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GROWTH, YIELD AND QUALITY OF WHEAT (*TRITICUM AESTIVUM*) IN THE PRESENCE OF ZINC UNDER ALKALINE CONDITIONS

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ABSTRACT

Background and Aims The deficiency of micronutrients is persistently afflicting millions of people living across the world. Among these micronutrients, zinc (Zn) deficiency is an emerging threat for human beings and plants. Bio-fortification of wheat and other staple foods with Zn is, therefore, a high-priority research task.

Methodology A field experiment was conducted to examine the effect of Zn on growth, yield and quality of wheat (*Triticum aestivum* L.) under alkaline conditions. Experimental treatments comprised of control, 30 kg Zn ha^{-1} and two foliar spray with 0.1, 0.2 and 0.3% Zn solution at booting and milking stage.

Results Zinc application either as soil incorporation or foliar spray could significantly improve wheat growth, yield and quality. However, foliar spray with 0.3% Zn solution was found more efficient as evidenced by highest plant Zn content (50.4 ppm) and grain yield of 4907 kg ha^{-1}. Minimum grain yield of 4635 kg ha^{-1} and Zn contents of 28.3 ppm were recorded in control treatment where no Zn was applied.

Conclusion Present investigation suggested that foliar spray with 0.3% Zn solution at booting and milking stage could markedly improve wheat growth, yield and quality under alkaline conditions.

INTRODUCTION

Zinc (Zn) is considered an essential micronutrient for the proper growth and development of humans (Salgueiro et al. 2000; Brown et al. 2001; Tahir et al. 2017), animals and plants (Broadley et al. 2007). It has been reported that over two billion of the world population is suffering from Zn deficiency (Cakmak et al. 2010). Wheat (*Triticum aestivum* L.) crop, a major staple food grown and consumed worldwide, plays a pivotal role in meeting food needs of masses. It is grown on an area of 220 Mha with 729 MT of production throughout the world. The green revolution era 1965-67, a major land mark in the history of agriculture is characterized by the development of short statured wheat varieties, adoption of intensive irrigation practices and heavy application of nitrogenous fertilizers. However, during this era, most of the farmers neglected the application of micronutrients (Hussain et al. 2018). Wheat plants lacks the mechanism of Zn absorption as compared to legumes which results in Zn deficiency not only in plants but also in human beings mainly due to low dietary intake (Boonchuay 2013). Growing of cereal grains having inherently low Zn concentrations on already Zn depleted soils results in further low grain Zn concentration (Alloway 2008). This problem is prevalent in countries/regions such as India, China, Pakistan and Turkey with cereals as major crops grown on Zn deficient soils.

Adverse effects of Zn deficiency on human heath, especially in children include physical growth impairment, malfunctioning of immune system, weakening of learning ability, DNA damage and cancer development (Keen and Gershwin 1990; Ho et al. 2003; Black et al. 2008). Therefore, increasing Zn concentration of staple food crops is an important humanitarian challenge. As one-third of the world's population is challenged with Zn deficiency (Hotz and Brown 2004). This issue has got prime importance, particularly in areas where wheat is grown and consumed. Zinc deficiency in human diet can be over-

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come by increasing bioavailable concentration of Zn in edible portions of crop plants through agronomic intervention or genetic selection (Philip et al. 2005). Bio-fortification is a process of increasing the bioavailability of an element in a food constituent or a meal that can be absorbed and used by a person eating the food. A thorough review of literature suggests that different forms of Zn, its method of application, type and/or variety of crop, growth stage of crop at which Zn is applied, concentrations of Zn, various soil reactions are some factors that determine the efficacy of applied Zn (Gopal and Nautiyal 2012; Tahir et al. 2018). Studies have revealed that Zn application in wheat has positive correlation with grain Zn concentration; however method and rate of Zn application are main contributing factors in increasing grain Zn concentration (Ozturk et al. 2006; Yang et al. 2011; Zhang et al. 2012)

Keeping the above facts in view, the present study was conducted to identify the suitable method and rate of Zn application for enhancing wheat yield and grain Zn contents under alkaline conditions.

MATERIAL AND METHODS

Experimental treatments

Wheat was grown at farmer's field to determine the soil and foliarly applied Zn on growth, yield and quality. The composite soil samples were taken from the top soil layer (0–30 cm). The samples were air dried, ground and sieved through <2.00 mm sieve. Soil samples obtained were analyzed using the method described by Homer and Pratt (1961). The climatic conditions during crop growing season are shown in Table 1 while physico-chemical properties of experimental soil are given in Table 2. Experimental treatments were comprised of; no Zn, soil application of 30 Kg Zn ha^{-1}, 2-foliar spray with 0.1% Zn solution (booting and milking stage), 2-foliar spray with 0.2% Zn solution (booting and milking stage) and 2-foliar spray with 0.3% Zn solution (booting and milking stage). The source of Zn was $ZnSO_4$. A uniform dose of 160, 114 and 60 kg ha^{-1} N as urea, P as single superphosphate and K as K_2SO_4were applied.

Determination of zinc in soil

The concentrations of Zn in soil was determined by the AB-DTPA extraction procedure (Soltanpour and Schwab 1977). Soil sample (10 g) was shaken with 20 ml AB-DTPA in an open Erlenmeyer flask for 15 minutes, the extract filtered and run for Zn on an atomic absorption spectrophotometer (Varian, Spectraa 220).

Sampling and measurements of crop yield

For the determination of yield, the crop was harvested and tied into bundles at maturity stage. The individual plots were threshed using a thresher and yield was recorded from grain weight for each treatment using digital balance. Obtained yield was expressed in kg per hectare. The grain samples were labeled and stored in separate plastic bags for determination of Zn concentration.

Determination of grain Zn

Wheat grain samples were dried in an oven at 60°C for 48 h (Liu et al. 2006). Dried samples were ground using a grinding mill (IKA Werke, MF 10 Basic, Staufen, Germany) fitted with a stainless steel chamber and blades. Subsequently, finely ground 1.0 g samples of wheat flour were placed in a conical flask and kept overnight after adding a di-acid (HNO_3:$HClO_4$ ratio of 2:1) digestion mixture (Jones and Case 1990). After 24 h, samples were digested on a hot plate at 150°C until all the material was digested. After digestion, the material was cooled and diluted to 50 mL by adding de-ionized water. Digestion mixture was then filtered with Whatman filter paper No. 42 and stored in air tight plastic bottles. Zinc concentration in the digested samples was determined by atomic absorption spectrophotometer (Varian spectraa 220).

Statistical analysis

The experiment was laid out in a randomized complete block design with three replications. Data were statistically analyzed using Statistix 8.1 (Analytical, Tallahassee, FL, USA), while the least significant difference (LSD) test at 5% probability was used to compare treatment means (Steel et al. 1997).

RESULTS AND DISCUSSION

Plant height

Results revealed that Zn application significantly ($p \leq 0.05$) affected the wheat plant height (Figure 1). Maximum plant height of 110 cm was recorded in plots where 2-foliar sprays with 0.3% Zn solution (booting and milking stage) were made, whereas minimum plant height of 105 cm was observed from plants without Zn (untreated control). The increase in plant height with foliar application of Zn at different stages of wheat was probably due to availability of Zn at peak requirement. Arafat et al. (2016) also reported significant variation in wheat plant height due to Zn application rate and method.

Number productive tillers

Data regarding productive tillers per unit area as influenced by Zn levels and its application methods is presented in Figure 2. Statistical analysis of the data showed that different rates of Zn and its application methods significantly affected productive tillers. Two

Table 1 Climatic conditions of the experimental site during crop growth period

Months	Rainfall (mm)	Mean max. Temp. (°C)	Mean min. Temp. (°C)	Average Temp. (°C)	Relative humidity (%)
November	0	28	17	21	23
December	0	24	13	17	24
January	0	20.6	5.9	10.7	26
February	12.36	25	13	18	36
March	10.61	31	17	23	36
April	11.61	35	22	28	30

Table 2 Physiochemical properties of experimental soil

Characteristics	Value
Texture	Loam
EC (dS m^{-1})	1.17
pH	7.95
Organic matter (%)	0.80
N (%)	0.033
P (ppm)	7.40
K (ppm)	160
Zn (ppm)	0.80

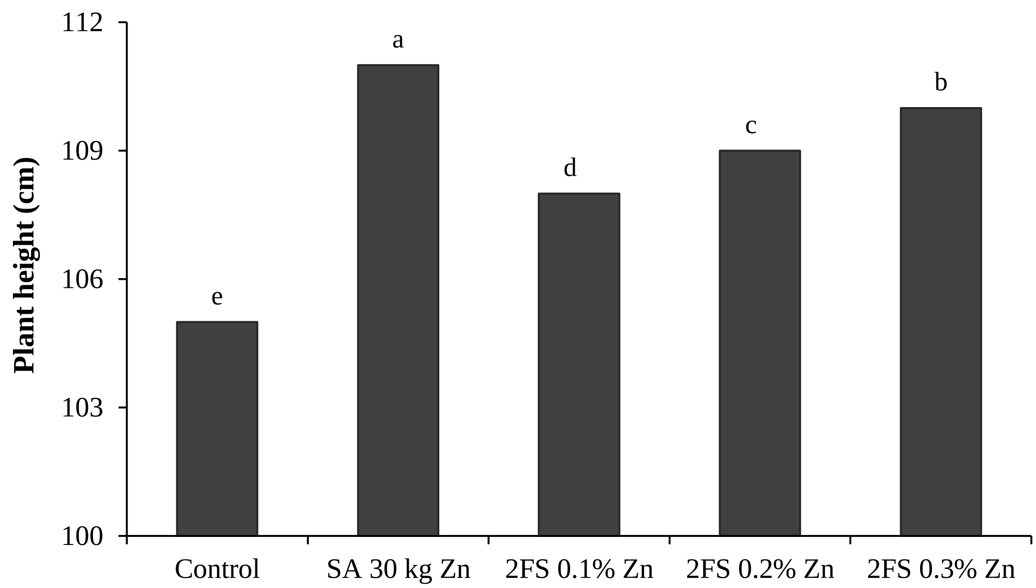

Figure 1: Effect of method and level of Zn application on wheat (*Triticum aestivum* L.) plant height. SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

foliar sprays of 3% Zn solution resulted in maximum productive tillers while these were minimum in plots where no Zn was applied. These results were in conformity with Bhutto et al. (2016) who found that wheat treated with foliar application of Zn at 2.0% gave more tillers followed by Zn at 1.5, 1.0 and 0.5%, respectively. However, control treatment (0.0% Zn) produced lowest number of tillers.

Spike length

The impact of different levels and methods of zinc (Zn) application on spike length of wheat is presented in Figure 3. Results revealed that Zn applied as two foliar sprays at 0.3% exhibited maximum spike length of 12 cm. While, wheat plants that were grown without Zn application produced minimum spike length. Shaheen et al. (2007) conducted a pot experiment with two rates of Zn i.e. 0 ppm per pot and 10 ppm Zn per pot as zinc sulfate ($ZnSO_4$) and reported that spike length, weight of 1000 grains, grain yield and straw yield were significantly ($p \leq 0.05$) higher in pots receiving 10 ppm Zn.

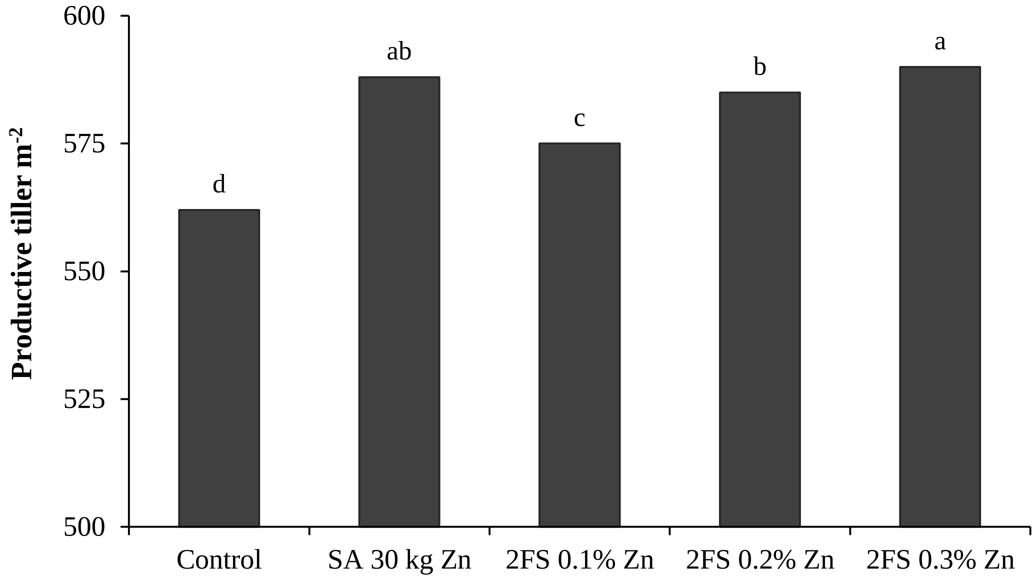

Figure 2 Effect of method and level of Zn application on productive tillers m^{-2} of wheat (*Triticum aestivum* L.). SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

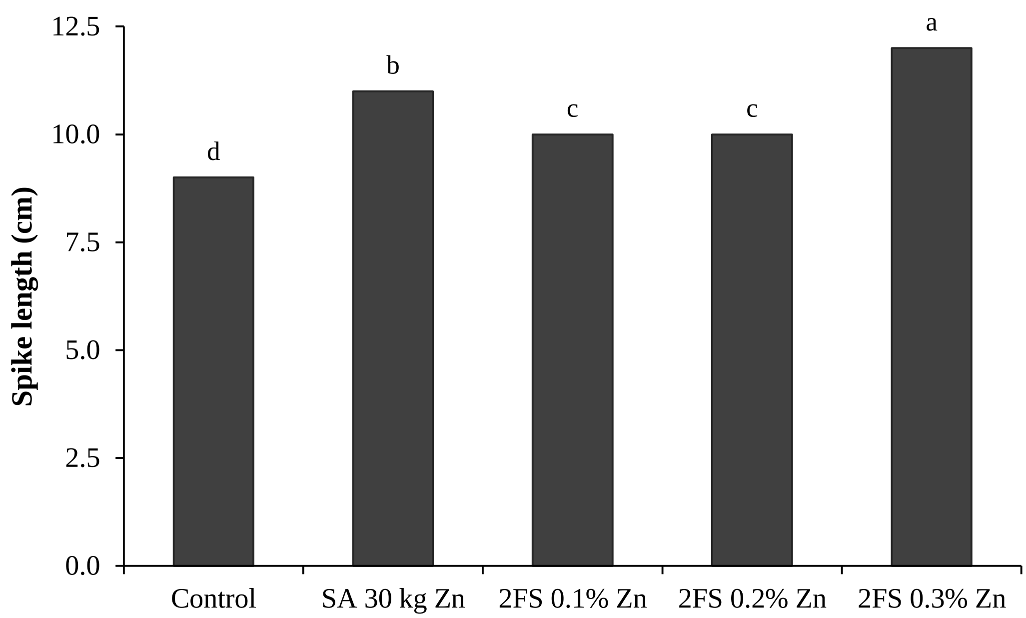

Figure 3 Effect of method and level of Zn application on spike length (cm) of wheat (*Triticum aestivum* L.). SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

1000-grain weight

The results regarding mean 1000-grain weight as influenced by different Zn application rates and methods are presented in Figure 4. It is evident from the data that the impact of Zn treatments on 1000-grain weight of wheat was statistically significant ($p \leq 0.05$). Maximum 1000-grain weight of 42 g recorded from plots where wheat was treated with two foliar sprays of Zn @ 0.3% solution and it was followed by soil application of Zn @ 30 kg ha^{-1}. Wheat 1000-grain weight was minimum in those plots where crop did not receive any Zn. The greater 1000-grain weight observed with the foliar application of higher Zn concentration was perhaps due to more availability of

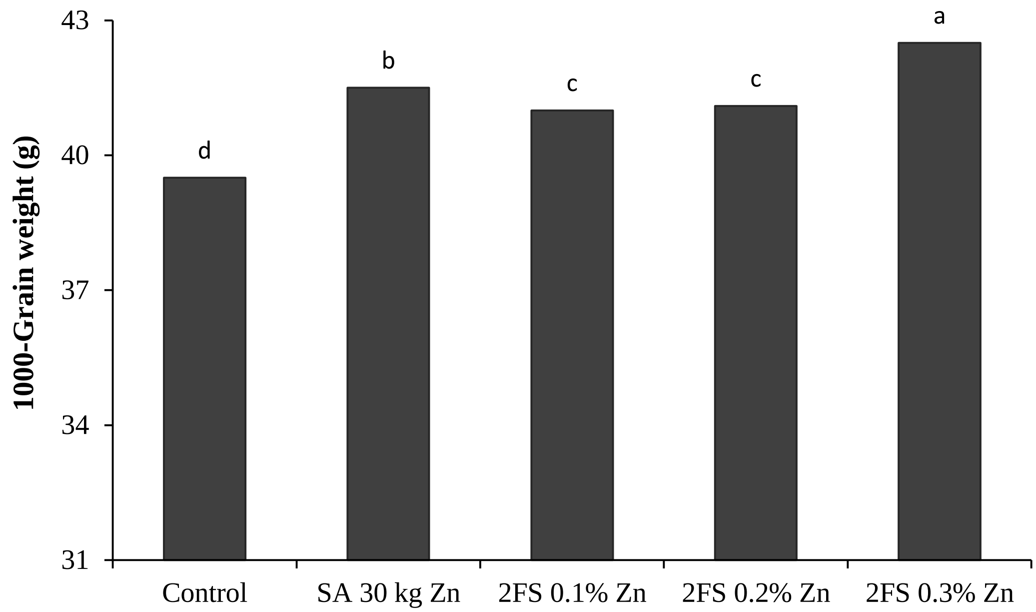

Figure 4 Effect of method and level of Zn application on 1000-grain weight (g) of wheat (*Triticum aestivum* L.). SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

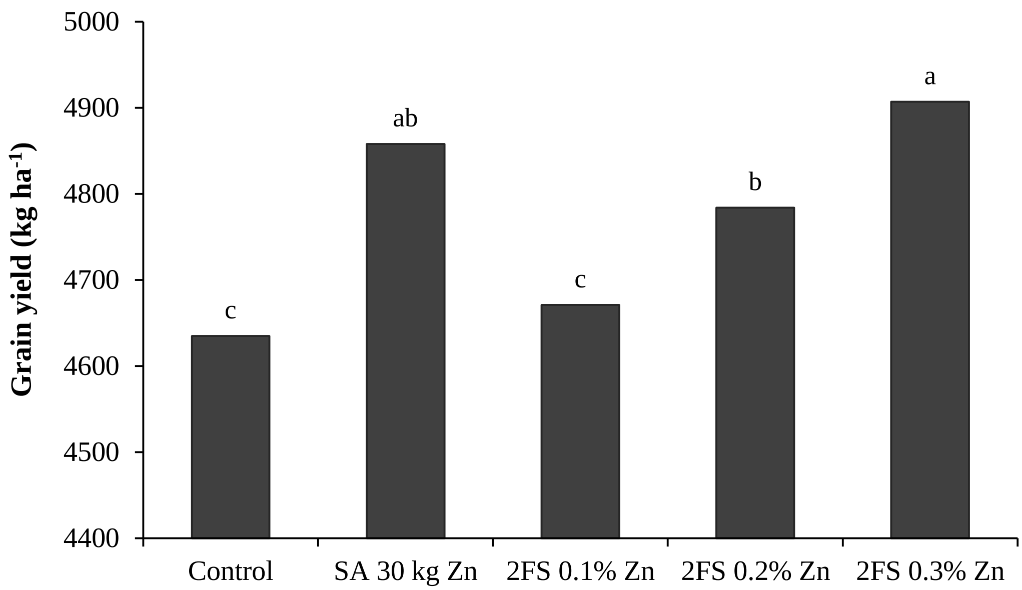

Figure 5 Effect of method and level of Zn application on grain yield (kg ha^{-1}) of wheat (*Triticum aestivum* L.). SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

Zn for normal growth of crop. Our findings are in agreement with Bhutto et al. (2016) who recorded higher 1000-grain weight of wheat with the application of higher content of Zn solution (2.0%) compared to 1.5% Zn solution.

Grain yield

Results shown in Figure 5 revealed that Zn application significantly ($p \leq 0.05$) affected the grain yield of wheat. Two foliar sprays of Zn with 0.3% concentration at booting and milking stages resulted in maximum grain yield of 4907 kg ha^{-1} and it was followed by soil application of Zn @ 30 kg ha^{-1}. A statistically similar grain yield of wheat was obtained with two foliar sprays of 0.1 and 0.2% Zn solution at booting and milking stages. The grain yield of wheat

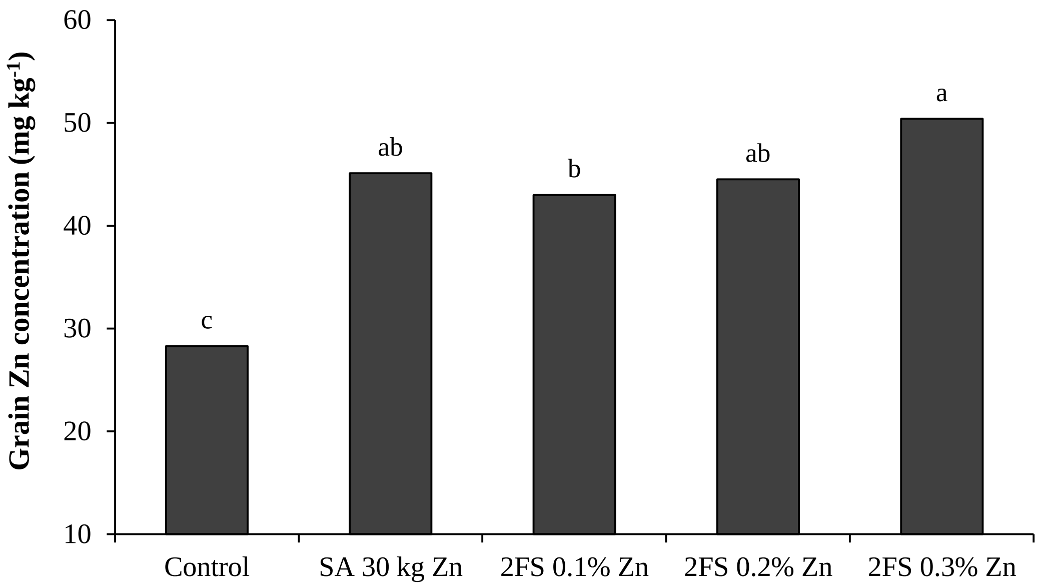

Figure 6: Effect of method and level of Zn application on wheat (*Triticum aestivum* L.) grain Zn concentration. SA: Soil application of Zn @ 30 kg ha^{-1}; 2FS: 2 Foliar spray of Zn @ 0.1, 0.2 and 0.3% solution

was minimum (4635 kg ha^{-1}) in plots where Zn was not applied. The grain yield of wheat increased with Zn treatment followed the order of 2-foliar sprays with 0.3% Zn solution at booting and milking >Zn soil application @ 30 kg ha^{-1} > 2-foliar sprays with 0.2% Zn solution at booting and milking > 2-foliar sprays with 0.1% Zn solution at booting and milking > control. The increase in wheat grain yield with the application of Zn was also reported by previous researchers (Kenbaev and Sade 2002; Ali et al. 2009; Bhutto et al. 2016). Our results are also in line with the findings of Khan et al. (2007) who reported a significant increase in grain yield of wheat with Zn application over control. Zhang et al. (2012) conducted a field study and reported that with 0.5% foliar Zn spray, grain yield was significantly improved.

Grain Zn content

Wheat grain Zn contents were significantly increased with the application of Zn (Figure 6) but the magnitude of increase was different under varying Zn treatments. Maximum grain Zn contents of 50.4 ppm were observed in plots where two sprays of Zn @ 0.3% concentration were made at booting and milking stages. It was found that minimum wheat grain Zn contents of 28.3 ppm were recorded in plots where no Zn was applied. All other Zn application treatments resulted in intermediate and similar Zn contents. Higher Zn accumulation in wheat grain with foliar application of Zn @ 0.3% at booting and milking stage was probably due to more concentrated solution and timing of application which was consistent with studies of Liu et al. (2019). Xue et al. (2012) reported that when the supply of Zn to plant roots was restricted by soil or weather factors, plants encounter difficulty in acquiring Zn, so post-anthesis shoot Zn uptake was minimized and under such situation, the Zn in grain mostly depended on the remobilization of Zn from vegetative parts. Our findings were also in good agreement with El-Dahshouri et al. (2018) who reported a significant increase in grain Zn content by foliar Zn application up to three time compared with no Zn application.

CONCLUSION

The results presented in this manuscript indicated that wheat productivity and grain Zn contents could be improved significantly with Zn application. However, more pronounced effect was found in case of two foliar sprays of 0.3% Zn at booting and milking stages followed by soil application @ 30 kg Zn ha^{-1}. Hence, farmers should adopt any one of these approaches suitable in their specific conditions to increase wheat yield and grain Zn concentration.

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