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COMPREHENSIVE EVALUATION OF THE VARIOUS EFFECTS OF FERTILIZATION WITH POTASSIUM, ZINC, AND BORON ON WHEAT GROWTH AND YIELD PERFORMANCE

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ABSTRACT

In Pakistan, wheat is a staple food crop, dominating both in terms of cultivated land area and productivity. It encompasses 37.1% of the total crop land, 65% of the land allocated to food grain cultivation, and plays a significant role in contributing to 70% of the nation's total agricultural output. The field experiments were carried out at the Latif Farm experimental field at SAU Tando Jam. Our study's findings revealed significant variations in the growth and yield components of the wheat variety Kiran-95. The extreme values were observed under treatment T7 (2000 g ha-1), including a plant height of 94.90 cm, number of tillers at 322.75 m-2, spike length of 11.60 cm, grains per spike of 47.01, grain weight per spike of2.44 g, seed index (1000 grain weight) of 47.89 g, a biological yield of 11911 kg/h, a grain yield of 5779 kg/h, and a harvest index of 48.80%. The next group, T6 (1500 g ha-1), had plants measuring 87.19 cm tall, with 300.88 m-2 of tillers, 11.20 cm long spikes, 45.80 grains per spike, 1.99 g of grain weight per spike, 47.79 g of seed index (1000 grain weight), 11025 kg/h of biological yield, 5380 kg/h of grain yield, and a harvest index of 47.20%. The control group (T1 = No fertilizer) recorded the lowest values, with a plant height of 69.10 cm, number of tillers m-1 of 238.55 m-2, spike length cm of 8.01 cm, grains per spike-1 of 30.80, grain weight per spike-1 of 1.35 g, seed index (1000 grain weight) of 27.60 g, biological yield of 7120 kg ha1, grain yield of 2885 kg ha1, and a harvest index of 39.10%. Deficiency in this substance can significantly affect plant growth and development, as it plays a vital role in several critical processes. Cell division, cell wall synthesis, water relations, meristematic tissue formation, carbohydrate transformations, and pollen tube formation are among the processes it influences. Consequently, a shortage of this substance could potentially impact all of these essential functions. The results indicate that a variety of yield-influencing factors significantly enhance wheat production through soil enrichment with micronutrients. It was found that the most effective method to increase wheat growth and grain yield involved applying potassium, zinc, and boron at a quantity of 2000 g per hectare in conjunction with the advised fertilizer amount.

Keywords: Wheat, Potassium, Zinc, Boron, Growth, Yield.

INTRODUCTION

The world produces wheat as its second-largest grain (Samar *et al*., 2019). Many people in Pakistan grow wheat as their main crop, which occupies the majority of the country's cultivated area, approximately 9.1 million hectares (Abdullah Niazi, 2023). Wheat is paramount as Pakistan's mainstay crop, playing a vital role in safeguarding the nation's food security. Wheat production contributes to 1.8 percent of Pakistan's GDP overall and 9.2 percent of agricultural value added. This is a significant contribution (Irshad *et al*., 2022). Research has demonstrated the importance of different fertilizers in agriculture worldwide. Micronutrient insufficiency is an expected trend among cereal crops, limiting grain output and nutritional value. Potassium, zinc, and boron are performing significant physiological roles in humans and animals (Aref and Rad, 2012). Potassium is an important fertilizer that controls various biochemicals, phenological, and physiological processes in plants (Johnson *et al*., 2022). K plays vital role in different metabolic activities, significantly influencing both yield and yield quality. Plant roots quickly absorb potassium, unlike nitrogen and phosphorus (Ravichandran and Sriramachandrasekharan, 2011). Zinc plays a crucial role in carbohydrate metabolism, stimulating most of the enzymes involved. Zinc is the foremost building block of many enzymes, and it is essentially necessary for the development of some significant plant enzymes. In

accumulation, it initiates many enzymatic responses. It is essential for many enzymes' proper functioning and plays a vital role in DNA transcription (Kumar *et al*., 2016). Z is an necessary micronutrient for plants, actively participating in key cellular functions that are critical for important metabolic and physiological activities. It is essential for the plant's system's ion balance control and activity of enzymes (Alsafran *et al*., 2022). 31% of the arable land on Earth and 49% of the arable land in Pakistan are deficient in boron (Ashraf, 2004). Grain fertility results from growing wheat crops in soil low in boron (Islam Jahiruddin, 2008). Additionally, boron is essential for a number of biological processes in plants, such as the production of proteins and cell walls, the metabolism of carbohydrates and nucleic acids, the growth of cell walls, and the movement of absorbs (Ijaz *et al.*, 2023). In the wheat crop, insufficient boron can cause irregular growth patterns, impede the development of shoots and roots, and ultimately lead to a reduction in crop yield (Hu *et al*., 2013). This study's main objective was to identify the optimal growth stage for wheat at which potassium (K), zinc (Z), and boron (B) application would result in the highest yield. Furthermore, it sought to determine the appropriate amounts of K, Z, and B to apply and evaluate the impact of these nutrients on different wheat yield characteristics.

MATERIAL AND METHODS

The Latif Experimental Field at Sindh Agriculture University, Tando Jam in Sindh, Pakistan, hosted the study during the Rabi season of 2023–2024. The details of the experiment followed the RCBD design Replication = 03. The net plot is 3 m x 4 m, or 12 m^2.
Variety =TJ-83
Treatments=07
T1 = untreated (control), and T2 = 250 g ha^{-1}. T3 = 500 g ha^{-1}, T4 = 1000 g ha^{-1}, T5 = 1250 g ha^{-1}, T6 = 1500 g ha^{-1}, T7 = 2000 g ha^{-1}

Culture practices

To establish an optimal seedbed, the soil underwent careful preparation involving two comprehensive plowings, followed by leveling of the land. During the sowing process, we evenly distributed the recommended quantity of DAP fertilizer across all plots. Throughout the research, we provided potassium, zinc, and boron at different stages of wheat growth. Every five days during the first ten days after crop planting, we selected five plants from each plot to evaluate the plant characteristics.

Observations

Important indicators for evaluating crop performance include plant height, tillers per square meter, spike length, grains per spike, grain weight per spike, seed index (weight of 1000 grains), biological yield per hectare, grain yield per hectare, and harvest index.

Statistical analysis

Statistix 8.1 was used to perform statistical analysis on the data. At a significance level of 5%, the means of various treatments were compared using the LSD test.

RESULTS

Plant height (cm)

The use of potassium, zinc, and boron in wheat crops positively and substantially impacted a number of physiological yields and yield related traits (Table 1). Different concentrations of potassium, zinc, and boron have an impact on the plant height (cm) of wheat. The crops receiving T6 = 1500 g ha^{-1}, T5 = 1250 g ha^{-1}, and T4 = 1000 g ha^{-1} produced mean plant heights of 87.19 cm, 83.25 cm, and 82.10 cm, respectively, whereas the treatments T7 = 2000 g ha^{-1} produced a maximum plant height of 94.90 cm. Similarly, we observed mean plant heights of 80.65 cm and 74.66 cm when we applied crop treatments including T3 and T2. Furthermore, T1 = Control no fertilizers 00 kg/ha was responsible for the lowest mean plant height (69.10 cm).

Number of tillers: m^2

Different levels of potassium, zinc, and boron have an impact on the number of wheat tillers m^{-1}. The crops receiving T6 = 1500 g ha^{-1}, T5 1250 g ha^{-1}, and T4 1000 g ha^{-1} generated a mean number of tillers m^{-1} of 300.88 cm, 287.10 cm, and 278.20 cm, respectively. The treatments T7 = 2000 g ha^{-1} produced a maximum number of tillers m^{-}

^{1} of 322.75 cm. Similarly, the application of crop treatments T4, T3, and T2 resulted in mean numbers of tillers m^{-1} of 270.15 cm and 258.99 cm, respectively. Furthermore, T1 = Control, which did not apply any fertilizers, resulted in the lowest mean plant height of 238.55 cm.

Spike Length (cm)

Potassium, zinc, and boron concentrations have each an impact on the length of the wheat spike (cm). The crops treated with T6 = 1500 g ha^{-1} and T5 = 1250 g ha^{-1} produced mean spike lengths of 11.20 cm and 10.13 cm, respectively, whereas the treatments T7 = 2000 g ha-1 produced a maximum spike length of 11.60 cm. Similarly, we observed mean spike lengths of 278.20 cm, 270.15 cm, and 258.99 cm when we administered crop treatments including T4, T3, and T2. Furthermore, we found that T1 = Control, which did not use any fertilizers, had the lowest mean spike length (8.01 cm).

Table1. Potassium, Zinc and Boron Fertilization Assessing Their Differential Impact on Wheat Crops.

Potassium (K) + Zinc (Z) and Boron (B) Levels	Plant height (cm)	Number of Tillers m^{-2}	Spike Length (cm)
T1=Untreated (Control)	69.10	238.55	8.01
T2=250g ha^{-1}	74.66	258.99	8.97
T3=500g ha^{-1}	80.65	270.15	9.10
T4=1000g ha^{-1}	82.10	278.20	9.99
T5=1250g ha^{-1}	83.25	287.10	10.13
T6=1500g ha^{-1}	87.19	300.88	11.20
T7=2000g ha^{-1}	94.90 a	322.75	11.60
S.E± =	1.0150	1.9817	0.0576
$LSD_{0.05}$ =	2.4900	3.999	0.1298

Grain per spike

The use of potassium, zinc, and boron in wheat crops positively and substantially impacted a number of physiological yields and yield related traits (Table 2). Different levels of potassium, zinc, and boron affect wheat grain per spike. The treatments T_7 = 2000 g ha^{-1} produced a maximum spike length of 47.01 cm, while the crops receiving T_6 = 1500 g ha^{-1} and T5 = 1250 g ha^{-1} resulted in mean grain per spike of 45.80 cm and 40.55 cm, respectively. Similarly, applying crop treatments with T4, T3, and T2 resulted in the following mean grain per spike: 38.77 cm, 36.11 cm. Furthermore, we observed the lowest mean grain per spike (30.80 cm) when we applied T1 = Control, no fertilizer, and 00 kg/ha.

Grain weight per spike

Different levels of potassium, zinc, and boron affect wheat grain weight per spike. The treatments T_7 = 2000 g ha^{-1} produced a maximum grain weight per spike of 47.01 cm, while the crops receiving T_6 = 1500 g ha^{-1} and T5 = 1250 g ha^{-1} resulted in mean grain weight per spike of 45.80 cm and 40.55 cm, respectively. Similarly, applying crop treatments with T4, T3, and T2 resulted in the following mean grain weight per spike: 38.77 cm, 36.11 cm, and 34.40 cm. Furthermore, we observed the lowest mean grain weight per spike (30.80 cm) when we applied T1 = Control, no fertilizer, and 00 kg/ha (Table 2).

Seed index-1000 g w,g

Seed index-1000 g w,g affects the various quantities of potassium, zinc, and boron. While the treatments T7 = 2000 g ha-1 produced a maximum seed index (1000) grain weight of 47.89 cm, the crops receiving T6 = 1500 g ha-1 and T5 = 1250 g ha-1 produced mean seed index (1000) grain weights of 46.33 cm and 42.89 cm, respectively. For crop treatments containing T4, T3, and T2, we also recorded the mean seed index (1000), grain weight, and g (40.99 cm, 37.50 cm, and 31.16 cm). Furthermore, it showed that the T1 = Control group had the lowest mean seed index (1000) grain weight, g (27.60 cm), although receiving no fertilizer at a rate of 00 kg/ha (Table 2).

Table 2. Potassium, Zinc and Boron Fertilization Assessing Their Differential Impact on Wheat Crops.

Potassium (K) + Zinc (Z) and Boron (B) Levels	Grain/spike	Grain weight/spike	Seed index-1000 g w,g
T1= Control	30.80	1.35	27.60
T2=250g ha^{-1}	34.40 f	1.55	31.16
T3=500g ha^{-1}	36.11 e	1.60	37.50
T4=1000g ha^{-1}	38.77 d	1.65	40.99
T5=1250g ha^{-1}	40.55 c	1.80	42.89
T6=1500g ha^{-1}	45.80 b	1.99	46.33
T7=2000g ha^{-1}	47.01	2.44	47.89
S.E± =	0.5201	0.1401	5.2128
$LSD_{0.05}$ =	1.0960	0.3302	11. 072

Table3. Potassium, Zinc and Boron Fertilization Assessing Their Differential Impact on Wheat Crops.

Potassium (K) + Zinc (Z) and Boron (B) Levels	Biological yield (kg/h)	Grain Yield (kg/h)	Harvest Index (kg/h)
T1=Untreated (Control)	7120	2885	39.10
T2=250g ha^{-1}	7590	3738	43.11
T3=500g ha^{-1}	8180	3860	44.86
T4=1000g ha^{-1}	9020	4355	46.58
T5=1250g ha^{-1}	9767	4676	46.77
T6=1500g ha^{-1}	11025	5380	47.20
T7=2000g ha^{-1}	11911	5779	48.80
S.E± =	39.125	92.480	0.5570
$LSD_{0.05}$ =	85.180	189.301	1.4191

Biological yield (kg/h)

In wheat crops, adding potassium, zinc, and boron improves production significantly and improves several physiological indicators of the crop's composition (Table 3). Various concentrations of potassium, zinc, and boron are impacted by wheat's biological yield kg/h. The treatments T6 = 1500 g ha^{-1} and T5 = 1250 g ha^{-1} gave the crops average biological yields kg/ha of 11025 kg/h and 97.67 kg/ha, respectively. The treatments T7 = 2000 g ha^{-1} gave the maximum biological yield kg/h of 11911 kg/ha. Similarly, the application of crop treatments containing T4, T3, and T2 resulted in the following mean biological yields kg/h: 9020 kg/h, 81.80 kg/h, and 75.90 kg/h. Moreover, T1 = Control, no fertilizers 00 kg/h, had the lowest mean biological yield kg/h (7120 kg/ha).

Grain yield kg ha^{1}

Various concentrations of potassium, zinc, and boron have an impact on wheat grain yield kg/h. The crops receiving T6 = 1500 g ha^{-1} and T5 = 1250 g ha^{-1} produced mean grain yield kg/ha of 11025 kg/ha and 97.67 kg/ha, respectively, whereas the treatments T7 = 2000 g ha-1 produced a maximum grain yield kg/h of 11911 kg/h. Similarly, we noted the following mean grain yield kg/ha (9020 kg/ha, 81.80 kg/ha, and 75.90 kg/ha) when we used crop treatments containing T4, T3, and T2. Moreover, T1 = Control, no fertilizers 00 kg/h, had the lowest mean grain yield kg/ha (7120 kg/ha) (Table 3).

Harvest Index (kg/h)

Differences in potassium, zinc, and boron concentrations affect the kg/h of wheat grain yield. While the treatments T7 = 2000 g ha-1 yielded a maximum grain yield kg/h of 48.80 kg/ha, the crops receiving T6 = 1500 g ha^{-1} and T5 1250 g ha^{-1} had mean grain yields kg/ha of 47.20 kg/ha and 46.77 kg/ha, respectively. Similarly, when we used crop treatments including T4, T3, and T2, we saw the following mean grain yield kg/ha (46.58 kg/ha, 44.86 kg/ha, and 43.11 kg/ha). Furthermore, T1 = Control, which received 00 kg/ha of fertilizer, had the lowest mean yield of grains (39.10 kg/ha) (Table 3).

DISCUSSION

The agricultural challenge extends beyond merely feeding the masses; it also involves delivering nutrient-rich food to impoverished individuals. To address this, there is a need to design agriculture systems that prioritize the overall health and well-being of the population Maberly and Carvalho, (2010). Typically, incorporating different fertilizers such as potassium, zinc, and boron into the soil can significantly improve wheat crops' growth and yield. Farmers and agricultural experts recommend incorporating this fertilizer into their cropping plans to increase productivity and profitability. Our study's findings revealed significant variations in the growth and yield components of the wheat variety TJ-83. Under treatment T7 (2000 g ha^{-1}), we observed extreme values, such as a maximum plant height of 94.90 cm, a number of tillers at 322.75 m^{-2}, a spike length of 11.60 cm, grains per spike of 47.01, grain weight per spike of 2.44 g, seed index (1000 grain weight) of 47.89 g, a biological yield of 11911 kg/ha, a grain yield of 5779 kg/ha, and a harvest index of 48.80%. The experiment's results indicated that trace elements are critical in affecting the growth and yield of the wheat variety TJ-83. In soils deficient in potassium and micronutrients such as zinc and boron, crop yields improved with the proper application of these nutrients (Dash *et al*., 2015; Nadim *et al*., 2012; Sultana *et al*., 2016). Potassium, zinc, and boron fertilizers were administered at a rate of 2000 g/ha. Subsequently, various plant parameters were assessed, including plant height, tillers per square meter, spike length, grains per spike, grain weight per spike, seed index, biological yield, grain yield, and harvest index. Using potassium, zinc, and boron improved plant growth in a number of ways, such as plant height, number of tillers m-2, spike length cm, grain per spike, grain weight per spike, seed index 1000 grain weight g, biological yield kg/h, grain yield kg/h, and harvest index kg/h. This observation was confirmed with findings previously reported by Khan *et al*. (2010) and Hussain *et al*. (2005). Kaleri *et al*. (2024) conducted research that is consistent with the findings of this study. Potassium (K) is an essential fertilizer that controls many physiological processes in mature plants, such as water uptake, nutrient mobilization, protein production, enzyme activation, photosynthesis, and starch and sugar movement (Johnson *et al*., 2022; Sardans and Penuelas, 2015; Siddiqui *et al*., 2021). Hussain *et al*. (2011) also reported that plant growth increased with increased potassium (K) supply. A similar observation was made by Islam *et al*. (2014), who found that plant height, the number of tillers per square meter, and dry matter accumulation were enhanced when potassium was applied in two equal split doses at sowing and tillering stages rather than in a single basal application. By applying zinc and potassium fertilizers, the current study's growth and yield metrics revealed more variation between the local landrace and the enhanced variety. According to Aboyeji *et al*. (2019) Fertilizers containing zinc and potassium significantly affected plant height. According to other studies, zinc fertilizer promotes many physiological processes that lead to increased plant height, including chlorophyll production, enzyme activation, stomatal regulation, etc. Habib (2009) and Naqeebullah *et al*. (2024) conducted these studies. Ali *et al*. (2019) reported similar findings for the number of tillers after K fertilization. Sadeghi *et al*. (2021) reported that zinc and magnesium treatments did not affect crop tillering, suggesting that genetic factors determine this characteristic. Sher *et al*. (2022) discovered taller spikes in the cultivar Fakhr-e-Sarhad after applying zinc sulfate. Furthermore, Prajapati *et al*., (2022) observed longer spike lengths upon application of zinc and potassium at 375 and 15 kg ha1, respectively. 6) Investigated how soil zinc affects wheat grains' physiological, phenological, yield parameters, and zinc concentration, respectively. Hassan *et al*. (2019) conducted empirical research and found that applying zinc as a soil amendment during the tillering and earing stages of wheat significantly increased the grain's yield and quality compared to the control plants. Ramzan *et al*. (2020) investigated the effect of soil zinc on wheat grains' physiological, phenological, yield parameters, and zinc concentration. They discovered that the leaf area, tiller m^2, productive tiller, and yield components all increased. Gomma (2015) observed similar results, noting that the application of zinc through soil increased tall. Plant height (in cm), spike length (in cm), grains per spike (in cm), 1000-grain weight (in g), and wheat grain yield (in t/ha). Mosaad *et al*. (2017) revealed that the use of zinc fertilizer in soil has been helpful in improving grain quality. The application of boron had a positive impact on the grain yield of wheat crops due to the different distribution of boron in the dry meter of the plant, as observed by Hussain and Yasin (2004). On the other hand, if boron is not present in the soil, grain sterility results in a very low grain yield, as stated by Subedi *et al*. (2000). The application of potassium, zinc, and boron fertilizers represents an additional cost

for farmers without increasing wheat productivity, which is the primary crop in the study areas. Wheat, being a nutrient-demanding crop, can clearly indicate any deficiencies that affect its optimal production.

Conclusions

It is thus possible to assert that the yield-affecting traits of the wheat variety TJ-83 are significantly affected by the different SAs of potassium, zinc, and boron. The findings also indicate that using potassium, zinc, and boron in the soil increases wheat yield, as well as that a number of elements play a role in yield. After conducting research on the most effective procedure to boost wheat growth and increase grain yield, we found that applying potassium, zinc, and boron at a rate of 2000 kg/ha, along with the recommended fertilizer dose, yields the best results.

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