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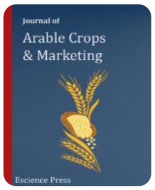

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Exogenous Application of Potassium and Zinc for the Growth, Yield and Agronomic Zinc Biofortification of Wheat (*Triticum aestivum* L.)

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ABSTRACT

In agriculture, the application of micronutrient application takes place through soil application, foliar spraying, or added seed treatments. Potassium (K) application fulfills the deficiency of K in soil due to a continuous exhaustive cropping system. Zinc (Zn) bio-fortification of seed by priming is responsible for increasing the concentration of Zn in the edible part of a seed with the aim of remedying malnutrition. For this, a field experiment was conducted at the Agronomic research area, Bahauddin Zakariya University, Multan. Treatment included different rates of K (0, 40, 60, and 80 kg ha^{-1}) and different rates of Zn (0, 0.2, 0.4, and 0.6%). Potassium was applied in fertigation while zinc was applied in foliar form. The experiment was designed in Randomized complete block design (RCBD) and was repeated three times. It resulted that different rate of potassium and zinc application showed a significant effect on plant growth and yield attributes. Plant growth and yield increased with increasing the rate of potassium and zinc application and decreased with the decreasing the rate of application of potassium and zinc application. The maximum values for plant growth and yield attributes were observed with K_3 and Zn_3 while the minimum values were recorded with the application of K_0 and Zn_0. Results regarding the nutrient uptakes showed that maximum values for zinc uptake were also recorded in seed and stem attributes. Maximum values for zinc uptake in seed and stem (37.2 and 14.5 mg/kg) were observed in the Zn_3 treatment and the minimum values for zinc uptake (30.1 and 11 mg/kg) were recorded Zn_0 treatment, respectively. It was concluded that 80 kg ha-1 application of potassium with 0.6 % foliar application of zinc significantly affects the growth and yield of wheat crops. Zinc foliar application can be helpful for zinc fortification.

Keywords: Potassium, Zinc, fortification, wheat, growth, yield.

INTRODUCTION

Wheat (*Triticum aestivum*) is the most important staple food for Pakistanis, and it is consumed by almost 40% of the world's population (According to Malik *et al*., 2006). Pakistan is facing a problem of food security due to low yields over the last decade. There are several reasons for this low yield like low soil fertility. Plant development and physiological activities, such as photosynthetic functions, are negatively impacted by nutrient deficit (Kalaji *et al*., 2018). Photosynthetic machinery suffers when essential nutrients are lacking, as these nutrients are used in many photosynthesis-related components. Iron, sulfur, and nitrogen deficiencies have detrimental effects on the structures and enzymatic functions of protein complexes (Jin *et al*., 2015). Wheat is just one of many crops negatively impacted by the worldwide potassium (K+) depletion problem (Ruan *et al*., 2015). Crop establishment, growth, and production are all hindered by a deficiency in K (Rengel and Damon, 2008). As an activating factor for a number of enzymes, cell expansion, turgor pressure maintenance, osmoregulation, and stomatal movement regulation are just a few of the many roles that potassium plays in plant growth and development (Hawkesford *et al*., 2012). K+ is essential for photosynthesis, osmoregulation, and the activation of enzymes in numerous metabolic pathways in plants (Maathuis, 2009). K+ modulates enzyme activity in two distinct ways: during transcription and after it has been transcribed (Maathuis, 2009). It has major importance for increasing agricultural output because of the crucial roles it plays in plant growth and development (Pettigrew, 2008). K+ shortage has been proven to be an abiotic stress that causes a number of reactions leading to stunted plant development and lower yields (Hafsi *et al*., 2014). Although plants can modify their morphology and physiology and alter their K+ transport systems in response to K+ deprivation, the molecular processes underlying this adaptation remain poorly known (Hafsi *et al*., 2014). Maximizing crop yields and quality requires more research into the impact of K+ depletion on plants and the identification of the mechanisms involved in generating the observed changes.

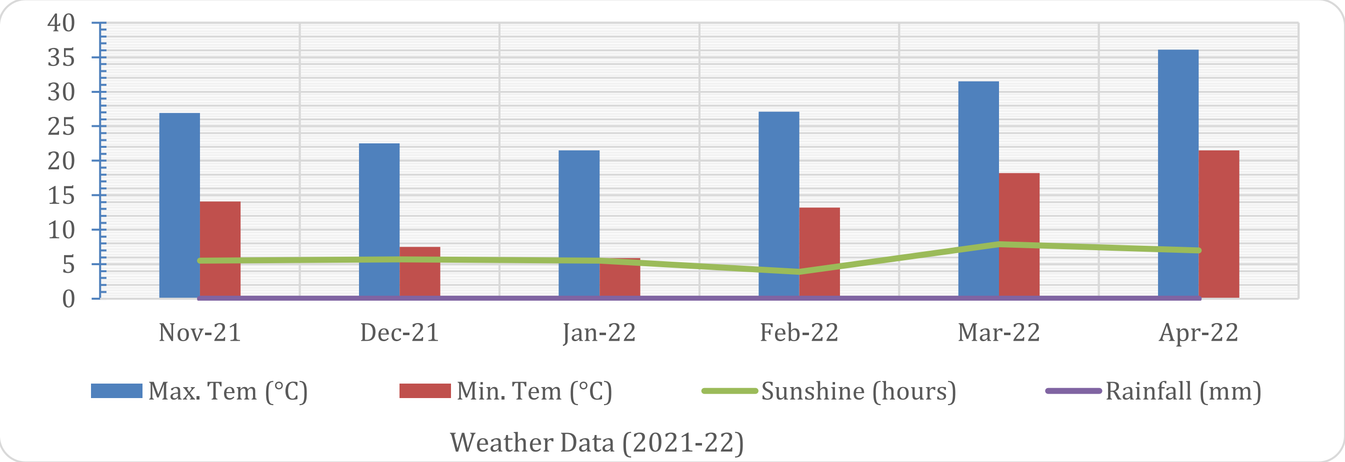
Researchers in the field of agriculture are beginning to face a new and significant challenge: hidden hunger. With a growing global population comes a higher demand for food. Two billion people worldwide, particularly those living in underdeveloped nations, are malnourished due to a lack of micronutrients, according to recent studies (Stein 2010; Cakmak *et al*. 2010). As a result of relying on cereal crops like wheat, rice, and maize for their daily nutrition, more than half of the world's population is at risk of metals deficiencies (Kenzhebayeva *et al*., 2019). Many enzymes involved in auxin and glucose metabolism, protein synthesis, and membrane integrity rely on zinc as a structural component (Cakmak, 2000; Rehman *et al*., 2018). Micronutrient deficiencies have emerged as a result of farmers' pursuit of increased yields through the excessive use of fertilizers like potassium, phosphorus, and nitrogen (Cakmak, 2002). Soil Zn deficiency affects roughly 50% of cereal crops. About 70 percent of Pakistan's farmland is deficient in zinc (Imtiaz *et al*., 2010).

Post-harvest food fortification, mineral supplementation, dietary diversity, and biofortification are just some of the methods that have been proposed as potential solutions to the problem of hidden hunger (Borrill *et al*., 2014). Increasing the amount of zinc in grains through agronomic biofortification is a common agricultural practice (Cakmak *et al*., 2010). Micronutrient application to soil or/and crop leaves has been shown to be an effective and sustainable alternative to genetic engineering and other methods (De-Valenca *et al*., 2017; Cakmak, 2008). Overcoming micronutrient deficiency in impoverished countries through agronomic biofortification of crops is an emerging strategy (Ngozi, 2013). The quality of grains and the yield of wheat crops can both benefit from the exogenous application of micronutrients.

MATERIAL AND METHODS

The designed experiment was laid out at the Agronomic research area, Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan. Treatments included the different rates of Potassium (0, 40, 60, 80 kg ha^{-1}) and different rates of Zinc (0, 0.2%, 0.4% and 0.6%). The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement, and it was repeated three times. Potassium was applied by fertigation method in two splits while zinc was sprayed in foliar form. Half a dose of potassium was applied at the time of sowing and the remaining half dose was applied after 30 days of sowing. Other micronutrients like nitrogen and phosphorus were applied @ 120 kg ha^{-1} and 90 kg ha^{-1}, respectively. Nitrogen fertilizer was applied in two splits, half was applied at the time of sowing and the remaining half was applied at the time of first irrigation. On the other hand, phosphorus was applied at the time of sowing. Murate of potash (MOP) fertilizer was applied as a source of potassium, Urea was used as a source of nitrogen and single super phosphate (SSP) was used as a source of phosphorus.

The experimental soil was clay loam in texture. It contained 0.62% organic manure, 3.04 d S m^{-1} EC, 7.5 soil pH, 0.03 % nitrogen, 7.7 ppm phosphorus and 222 ppm potassium. A wheat variety Akbae-2019 was purchased from a nearby authorized dealer. The size of each experimental unit was 2×3 m^2. The crop was sown by drill method. The environmental weather during the crop growth is given in Fig. 1. Ten plants from each experimental unit were tagged for data collection. All the agronomic practices like seed management, pest and disease control were kept constants for all the experimental units. Irrigation was applied when needed. The crop was harvested at its physiological maturity. All the growth and yield attributes were measured as per the subscribed method. Leaf area index (LAI) and seasonal leaf area duration (SLAD) were measured after 30, 45, 60 and 75 days while crop growth rate (CGR) and net assimilation rate (NAR) were measured after 40, 55 and 75 days after emergence by Hunt (1978).



RESULTS

Growth and Yield Attributes

Results showed that plant growth increased with increasing the rate of potassium and the same results were noticed in different rates of zinc foliar application. Among the different rates of potassium, the maximum value for growth and yield attributes were measured with 80 kg ha^{-1} application of potassium followed by the 60 kg ha^{-1} application of potassium. Plant growth increased with increasing the rate of potassium and decreased with decreasing the rate of potassium. The same trend was noted for the different rates of zinc application. Plant growth increased with increasing the rate of zinc foliar application and maximum growth and yield were noticed with the 0.6 % foliar application of zinc. Plant growth decreased with decreasing the rate of zinc.

The number of fertile tillers showed that different rates of potassium and zinc showed a significant effect while their interactive effect showed a non-significant effect. Results showed that among the K application and Zn application rates, the maximum LSD values for the number of fertile tillers (266 and 255.3 m^2) were counted in K$_3$ and Zn$_3$ treatments and the minimum LSD values for the number of fertile tillers were counted in K$_0$ and Zn$_0$ treatment, respectively. Plant height and spikes length were affected significantly by the different rates of K and Zn application also their interactive effect was also significant. Maximum plant height and spike length (95.4 cm and 16.2 cm) were measured with K$_3$× Zn$_3$ treatment, respectively. Different potassium application rates (K) showed a significant effect on the number of grains per spike, 1000-grain weight, and grain yield while zinc application (Zn) and their interactive effect (K×Zn) was non-significant. K$_3$ treatment showed a maximum LSD value for the number of grains per spike (58.8) followed by K$_2$ (48.6) and K$_1$ (47.8) and the minimum LSD values for the number of grains per spike were counted in the K$_0$ treatment. Maximum LSD values for the 1000-grain weight (38.1 g) were measured from the K$_3$ application and minimum LSD values for the 1000-grain weight (25.4 g) were measured in the K$_0$ application. Maximum LSD values for grain yield (4.56 t ha^{-1}) were also observed from the K$_3$ application. Grain yield decreased with decreasing the rate of potassium and minimum LSD values for grain yield were collected from the K$_0$ application. On the other hand, different rates of potassium and zinc also their interactive effect were found significant in the biological yield of wheat. Maximum grain yield (14.2 t ha^{-1}) was obtained in the K$_3$Zn$_2$ application and minimum grain yield (12.6 t ha^{-1}) was obtained from the K$_0$Zn$_0$ treatment. The maximum LSD value for the harvest index (32.9 %) was noted in K$_3$ treatments followed by K$_2$ and the minimum LSD value for the harvest index was noted in K$_0$ treatments (Table 1).

Concerning the effect of different rates of potassium and zinc on leaf area index, seasonal leaf area index, crop growth rate and net assimilation rate, it was noticed that all these attributes increased with increasing the different rates of potassium and zinc. All the attributes increased with increasing the days after sowing. The leaf area index and net assimilation rate increased with the exogenous application of potassium and zinc. The maximum leaf area index and net assimilation rate were noticed at 55 days after sowing and a dramatic decrease in leaf area index and net assimilation was noted at 75 days after sowing. While values for seasonal leaf area duration and crop growth rate were increased with increasing the rate of potassium and zinc. Maximum values for seasonal leaf area index and crop growth rate were measured at 75 days after sowing (Figure 2).

Concerning agronomic biofortification, the maximum zinc contents (37.2 and 14.5 mg/kg) in seed grains and wheat stems were measured in K_3Zn_3 treatment, respectively. While the minimum zinc contents (30.1 and 11 mg/kg) were measured in the K_0Zn_0 treatment. Zinc contents increased with increasing the rate of zinc and decrease with the decrease in zinc contents (Figure 3).

Table 1. Effect of different rates of potassium and zinc rates on growth and yield attributes of wheat

Treatments	NFT	PH	SL	NGPS	GW	GY	BY	HI
Least significant difference (LSD) means for different rates of potassium (K)								
K_0	240.6 C	69.2 D	13.1 D	46.0 B	25.4 C	3.19 C	12.6 C	25.2 B
K_1	242.3 C	70.2 C	14.1 C	47.8 B	33.7 B	3.96 B	12.7 C	31.3 A
K_2	252.9 B	78.6 B	15.7 B	48.6 B	31.5 B	4.19 AB	13.8 B	30.5 A
K_3	266.0 A	89.7 A	15.8 A	58.8 A	38.1 A	4.56 A	13.9 A	32.9 A
Least significant difference (LSD) means for different rates of zinc (Zn)								
Zn_0	247.2 C	73.5 D	14.0 D	48.5 AB	31.1 AB	3.94 A	13.1 C	29.5 A
Zn_1	248.2 BC	75.1 C	14.5 C	47.5 B	30.4 B	3.91 A	12.8 D	30.2 A
Zn_2	250.9 B	78.6 B	14.9 B	53.7 A	34.4 A	4.11 A	13.6 A	30.2 A
Zn_3	255.3 A	80.5 A	15.3 A	51.6 AB	33.0 AB	3.96 A	13.4 B	29.5 A
Interactive effect of different rates of potassium and zinc (K×Zn)								
$K_0\times Zn_0$	236.3	66.2 m	12.3 j	45.8	25.0	3.05	12.6 i	24.2
$K_1\times Zn_0$	239.0	66.3 m	13.0 hi	46.3	33.0	3.91	12.6 i	30.9
$K_2\times Zn_0$	249.7	74.1 h	15.5 c	47.8	30.7	4.73	13.7 d	34.4
$K_3\times Zn_0$	264.0	87.4 c	15.1 d	54.2	35.5	4.06	13.6 e	30.1
$K_0\times Zn_1$	239.0	68.5 l	13.0 i	43.7	24.1	2.99	12.1 j	24.7
$K_1\times Zn_1$	241.0	69.2 kl	14.0 g	44.4	31.8	3.77	12.2 j	30.9
$K_2\times Zn_1$	251.3	77.6 g	15.2 d	44.3	28.3	4.32	13.2 f	32.6
$K_3\times Zn_1$	261.7	85.1 d	15.7 b	57.4	37.1	4.54	13.9 cd	32.8
$K_0\times Zn_2$	242.0	70.1 k	13.2 h	48.2	26.5	3.51	13.0 g	27.0
$K_1\times Zn_2$	243.0	72.0 j	14.3 f	51.2	36.0	4.18	13.1 g	32.0
$K_2\times Zn_2$	253.3	80.5 f	15.8 b	52.0	34.2	3.86	14.1 ab	27.4
$K_3\times Zn_2$	265.3	91.8 b	16.1 a	63.3	40.8	4.90	14.2 a	34.6
$K_0\times Zn_3$	245.0	72.1 j	14.0 g	46.4	25.9	3.20	12.8 h	25.0
$K_1\times Zn_3$	246.0	73.1 i	14.9 e	49.4	34.3	4.02	12.8 h	31.4
$K_2\times Zn_3$	257.3	82.1 e	16.1 a	50.3	32.8	3.85	13.9 c	27.6
$K_3\times Zn_3$	273.0	94.5 a	16.2 a	60.2	38.8	4.76	14.0 bc	34.1

K0= 0 kg ha^{-1}, K1=40 kg ha^{-1}, K2=60 kg ha^{-1}, K3=80 kg ha^{-1}, Zn0= 0 %, Zn1=0.2 %, Zn2=0.4 %, Zn3=0.6 %, PH= plant height (cm), NFT= number of fertile tillers, NGPS= number of grains per spikes, GW= 1000-grain weight (g), GY= grain yield t ha^{-1}, BY= biological yield t ha^{-1}, $P\leq 5\%$,

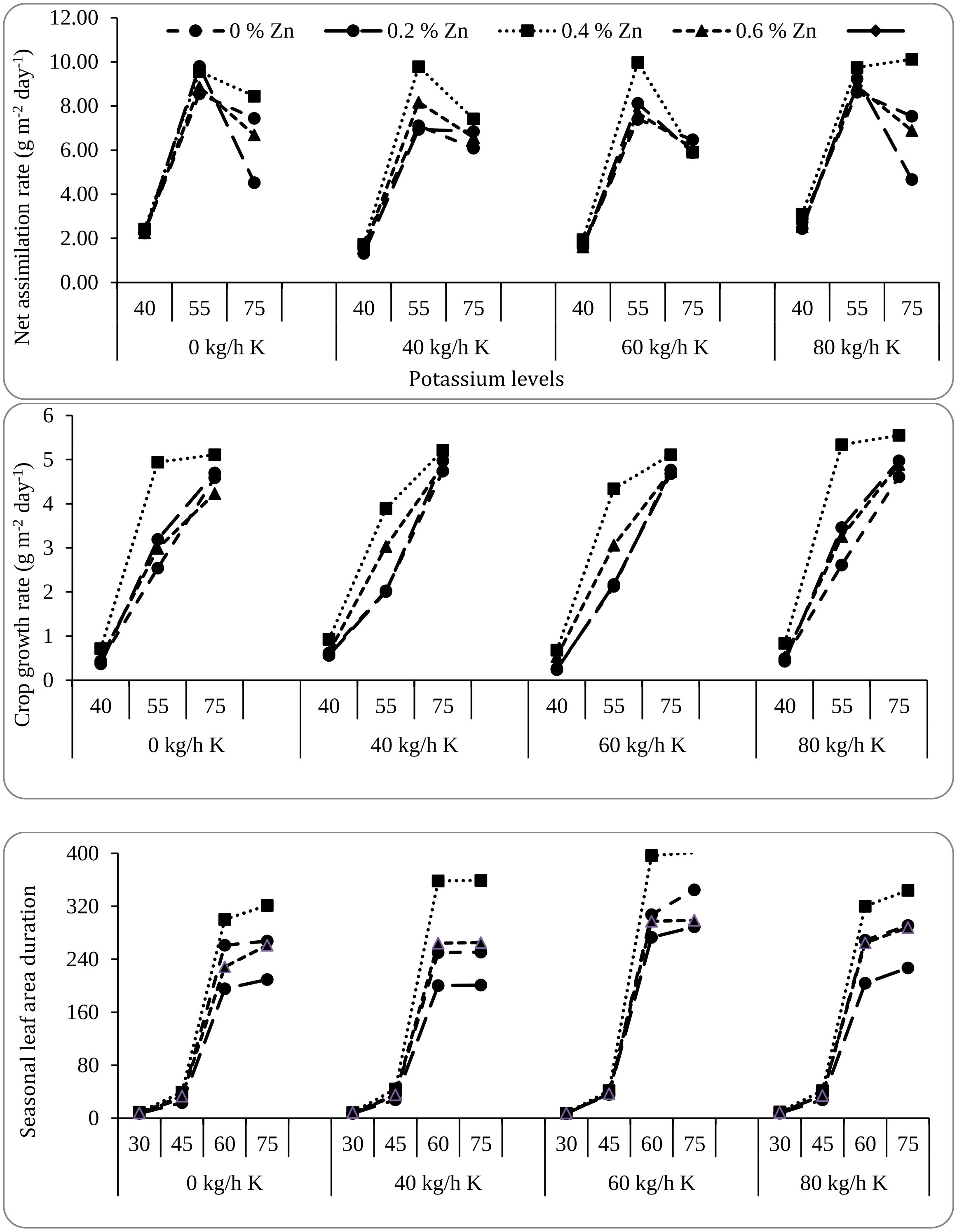


Figure 2 (a). Exogenous application of different rates of potassium (K) and zinc (Zn) on leaf area index (LAI), seasonal leaf area duration (SLAD), crop growth rate (CGR) and net assimilation rate (NAR).

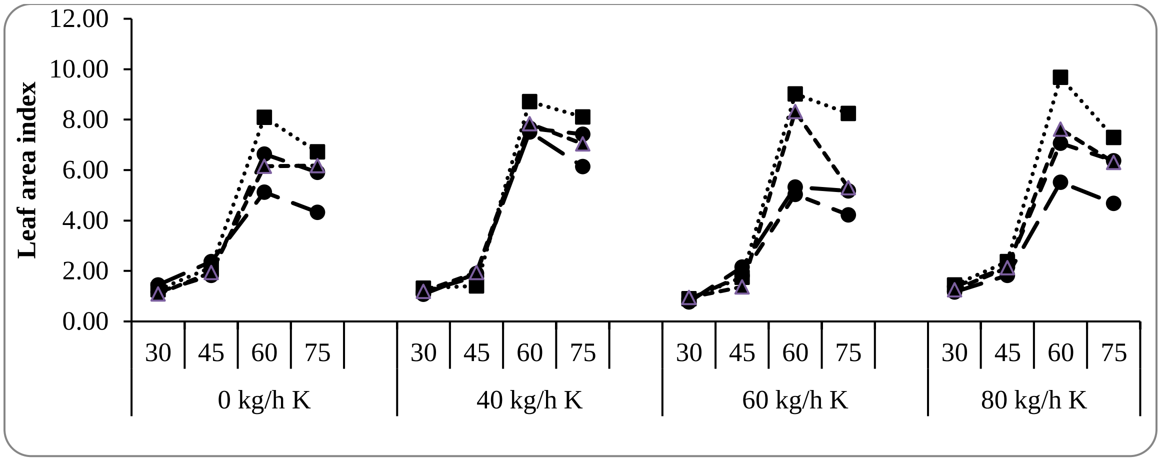


Figure 2 (b). Exogenous application of different rates of potassium (K) and zinc (Zn) on leaf area index (LAI), seasonal leaf area duration (SLAD), crop growth rate (CGR) and net assimilation rate (NAR).

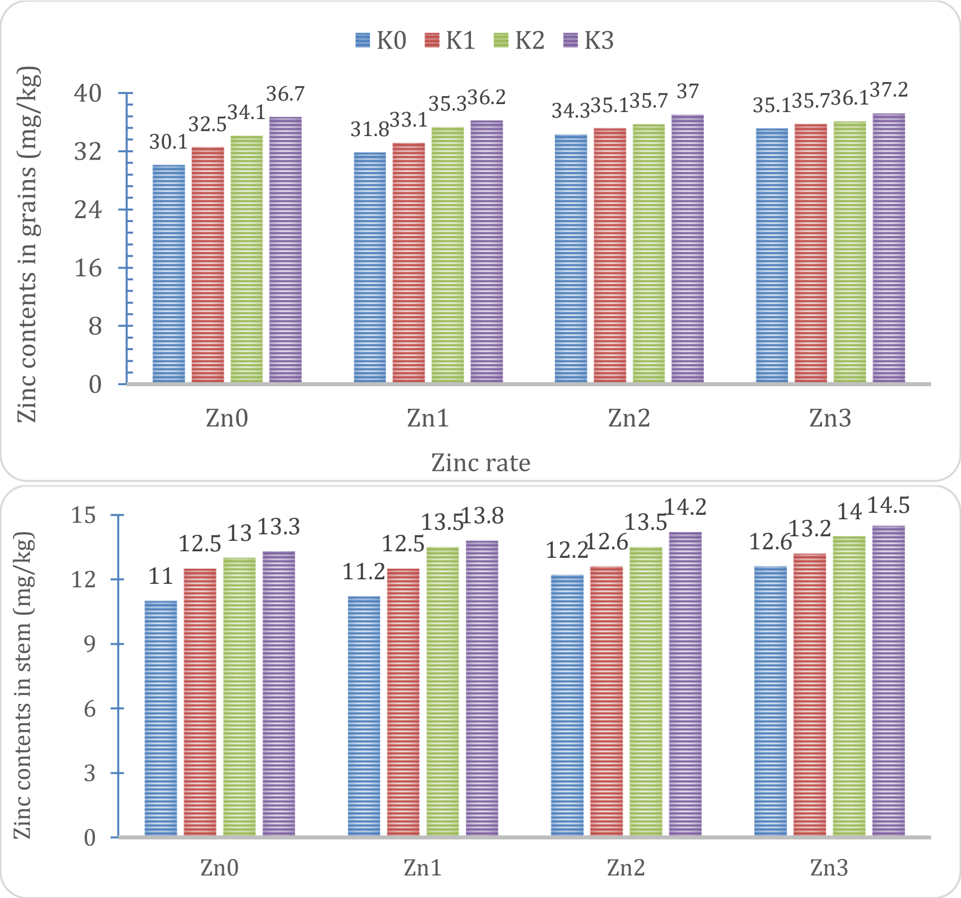


Figure 3. Zinc contents in grains and stem of wheat.

DISCUSSION

Findings of current study was in agreement with Niyigaba *et al*. (2019), they reported that foliar treatment of Zn and Fe significantly improved the yield and quality parameters of wheat crop including 1000-grain weight, crude proteins, spike length, kernels per spike, grain yield, Zn and Fe contents in grains. Sultana *et al*. (2016) also stated that foliar treatment of Zn played a significant role in enhancing grain yield and other yield components of wheat. They recorded maximum plant height, grain yield, 1000-grain weight, No. of grains per spike and spike length by foliar application Zn @ 0.04%. Pahlavan-Rad and Pessarakli (2009) reported that the highest number of grains were obtained by combined application of Zn and Fe in wheat crop. Hassan *et al*. (2019) stated that treatment of Zn in wheat crop produced more number of seedlings, biological yield, and grain yield and also others yield related parameters.

Mengel (2001) reported that Potassium and zinc might have a greater role in plant morphology and physiology. The increase in plant height might be due to the involvement of zinc and potassium in different physiological processes. Our finding are similar with the past researches, they concluded that Plant height (Reddy, 2004; Mengel, 2001; Yaseen *et al*., 2011), number of fertile tillers m^2 (Elayan, 2008; Rahimi *et al*., 2012), number of grains per spikes (Narimani *et al*., 2010; Jan *et al*., 2012; Nadim *et al*., 2012), 1000-grain weight (Jan *et al*., 2012), biological yield (Ketterings *et al*., 2005; Hussain *et al*., 2012), grain yield (Broadley *et al*., 2007; Sharma *et al*., 2014) and harvest index (Hao, 2008) are significantly affected by the application of potassium and zinc.

CONCLUSION

It was concluded that potassium and zinc application play an important role in crop morphology and physiology which resulted in the increase in growth and yield attributes of wheat crop. Plant growth and yield increase with increasing the rate of potassium and zinc. Among the different rates of exogenous application of potassium and zinc, 80 kg ha^{-1} application of potassium with 0.6 % application of zinc significantly affects the yield of wheat crop.

COMPETING INTEREST

The authors show there is no competing interest.

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