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Influence of different levels of zinc fertilizer on some growth and yield parameters of rice (*Oryza sativa* L.) crop

Hafiz Zeeshan Hussain[1], Niaz Ahmed[1*], Muhammad Arif Ali[1], Subhan Danish[1], Munaza Gilani[2], Muhammad Mubashir[3], Muhammad Suleman[4]

[1]*Department of Soil Science, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University Multan, Punjab, Pakistan*

[2]*Institute of Molecular Biology and Biotechnology Bahauddin Zakariya University, Multan, Punjab, Pakistan*

[3]*Soil & Water Testing Laboratory for Research, Bahawalpur, Punjab, Pakistan*

[4]*Soil & Water Testing Laboratory, PakArab Fertilizer Corporation, Multan, Punjab, Pakistan*

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Abstract

Low availability of micronutrients significantly decreases the growth and yield of cereal crops. Among various micronutrients, zinc induced potential positive effects on growth and yield of cereals, especially rice crop. So, far a lot of work has been documented regarding the effect of Zn on growth and yield of rice. However, the aim of the current study was to modify the application rate of Zn in rice under the current scenario for the improvement in growth and yield of rice. Therefore, a field study was planned and conducted under different levels of zinc fertilizer on coarse and fine grain rice varieties i.e., Super Basmati and KSK 434. There were six level of zinc fertilizer including 0.0, 5.0, 7.5, 10.0, 12.5 and 15 kg Zn ha^{-1}. Results confirmed that higher application rate of Zn (15 kg Zn ha^{-1}), significantly increase plant height (15.2%), number of tillers / m^2 (4.42%) and spikelets/panicle (82.5%) as compared to control in Super Basmati. Similarly, application of Zn (15 kg Zn ha^{-1}), also improved number of tillers / m^2 (2.75%) and spikelets/panicle (37.9%) as compared to control in KSK 434. A significant maximum increase in panicle length and rice yield validated the effectiveness of Zn (15 kg Zn ha^{-1}) as compared to control. It is concluded that for economic point of view application of Zn (12 kg Zn ha^{-1}) is a good but to achieve maximum yield Zn (15 kg Zn ha^{-1}) is a better approach.

* **Corresponding Author:** Niaz Ahmed ✉ niaz.ahmad@bzu.edu.pk

Introduction

Micronutrients deficiency is creating an epidemic condition in all over the globe (Stephenson *et al.,* 2000). Many children under the age of 5 (1.7% = 116,000 children) died every year due to deficiency of micronutrients (Kotecha, 2008; Black *et al.,* 2013). In humans nutrition, the deficiency of zinc (Zn) is the most critical one after iron (Hambidge and Krebs, 2007; Black *et al.,* 2008). It has been observed that the immune system of humans become susceptible towards many infections when Zn become deficient (Hotz and Brown, 2004). About 2 billion people in the world are Zn deficient (Streim and Oslin, 2015). In South Asia, 95% of the population is Zn deficient. In addition, 0.4 million people died due to Zn deficiency every year (Hettiarachchi *et al.,* 2004). To overcome the problem of Zn deficiency in humans there are many strategies i.e., consumption of Zn enriched food, intake of supplements and biofortification of Zn in staple food. However, supplements and Zn enriched food consumption have less adoptability due to time taking and costly approaches (Cakmak, 2008). In under developed countries, cereals i.e., maize, wheat and rice, are mostly consumed as a staple food by the majority of population (Choudhury, 1991). Thus, the idea of staple food Zn fortification could be an effective and less costly approach to overcome the Zn deficiency problem (Hettiarachchi *et al.,* 2004; Brown *et al.,* 2010). Rice is a staple food crop and is consumed by 3.5 billion people around the globe (Wang *et al.,* 2007). In Pakistan, it is grown on an area of 2.79 million hectares, with the production of 6.79 million tons. However, productivity is 2437 kg ha^{-1}, which stands at the lower side of other rice-growing countries. The productivity can be enhanced by the adoption of integrated nutrient management, particularly the induction of zinc fertilizer in the system. Zinc nutrient plays a critical role in maintain various physiological processes, carboxylase and energy dissipation and overall enhancing the yield potential (Monnet *et al.,* 2005). However, high pH and calcareous nature of soil parent material and sandy texture usually decreased Zn availability to crops (Johnson *et al.,* 2005; Alloway, 2008). An increase in each unit of soil pH (5-7) is linearly linked with decreasing Zn concentration up to 30-folds (Quijano-Guerta *et al.,* 2002). Besides high soil pH, imbalance and over application of phosphorus (P) fertilizers also exacerbated the problem of Zn deficiency in crops (Cakmak, 2008). Likewise, intensive cultivation new high yield varieties have also played an important role in the development of Zn deficiency comparative to old adaptive varieties (Cakmak, 2008). As in cereals after maize, rice is highly susceptible towards Zn deficiency, thus current study was conducted to improve the Zn uptake in rice by application of various levels of Zn. The aim of the study was to explore the best application of Zn fertilizer rate in current scenario to modify the production technology of rice. It is hypothesized that balance application of Zn would be effective to enhance Zn yield and Zn concentration in staple food rice.

Material and methods

Experimental site

A field study was carried out to quantify the impact of zinc nutrient on dry seeded rice crop at experimental farm 71°, 30' 79" E latitude 31°, 16 N, 126 cm of Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Punjab, Pakistan. A presowing physicochemical characteristics of soil is given in Table 1.

Plot size and fertilizer application

For cultivation of rice in field. Plot size of 3m length and 3m width were made. The basal recommended dose of nitrogen, phosphorous and potassium fertilizers (143:88:68 kg N:P:K ha^{-1}) was applied to all experimental units (Jabran *et al.,* 2012). Initially, full amount of phosphorous, half amount of potassium and one-third of nitrogen fertilizer was applied for better development in seedlings. Other amounts of fertilizers of potassium and nitrogen were applied with irrigations after regular intervals.

Seeds collection and seed rate

Seeds of two rice varieties Super basmati and KSK-434 were collected from the local market from certified seed dealer of the government of Punjab, Pakistan. Initially, broken seeds were separated manually and after that healthy seeds were used in the experiment. Seeds sowing was done at the rate of 75 kg ha^{-1} by using the drill method with row to row distance of 30 cm (Jabran *et al.,* 2012).

Experimental layout

There were six levels of zinc (0, 5.0, 7.5, 10.0, 12.5, 15.0 kg Zn ha^{-1}) applied in the form of $ZnSO_4$ applied at the time of field preparation in a single dose on two rice varieties arranged in a randomized complete block design (RCBD) with three replications. Before application of $ZnSO_4$, level of Zn already presents in soil (0.42.

mg kg^{-1} = 0.84 kg ha^{-1}) was determined and was used in the calculation to maintain the desired application rates of Zn.

Harvesting

When plants were 60 days old gas exchange attributes and chlorophyll contents were determined as described below. At the time of maturity, plants were harvested. Morphological (plants height, numbers of tillers/plant, numbers of grains/panicle) and yield attributes (1000-grains weight and paddy yield) were noted.

Statistical analysis

Statistical analysis was carried out using standard statistical procedures as given by Steel *et al.* (1997).

Two factorials ANOVA was applied for the calculation of significance of treatments by using Statistix 8.1 software. All the treatments were compared using Tukey's test at $p \leq 0.05$.

Results

Plant height

Effect of various levels of zinc (Zn) and rice varieties (V) was significant for plant height of rice. For plant height, Zn15, Zn12.5, Zn10 and Zn7.5 remained statistically alike to each other but differed significantly better from control (No Zn) in Super Basmati (Fig. 1). No significant change was noted where Zn5 was applied as compared to control (No Zn) in Super Basmati. In the case of KSK-434, all the treatments remained statistically similar to each other for plant height. Maximum increase in plant height i.e., 15.2% was noted in Zn10 as compared to control (No Zn) in Super Basmati.

Table 1. Effects of various levels of Zn fertilizer on panicle length and yield of various rice varieties.

Various levels of Zn (kg ha^{-1})	Panicle Length (cm)			Yield (t/ha)		
	Super Basmati	KSK 434	ME (Zn)	Super Basmati	KSK 434	ME (Zn)
Control (Zn0)	15.40±0.53	16.47±0.55	15.93 ^{e}	3.02±0.19	3.25±0.18	3.14 ^{c}
Zn5	17.67±1.11	18.70±0.23	18.18 ^{de}	3.65±0.20	3.79±0.19	3.72 ^{bc}
Zn7.5	19.93±1.79	20.87±0.77	20.40 ^{cd}	3.86±0.34	4.08±0.24	3.97 ^{ab}
Zn10	22.37±1.28	23.00±1.46	22.68 ^{bc}	4.32±0.21	4.35±0.19	4.34 ^{ab}
Zn12.5	23.43±0.45	25.20±1.36	24.32 ^{ab}	4.37±0.26	4.45±0.27	4.41 ^{ab}
Zn15	25.10±0.66	26.87±0.20	25.98 ^{a}	5.11±0.41	4.34±0.27	4.73 ^{a}
ME (V)	20.65 ^{b}	21.85 ^{a}		4.06	4.05	

Means are average of 3 replicates ± error. Different letters showed significant difference at $p \leq 0.05$ compared by tukey's test. Non-significant effects have no lettering.

ME = Main effect.

Panicle length

Main effect of various levels of zinc (Zn) and rice varieties (V) were significant for panicle length of rice. For panicle length, application of Zn15 and Zn12.5 performed significantly better as compared to control (Table 1). However, Zn10 and Zn 7.5 did not differ significantly with each other but remained significant from control for panicle length. No significant change was noted among Zn5 and control for panicle length of rice. Maximum increase in panicle length i.e., 63.1% was noted in Zn15 as compared to control (No Zn). In the case of varieties, KSK 434 performed significantly better i.e., 5.81% as compared to Super Basmati for panicle length.

Number of tillers / m²

Effect of various levels of zinc (Zn) and rice varieties (V) was significant number of tillers / m² of rice. For number of tillers / m², Zn15, Zn12.5, Zn10 and Zn7.5 remained statistically similar to each other but remained significant from control (No Zn) in Super Basmati (Fig. 2). It was observed that Zn5 also differed significantly better as compared to control (No Zn) for number of tillers / m² in Super Basmati. In case of KSK 434, Zn15 and Zn12.5 differed significantly as compared to control (No Zn) for number of tillers / m². Application of Zn10, Zn7.5 and Zn5 did not give any significant change in number of tillers / m² as compared to control in KSK 434. Maximum increase in number of tillers / m² i.e., 4.42% in Super Basmati while 2.75% in KSK 434 was noted as compared to control (No Zn) where Zn15 was applied.

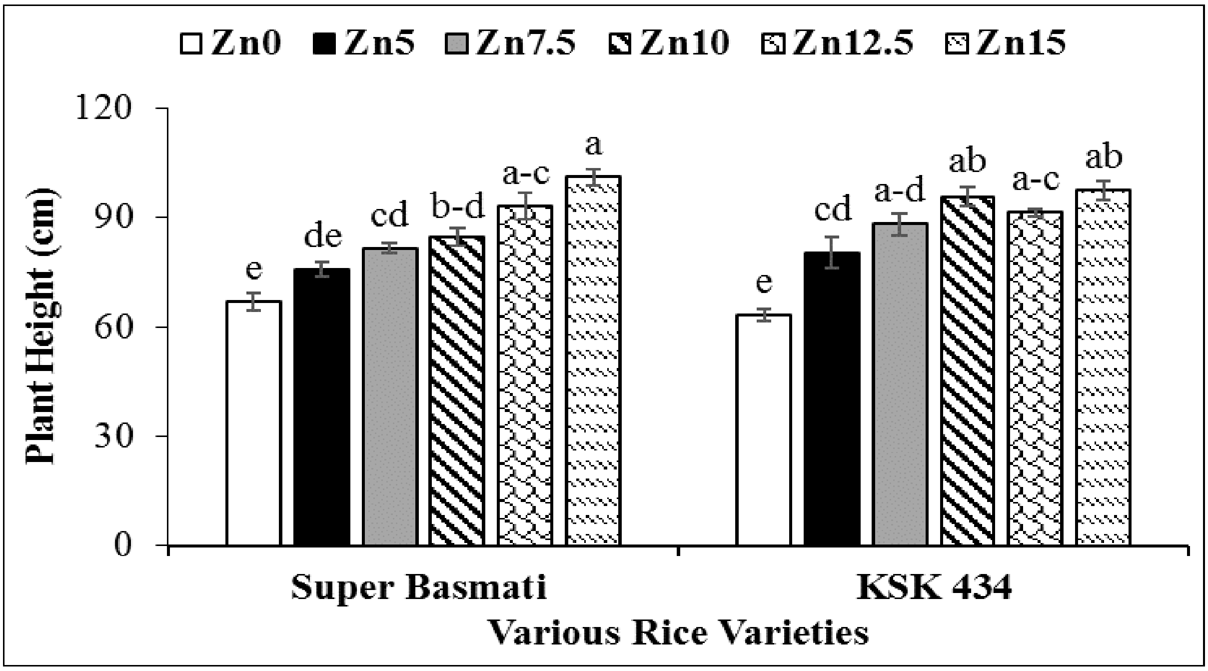

Fig. 1. Effect of various levels of Zn fertilizer on plant height of various rice varieties.

Spikelets/panicle

Effect of various levels of zinc (Zn) and rice varieties (V) was significant on spikelets/panicle of rice. Results confirmed that Zn15, Zn12.5 and Zn10 remained statistically alike to each other but differed significantly as compared to control (No Zn) in Super Basmati and KSK 434 for spikelets/panicle (Fig. 3). Application of Zn7.5 and Zn5 differed significantly better in Super Basmati but did not differ significantly in KSK 434 as compared to control for spikelets/panicle. Maximum increase in number of spikelets/panicle i.e., 82.5% in Super Basmati while 37.9% in KSK 434 was noted as compared to control (No Zn) where Zn15 was applied.

Grains/panicle

Interactive effect of various levels of zinc (Zn) and rice varieties (V) was significant on grains/panicle of rice. Results confirmed that Zn15, Zn12.5 and Zn10 remained statistically alike to each other but differed significantly as compared to control (No Zn) in Super Basmati and KSK 434 for grains/panicle (Fig. 4). Application of Zn10, Zn7.5 and Zn5 did not differ significantly better in Super Basmati but differed significantly in KSK 434 as compared to control for grains/panicle. Maximum increase in number of grains/panicle i.e., 32.5% in Super Basmati while 105% in KSK 434 was noted as compared to control (No Zn) where Zn15 was applied.

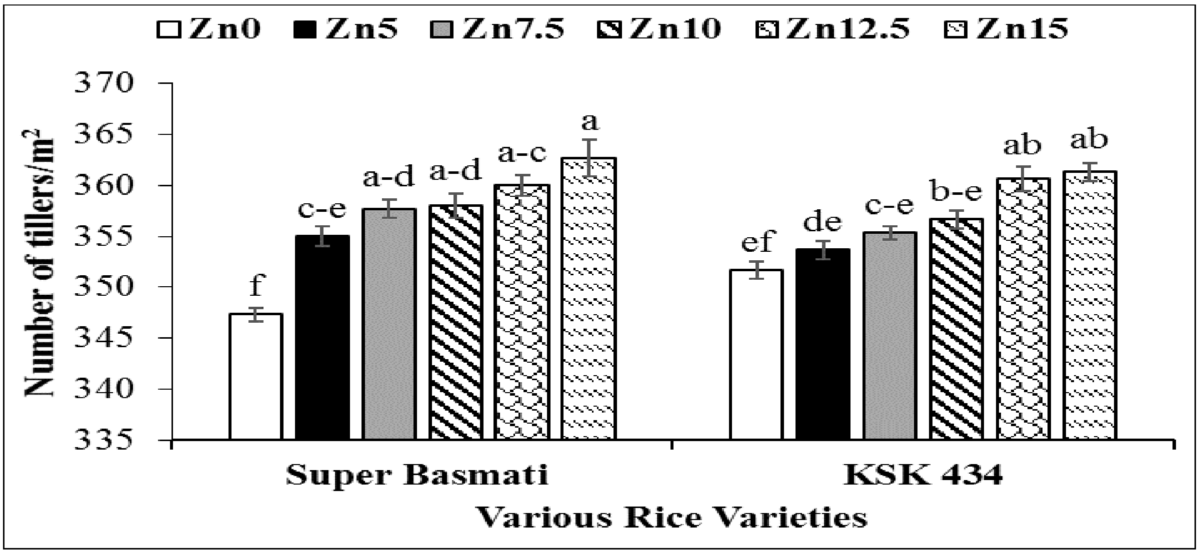

Fig. 2. Effect of various levels of Zn fertilizer on number of tillers/m² of various rice varieties.

Rice yield

Main effect of various levels of zinc (Zn) was significant but rice varieties (V) remained non-significant for rice yield (Table 1). It was observed Zn15, Zn12.5, Zn10 and Zn7.5 performed significantly better compared to control for rice yield. Application of Zn did not give any significant change in the yield of rice as compared to control. Maximum increase in rice yield i.e., 50.7% was noted as compared to control (No Zn) where Zn15 was applied.

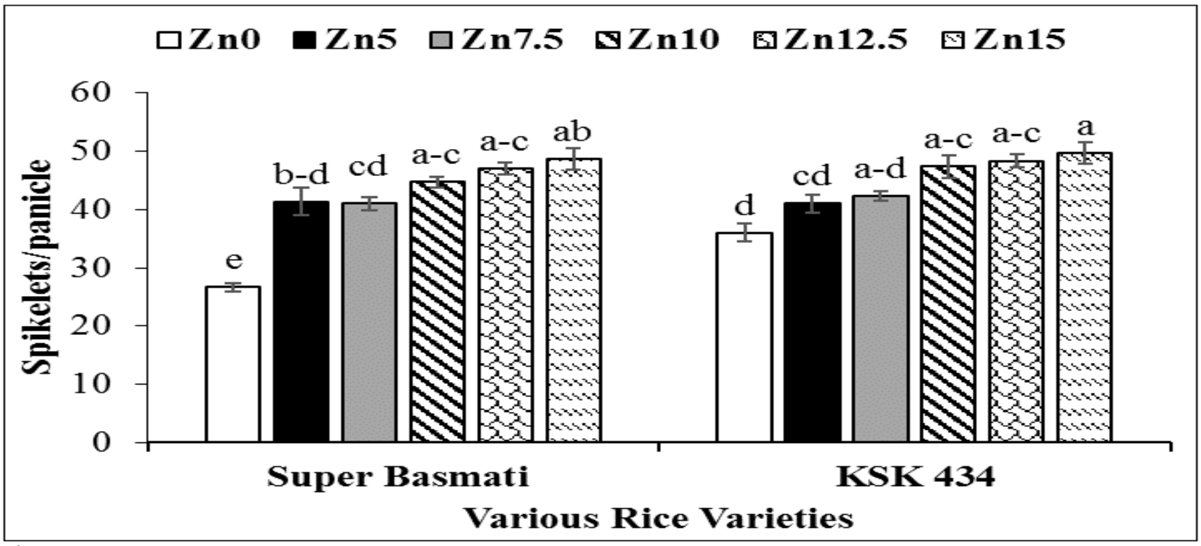

Fig. 3. Effect of various levels of Zn fertilizer on spikelet's/panicle of various rice varieties.

Discussion

In the current study, a significant reduction in growth and yield of rice was observed especially in control where Zn was not applied. This reduction in growth and yield of rice was might be due to deficiency of Zn in rice. However, the increasing level of Zn in rice promote the growth and yield attributes in both varieties of rice. The improvement in the plant height was possibly due to better cell division and elongations where Zn15 was applied in the current study as compared to control. Ahmad and Iqbal (2013) also noted a significant increase in plant height when they applied Zn as fertilizer. The increase in number of tillers per m² was also due to better enzymatic activity and improved auxin production by higher levels of Zn application in the current study. The findings of Maqsood *et al.* (1999) supported the above argument.

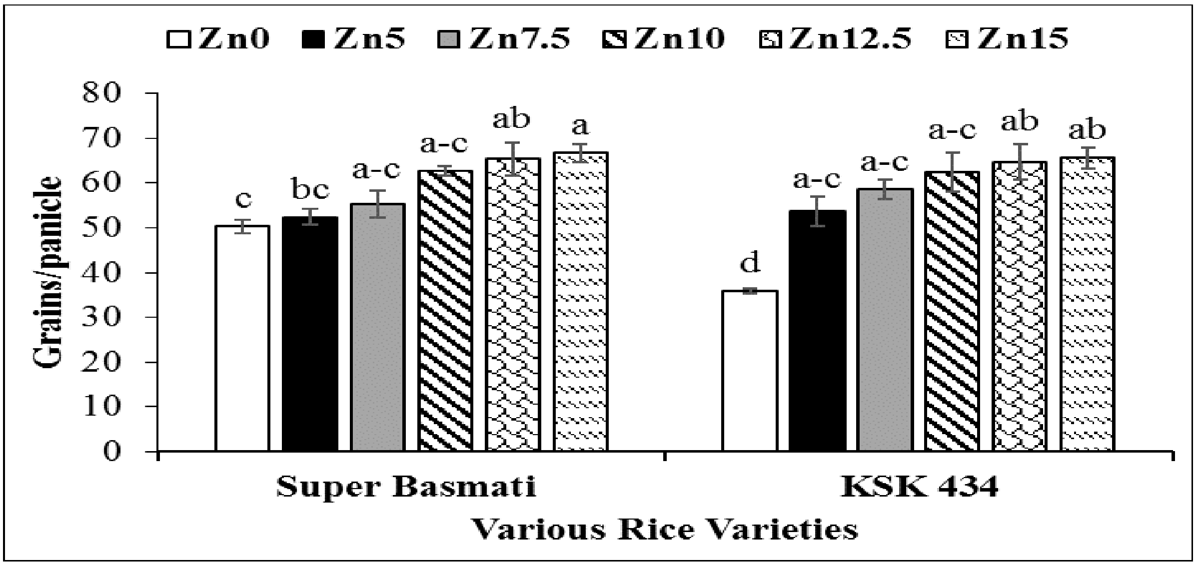

Fig. 4. Effect of various levels of Zn fertilizer on grains/panicle of various rice varieties.

The results of the current experiment are supported by the work of Anzer and Manoj (2015), Maqsood *et al.* (1999) and Bodruzzaman *et al.* (2000). They reported that an adequate supply of Zn has potential to improve the panicle length and spikelets / panicle. Similarly, in current study higher application rate of Zn played an imperative role regarding an improvement in panicle length and spikelet's / panicle. Zeidan *et al.* (2010) reported that the application of zinc and iron can increase grain yield and 1000 grain weight. Pooniya *et al.* (2012) suggested that 2.0% Zn as $ZnSO_4.H_2O$ can give the greatest yield of Basmati grain (79 t/ha) comparative to control.

The increase in yield of rice in current study was possibly due to better enzymatic activities by better uptake of Zn. According to Ozturk *et al.* (2006) at early stage of seed formation better availability of Zn enhanced the formation of protein. The findings of Martre *et al.* (2003) also supported above arguments regarding better biosynthesis of protein due to availability of Zn. Kausar *et al.* (2001) and Rahman *et al.* (2001) also showed similar kind of results regarding the yield responses of rice towards zinc.

Conclusion

In conclusion, application of Zn could improve the growth and yield of rice under the current scenario. Zn 5 and Zn 7.5 are low levels of Zn application. In addition, Zn10 and Zn12.5 are equally effective, but the application of 15 kg Zn ha^{-1} is a better approach to get maximum growth and yield of rice varieties Super Basmati and KSK 434. It was also noted that Zn15 is equally effective for Super Basmati and KSK 434 maximum yield.

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