop growth period in 2014-2015.

Months	Monthly average temp. (°C)	Mean humidity (%)	Total precipitation (mm)
Dec -2014	10.5	66.14	00.0
Jan -2015	12.02	84.14	1.17
Feb – 2015	16.5	65.28	5.25
Mar – 2015	19.5	69.28	3.3
April – 2015	27.0	62.71	4.62

2.2 Treatments

The experiment was performed in RCBD with a factorial arrangement having three replicates. The experiment consisted of three wheat cultivars, V_1= Galaxy-2014, V_2= Punjab-2011, V_3= Millat-2011 and five Zn application methods: T_0 (control), T_1 (foliar application at the rate of 0.5% Zn solution), T_2 (soil application at the rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation.), T_3 (seed Priming at the rate of 0.4% Zn solution), T_4 (seed priming at 0.4% Zn solution + soil application at the rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation + foliar application at the rate of 0.5% Zn solution). For priming, the seeds were soaked in Zn solution to maintain a seed solution ratio of 1:10 (w/v) for 12 h. After priming seeds were washed three times and dried by forced air near the original moisture level and then primed seeds were stored in a refrigerator at 7 ± 1 °C till use. The untreated seeds were also kept under similar conditions. Foliar

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application (0.5% Zn solution) was applied at the booting and milky stage.

2.3 Crop husbandry

The soil was cultivated twice with a cultivator and planked to prepare the seedbed and sowing was done using the hand drill on 15th December 2014 at 23 cm apart rows with a seed rate of 120 kg ha^{-1}. Nitrogen, phosphorus and potassium were given to crop at the rate of 100, 65, 65 kg ha^{-1}. The full quantity of P and K and one-third of N was applied at sowing and the remaining N was applied in 2 splits. A knapsack spray with a flat fan nozzle was used for foliar application. The rest of the agronomic practices remained uniform and followed the general recommendations for the wheat crop.

2.4 Field measurements and statistical analysis

Wheat plants from 50 cm × 50 cm area were harvested fortnightly to measure the leaf area and dry matter accumulation. Furthermore, crop growth rate and leaf area index was calculated by the procedure of Hunt (1978). The data on plant height, productive tillers, non-productive tillers, 1000 grain weight, grain and biological yield were recorded using standard methods. The complete plots were harvested to determine biological yield and threshed manually to determine the grain yield. The data on collected traits were analyzed by analysis of variance technique and difference amid the treatment was compared using LSD test at 0.05% probability level (Steel *et al*., 1997).

3. Results and Discussion

The combined Zn application; T_4 (seed priming + soil application + foliar spray) showed maximum improvement in growth parameters as compared to T_1 (foliar spray), T_2 (soil application), T_3 (seed priming) and T_0 (control). However, in the case of cultivars, V_1 (Galaxy-2014) performed well as compare to (Punjab-2011) and (Millat-2011) cultivar. The maximum leaf area index (LAI) was observed in combined Zn application as compared to alone Zn application either as foliar spray, soil application or seed priming, however, least LAI was noted in T_0 (control) (Figure 1). The maximum LAI in wheat varieties was noted in V_1 (Galaxy-2014) than V_3 (Millat-2011) and V_2 (Punjab -2011) as shown in (Figure 1). Similar results were observed for crop growth rate (CGR) (Figure 1d, e, f) and maximum CGR was recorded in T_4 (combine application of Zn) while minimum crop growth was observed in T_0 (control). Zn is considered to be involved in the regulation of auxin which improves the root growth and resulted in better nutrient and water uptake which consequently improved the plant growth traits and final yield. These findings are supported by previous findings of Zhoori *et al.* (2009) they also stated that Zn application improves the LAI.

Various Zn application methods had a significant impact on the plant height of wheat (Table 2). The maximal plant height (91.79 cm) was observed in T_4 (combine application of Zn) followed by T_2 (soil application), T_1 (foliar spray) and T_3 (seed priming) however, minimum plant height (84.10 cm) was recorded in T_0 (control). In the case of wheat varieties, V_3 (Millat-2011) had maximum plant height (89.13 cm) followed by V_2 (Punjab-2011) and V_1 (Galaxy-2014) achieved a minimum plant height (84.60 cm). The increase in plant height by Zn maybe because of better photosynthetic activities which lead to the production of more assimilates and thus resulted in the production of taller plants (Khan *et al*., 2009).

The application of Zn significantly affected yield traits of wheat cultivars. Maximal productive tillers (302.33) were observed in T_4 (seed priming + soil application + foliar spray) followed by T_2 (soil application) and T_1 (foliar spray) with 289 and 282 tillers, respectively. However, minimum productive tillers (261.89) were recorded in T_0 (control treatment). Furthermore, in wheat cultivars, V_1 (Galaxy-2014) produced maximum tillers (293.53) followed by V_3 (Millat-2011) and V_2 (Punjab-2011) (Table 2). The results regarding non-productive tillers were opposite to productive tillers as T_0 (control treatment) produced the highest non-productive tillers (18.78), however, T_4 (combine Zn application) produced the least number of non-productive tillers (15.11) than others Zn application methods. Among different cultivars, V_1 (Galaxy-2014) produced lowest number of non-productive tillers. These findings are in consistent with the outcomes of Maqsood *et al.* (2009), they also noticed a substantial increase in the productive tillers owing to the increase in activities of enzymes by Zn application.

Treatment T_4 (seed priming + soil application + foliar spray) produced maximum spike length (8.62 cm), spikelets/spike (16.66), grains/spike (39.18), and

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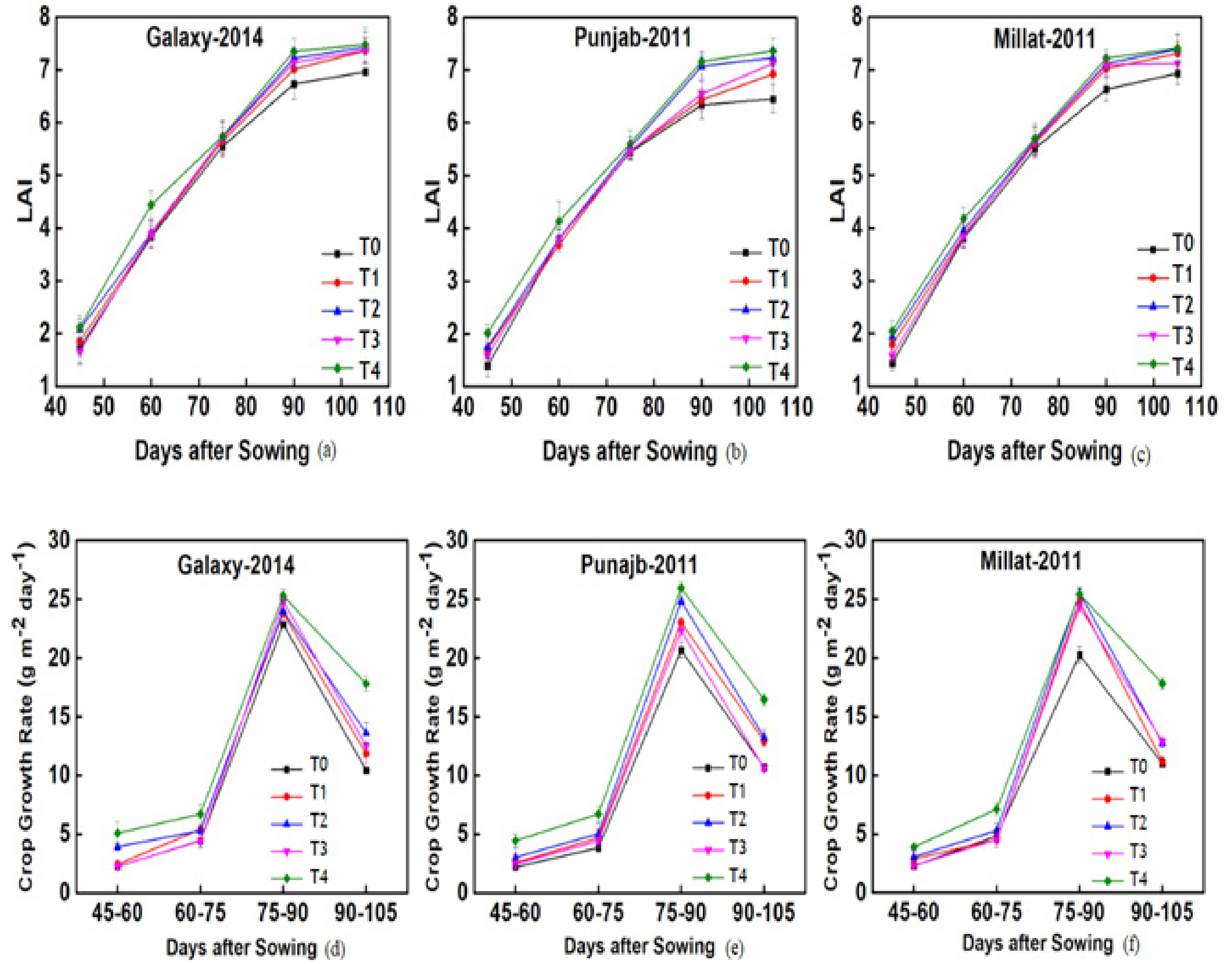

Figure 1: The outcome of various techniques of zinc application on leaf area index (LAI) (a), (b), (c) and crop growth rate (g day^{-1} m^{-2}) (d), (e), (f) of different wheat cultivars. T_0= Control, T_1= Seed Priming @ 0.4 % Zn sol., T_2= Soil Application @ 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation., T_3= Foliar Application @ 0.5 % Zn sol., T_4= Seed Priming @ 0.4 % Zn sol. + Soil Application @ 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation + Foliar Application @ 0.5 % Zn sol.

thousand grain weight (40.27 g) as compared to T_0 (control treatment). These findings are linked with the Cakmak *et al.* (2001) they stated that Zn application through various techniques such as soil application, foliar spray and seed priming considerably improved the yield-related parameters. Galaxy-2014 produced maximal spike length (8.50 cm), spikelets/spike (16.43), grains/spike (37.98), and thousand grain weight (39.76 g). There was no significant difference in spike length and spikelets per spike of (Punjab-2011) cultivar and (Millat-2011) cultivar. These findings are similar to previous studies of Soleimani (2006) they also noted an increase in yield components of wheat with Zn application.

For grain yield and biological yield, there was a significant difference among various Zn application methods. The maximum grain yield (5.12 t/ha) and biological yield (11.42 t/ha) were achieved under T_4 (combine application of Zn), while, lowest grain yield (4.35 t/ha) and biological yield (10.55 t/ha) were obtained under T_0 (control treatment). Among cultivars, Galaxy-2014 produced more grain yield and biological yield than V_2 (Punjab-2011) and V_3 (Millat-2011). The present increase in grain and biological yield can be due to an increase in the yield contributing traits. These outcomes are the same as the findings of Fageria *et al.* (2009) and Chattha *et al.* (2017c) they suggested that Zn application increased the yield contributing characters, and resultantly leads to an increase in grain and biological yield. Likewise, the highest harvest index (44.83%) was recorded in T_4

Table 2: The impact of different methods of Zn application, on plant height, productive and non-productive tillers, spike length and spikelets/spike of wheat cultivars.

Treatments	Plant height (cm)	Productive tillers	Non-productive tillers	Spike length (cm)	Spikelets per spike
T_0	84.10 D	261.89 E	18.78 A	7.74 B	15.11 B
T_1	87.19 BC	282.00 C	17.22 BC	8.29 AB	15.62 B
T_2	88.41 B	289.00 B	16.11 CD	8.06 AB	15.86 AB
T_3	85.96 CD	275.22 D	17.56 B	8.18 AB	15.78 AB
T_4	91.79 A	302.33 A	15.11 D	8.62 A	16.66 A
LSD ($p \leq 0.05$)	2.27	5.71	1.21	0.58	0.89
V_1 (Galaxy-2014)	84.60 B	293.53 A	15.13 B	8.50 A	16.43 A
V_2 (Punjab-2011)	88.76 A	270.13 C	18.06 A	8.24 AB	15.58 B
V_3 (Millat-2011)	89.13 A	282.60 B	17.67 A	7.80 B	15.41 B
LSD ($p \leq 0.05$)	1.75	4.42	0.93	0.45	0.69
Interaction = Treatments × Cultivars	NS	NS	NS	NS	NS

T_0 (control), T_1 (foliar spray at rate of 0.5% Zinc solution), T_2 (soil application at rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation.), T_3 (seed priming at rate of 0.4% Zinc solution), T_4 (seed priming at rate of 0.4% Zinc solution + soil application at rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation + foliar spray at 0.5% Zn solution). The common letters in a column do not vary significantly at 5% probability level.

Table 3: The outcome of various techniques of zinc application on grains per spike, 1000 grain weight (g), biological yield (t/ha) and harvest index of different wheat cultivars.

Treatments	Grains per spike	1000-grain weight	Biological yield (t/ha)	Grain yield (t/ha)	Harvest index
T_0	32.76 D	36.99 D	10.55 A	4.35 B	41.23 B
T_1	36.51 B	38.27 C	10.92 A	4.82 AB	44.14 A
T_2	37.08 B	39.21 B	10.60 A	4.51 AB	42.55 AB
T_3	34.78 C	37.80 C	10.90 A	4.63 AB	42.48 AB
T_4	39.18 A	40.27 A	11.42 A	5.12 A	44.83 A
LSD ($p \leq 0.05$)	1.45	0.78	0.96	0.67	2.90
V_1 (Galaxy-2014)	37.98 A	39.76 A	10.94 A	4.73 A	43.24 A
V_2 (Punjab-2011)	35.79 B	37. 50 C	10.90 A	4.72 A	43.30 A
V_3 (Millat-2011)	34.41 C	38.26 B	10.79 A	4.60 A	42.63 A
LSD ($p \leq 0.05$)	1.12	0.60	0.74	0.52	2.24
Interaction = Treatments × Cultivars	NS	NS	NS	NS	NS

T_0 (control), T_1 (foliar spray at rate of 0.5% Zinc solution), T_2 (soil application at rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation.), T_3 (seed priming at rate of 0.4% Zinc solution), T_4 (seed priming at rate of 0.4% Zinc solution + soil application at rate of 40 kg $ZnSO_4.H_2O$ ha^{-1} at first irrigation + foliar spray at 0.5% Zn solution). The common letters in a column do not vary significantly at 5% probability level.

(combine application of Zn) while, the least harvest index (41.23%) was noted in T_0 (control treatment) as shown in (Table 3). The rise in harvest index maybe because of the combined effect of an increase in yield related parameters and biological yield of wheat crop (Tabatabai *et al*., 2015).

Conclusions and Recommendations

The various Zn application significantly affected the growth and productivity of the wheat crop. The foliar spray, soil application, and seed priming applied together significantly enhanced the yield traits and yield of wheat crop. Among cultivars, Galaxy-2014 showed significantly higher values for different growth and yield-related parameters and produced maximum yield than Punjab-2011 and Millat-2011.

Novelty Statement

Zinc deficiency is continuously soaring up in the wheat growing areas especially in semi-arid areas. However, the effects of different methods of zinc application on wheat crop are not fully explored. Therefore, in this study we compared the effects of different methods of Zn application on the performance of wheat genotypes in order to determine the best method of zinc application for wheat crop in semi-arid area.

Author's Contributions

Conceived and designed the experiment: Imran Khan and Muhammad Umer Chattha. Performed the experiment: Muhammad Ilyas, Data collection: Muhammad Ilyas and Muhammad Zain, Analyzed the data: Muhammad Ilyas and Wajid Farhad, writing original draft: Muhammad Ilyas, Imran Khan, and Muhammad Umer Chattha, Reviewing and Editing: Muhammad Umair Hassan, Ateeq Shah, Sana Ullah, Safeer Ahmad, Bismillah Khan and Muhammad Adeel.

Conflict of interest

The authors have declared no conflict of interest.

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