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Full Length Research Paper

Foliar application of Zinc to improve growth, yield and grain content in rice (*Oryza sativa* L.)

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Present work envisions foliar application as a cost-effective agronomic strategy in order to manage zinc deficiency in rice to avoid any possible health hazards to low-income population in Pakistan. Significant increase in most of the vegetative and reproductive components was recorded at 6 and 8mM zinc sulphate treatment. The results obtained were important from economic as well as from nutritional perspective. From cost effectiveness prospect, 6mM zinc sulphate treatment was concluded to be beneficial to be adopted for per hectare foliar application of zinc sulphate.

Keywords: Foliar treatment, Zinc, Rice fortification

1. INTRODUCTION

Micronutrient malnutrition contributes almost 7.3% to the global disease burden and causes health hazards in more than 2 billion people worldwide (WHO, 2009; White and Broadley, 2009). Inherently low content of micronutrients in cereals and growing them in micronutrient deficient soils is the major cause of their deficit in human diet (WHO, 2002). Zinc is reported to be an important micronutrient with a critical role in growth and development of plants, humans and animals being part of photosynthesis; protein metabolism; auxin regulation; nucleic acid and lipid metabolism(Broadley *et al*., 2007; Alloway, 2008). Present research aims on combating zinc malnutrition through managing its optimum level in most commonly used staple diet like rice which is consumed in more than 175 countries around the world (Memon, 2013; Qadir *et al.,* 2013). Micronutrient supplementation, fortification, dietary diversification and introduction of biofortified crops are some of the strategies to manage zinc malnutrition. In this context, agronomic biofortification might act as a suitable resolution to address zinc deficit in staple crops like rice (Voogt, *et al*., 2013). Amongst other agronomic techniques foliar application is reported to be a contemporary, convenient and cost effective technique in managing zinc deficiencies (Imran *et al*., 2015; Yuan *et al.,* 2013).Conservation of soil and water resources; and efficient use of mineral and organic fertilizers is an important prerequisite for improved agro-technology. Foliar application should therefore be improved for the sustainability of agriculture (Alshaal & El-Ramady, 2017). Seventy percent of agricultural soils in Pakistan are deficient in zinc due to rainfed conditions; and because of alkaline, alluvial, calcareous and loessal nature of soils

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Table 1: Probability of F value of vegetative parameters and yield components of rice with respect to different zinc sulphate treatments, cultivars and treatment x cultivar

Traits	Probability of F		
	Treatments	Cultivars	Treatment x Cultivar
Leaf length (cm)	**0.05**	**0.00**	**0.01**
Leaf width (cm)	0.45	**0.00**	**0.00**
Leaf area $(cm)^2$	**0.01**	**0.00**	**0.00**
Days to flowering	**0.01**	**0.00**	**0.00**
Number of tillers	0.21	**0.00**	**0.04**
Plant height (cm)	0.08	**0.00**	**0.02**
Number of panicles	**0.04**	**0.01**	0.48
Panicle length (cm)	**0.00**	**0.00**	**0.00**
Number of grains per Panicle	**0.00**	**0.00**	**0.00**
Yield per plant (g)	**0.01**	**0.00**	**0.00**
Plant dry weight(g)	**0.01**	**0.00**	0.22
Harvest index	0.36	**0.00**	**0.00**
Root length (cm)	0.18	**0.00**	**0.00**
Shoot length (cm)	0.18	**0.00**	**0.00**
Root: shoot index	**0.00**	**0.00**	**0.00**
1000-grain weight (g)	**0.00**	**0.00**	**0.00**
Total soluble proteins (mg g^{-1})	0.09	**0.00**	0.54
Grain zinc content (mg g^{-1})	**0.00**	**0.00**	**0.02**

(Imtiaz, *et al.,* 2003; Qadir *et al*., 2013; Wasaya *et al*., 2017). More than 80% of wheat-rice systems are reported to be zinc deficient in Punjab, Pakistan (NDFC, 2014) leading to poor nutritional quality of this important staple crop and its more susceptibility towards diseases and environmental stresses (Broadley *et al.,* 2007). This crop is not only an important staple crop but also contributes around 6.7 % in value addition of agriculture and 1.3-1.6 percent in total GDP of Pakistan. Present investigation therefore, aims to exploit the suitability, convenience and economical affectivity of foliar application while using zinc sulphate as a nominal and easily accessible zinc source (Memon, 2013). A promising improvement in vegetative as well as reproductive traits in this experiment on rice advocates the idea of foliar application to be exploited in fields by farmers for per hectare application.

2. MATERIALS AND METHODS

2.1. MATERIALS

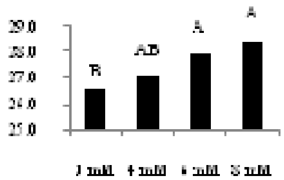
Seeds of five local cultivars of rice (Basmati-Super; Basmati-PS02; Basmati-515; KS-212; and PK-386); Zinc sulphate heptahydrate ($ZnSO_4.7H_2O$); and NPK fertilizers.

2.2. Experimental layout

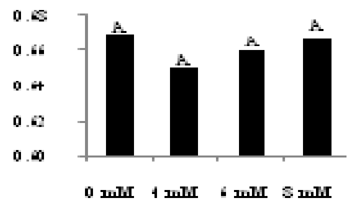
This experiment was performed in Seed Centre of Department of Botany, University of the Punjab, Lahore in *kharif* season of 2015. The soil test depicted it to be 'zinc deficient' for being loamy with a pH of 8.5, EC 0.8, SOM 0.79%, P 1.2 mg kg^{-1} and K 55 mg kg^{-1}.The experiment was set in completely randomized block design with five selected cultivars of rice. Total experimental area was divided into two equal blocks which were in turn divided into 5 equal plots. NPK was added to these plots at a recommended rate of 140-80-65 while, nitrogen was applied as split dose *i.e.,* half as basal dose and other half at the time of active tillering. Recommended seed rate of 5-6 kg $acre^{-1}$ was used and adequate irrigation was also done at recommended phonological stages of the crop. Each plot was in turn, divided into four subplots for four treatments of zinc sulphate.

2.3. Zinc foliar application and data collection

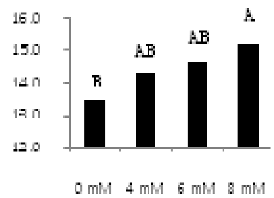
Three foliar applications of 0, 4, 6 and 8mM zinc sulphate were given at vegetative phase on weekly basis and data were recorded for leaf area on the 7th day of treatment. Days to flowering and days to anthesis for each stand of foliar treatments of zinc sulphate were recorded when 50 % of



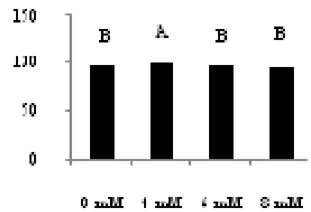
Graph 1. DMRT for leaf length



Graph 2. DMRT for leaf width



Graph 3. DMRT for leaf area



Graph 4. DMRT for days to flowering

the stand exhibited the flowering or anthesis. Two foliar applications of each treatment of zinc sulphate were given at milk and dough stage of grain filling. Days to maturity of grains were recorded when 50% spikes of a stand had lost their green colour. Plant height from ground level till the tip of main tiller and number of tillers of three randomly selected plants from each stand of respective treatment was also recorded. Rice crop was harvested when its grains attained complete physiological maturity. Plant fresh weight of three randomly selected plants was recorded at the time of harvest; while, plant dry weight and yield components like number of panicles per plant; panicle length; number of grains per panicle; 1000-grain weight; yield per plant;shoot/ root index; and harvest index (HI) of same plants was also recorded. Total soluble proteins and zinc content was determined rice grains of rice exposed to different levels of zinc sulphate by using Biuret method of Roenson and Johnson (1961); and Shar and Bhanger (2001) respectively.

2.4. Statistical analysis

Data were analysed for Type III sum of squares and Duncan's multiple range tests by PROC MIXED and PROC GLM in SAS statistical software package 9.3.1(SAS Institute Inc., Cary, NC).

3. RESULTS

3.1. Leaf length (cm), leaf width (cm) and leaf area (cm^2)

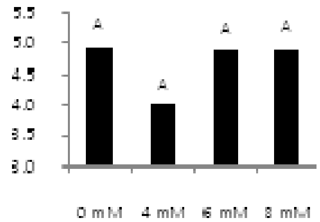
Increase in leaf length was statistically in the same range at 6 and 8mM treatment of zinc sulphate (Graph 1). Leaf width however, was found to have non-significant difference at all the treatments (Graph 2). Leaf area exhibited maximum increase at 8mM treatment while 0, 4 and 6mM treatments were found to be in same range (Graph 3).

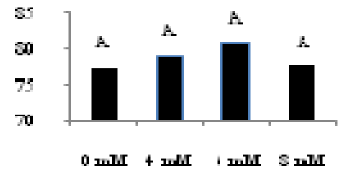
3.2. Days to flowering, number of tillers and plant height (cm)

Days to flowering at 4mM displayed significant increase over 0, 6 and 8 mM (Graph 4) while non-significant difference was recorded in number of tillers and plant height at all the four treatments of zinc sulphate (Graph 5 and 6).

3.3 Number of panicles, number of grains per panicle and panicle length (cm)

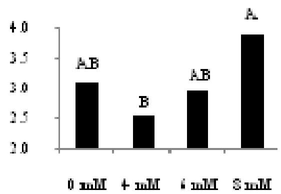
Significant increase in number of panicles was recorded at 0 mM and 4 mM while at 6 and 8 mM exhibited non-significant difference (Graph 7). Panicle length was

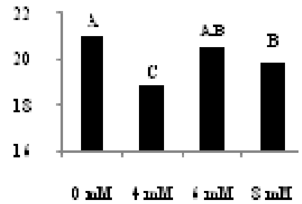




Graph 5. DMRT for number of tillers

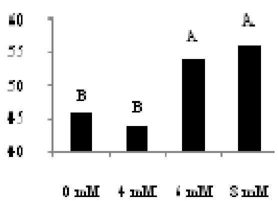
Graph 6. DMRT for plant height

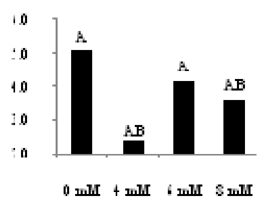




Graph 7. DMRT for of panicles

Graph 8. DMRT for panicle length





Graph 9. DMRT for number of grains per panicle

Graph 10. DMRT for yield per plant

recorded to be significantly lower at 4 mM (Graph8) while, number of grains per panicle was significantly high at 6 and 8 mM (Graph9).

3.4. Yield per plant (g), plant dry weight (g) and harvest index

Yield per plant was recorded to be significantly high at 0 and 6 mM while, at 4 mM and 8 mM this value was in same range (Graph 10). Plant dry weight at 6 mM was also significantly high than other treatments (Graph 11); harvest index however, exhibited non-significant difference at all treatments (Graph 12)

3.5. Root length (cm), shoot length (cm) and root:shoot index

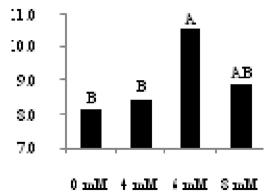
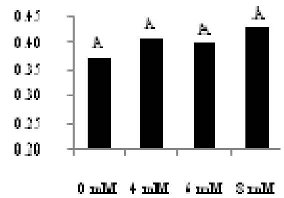
Non-significant difference was recorded in shoot and root length at all the four treatments (Graph 13; Graph 14). Root: shoot index at 0 and 6 mM was found to be lower than that at 4and 8mM (Graph 15).

3.6. 1000-grain weight (g), total soluble proteins (mg g^{-1}) and grain zinc content (mg g^{1})

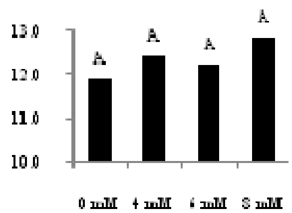
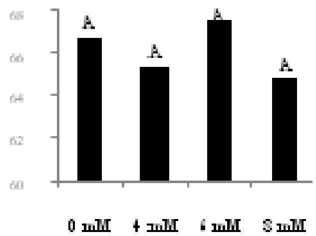
1000-grain weight was significantly high at 6 mM while, at 0 and 4 mM1000-grain weight was statistically in the same range at all treatments (Graph 16). Total soluble proteins were significantly high at 0mM than 6 mM (Graph 17); while, grain zinc content was recorded to be significantly high 4 mM (Graph 18).

4. DISCUSSION

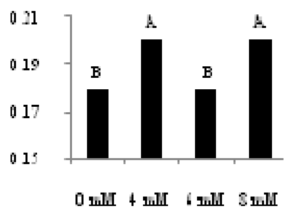
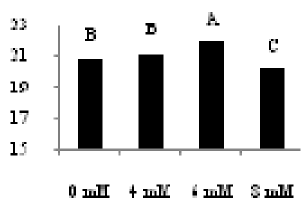
As rice crop is transplanted under complete submergence, the soils undergo physical and chemical changes leading to oxygen depletion (Rehman *et al.*, 2012). Changes in

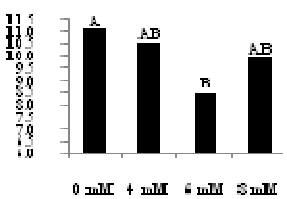
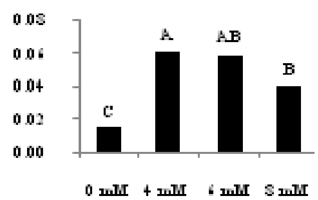
Graph 11. DMRT for plant dry weight **Graph 12.** DMRT for harvest index

Graph 13. DMRT for root length **Graph 14.** DMRT for shoot length

Graph 15. DMRT for root shoot index **Graph 16.** DMRT for 1000 grain weight

Graph 17. DMRT for total soluble **Graph 18.** DMRT for grain protein content zinc content

soils physical properties include changes in temperature and water regime in rhizosphere and subsequent decrease in availability of soil zinc (Hajiboland *et al.,* 2005). Prolonged submergence although, favours availability of Ca, Cu, Mg, Fe and P but hampers zinc availability (Das, 2014). Calcareous soils and growing rice in submerged conditions cause zinc deficiency in rice crop in Pakistan (Naik and Das, 2007). Rice crop in this experiment exhibited an improved vegetative growth after foliar application of zinc sulphate, leading to improvement in many of the yield components and grain zinc content. Leaf length and leaf area increased significantly on increasing

Fig. 1. Rice sowing

Fig. 2. Seedling emergence

Fig. 3. Tillering stage

Fig. 4. Stem elongation stage

Fig. 5. Grain filling stage

Fig. 6. Mature crop of rice

zinc sulphate concentration; supported by the work of Dubey (2005) who proposed that zinc application increases photosynthesis and nutrient uptake of the plants. Teale *et al*. (2006) also pointed at the role of zinc in regulating auxins; cell division; and their elongation. Chen *et al.* (2008) described that zinc is a constituent of carbonic dehydrogenase and zinc deficient plants have less chlorophyll. Rice crop under this experiment exhibited prolonged vegetative phase at 4 mM treatment. During this prolonged vegetative phase rice plants were able to photosynthesize well, and to accumulate sufficient carbohydrates. Plant height in this experiment exhibited non-significant difference at all treatments although Hossain *et al.* (2008) reported significant increase in plant height by zinc foliar application. Shoot and root length also did not exhibit any significant increase, but root: shoot index was highest at 4 mM followed by 8,0 and 6 mM. Number of tillers per plant, number of fertile panicles per plant and panicle length of zinc treated plants did not show significant increase over control. These results were in close proximity with the findings of Hussain *et al.* (2005) and Qadir *et al.* (2013)who also recorded non-significant increase in number of tillers and number of fertile panicles by zinc application. They also attributed it to the fact that tillering is predominantly controlled by genetic make-up, environment and nutrition of rice plants. Number of fertile panicles also exhibited non-significant increase in this experiment. Fageria *et al.* (2002) described that spikelet sterility is common in rice and generally 85% spikelets are filled and 15 % tend to remain unfertile. Percentage of ripened spikelets decreases with any stress to the crop. In our experiment, a fungal disease ‘blast’ might be one of the reasons of empty spikelets. Panicle length in this rice experiment also exhibited non-significant increase in analogy with the work of Hossain *et al*. (2008) who also reported similar results. Number of grains per panicle exhibited a significant increase at 6 and 8mM foliar applications of zinc sulphate, while in control and at 4 mM the number of grains per panicle was almost in the same range. Qadir *et al*. (2013)explained in their review that number of spikelets per spike was controlled by many factors like genotype; planting date; seedling rate; soil fertility and soil temperature. There was a non-significant difference in yield per plant with allthezinc sulphate treatments. This variability could possibly be due to grain damage during harvest. Decrease in grain yield at certain treatments also fits the idea of trade-off between grain yield and grain zinc content. Garvin *et al*. (2006) and McDonald *et al*. (2008) highlighted the inverse relationship between grain yield and grain zinc concentration due to dilution of grain accumulates. Plant dry weight in zinc treated rice plants was highest at 6 mM among other treatments. These results were analogous with the work of previous researchers including Hossain *et al*. (2008) and Imran *et al.* (2015) who reported an increase in straw and paddy yield with zinc application. Similarly, Naik and Das (2007) also reported that zinc increased the straw yield when applied to the rice grown in submerged conditions. Harvest index although exhibited a slight increase at 4 and 8 mM but it was in non-significant range due to genotypic difference in rice varieties used in this experiment. 1000-grain weight in rice experiment had a significant increase at 6 mM. Imran *et al*. (2015) correlated the increase in paddy yield partially with increased grain weight due to improved metabolic processes. This idea was also supported by Hossain *et al*. (2008) who reported a significant increase in 1000-grain weight in rice with foliar application of 0.5% zinc sulphate. Analysis of total soluble proteins and grain zinc content exhibited an inverse pattern of accumulation. Zinc was accumulated to a noticeable extent in rice grains but it traded off with the yield and protein content of rice grains. Eleiwa *et al*. (2012) and Jan *et al*. (2016) reported that foliar application of zinc was helpful in increasing free amino acids. The contradiction in our results could be related to the fact that frequent sprays of zinc sulphate probably might cause decline in nitrogen metabolism and activity of enzymes and growth hormones thus leading to a decline in many of the important traits. A significant increase in grain zinc content up to 0.060 mg g^{-1} and 0.058 mg g^{-1} was observed in rice experiment at 4 and 6mM treatment respectively. Boonchuay *et al.* (2013) and Imran *et al*. (2015) also stated that even 0.25% levels of zinc foliar application were effective in increasing grain zinc content up to 59%, in rice. Phattarakul *et al.* (2012), noticed a consistent increase in grain zinc content from 25 to 32% by foliar and foliar + soil zinc application. Slaton *et al.* (2005) described higher zinc content in rice had positive impacts on seed germination, seedling growth and field establishment in zinc deficient soil. They also emphasized that zinc application during grain formation results in better accumulation of zinc.

5. CONCLUSIONS

In this experiment significant increase in grain zinc content was noticed at 6 and 8mM treatments, but 6 mM zinc sulphate would be more beneficial to be adopted in agronomic practices as it will cost lesser amount per hectare of cultivated area. Increase in zinc grain content was recorded to be 0.060 mg g^{-1} at 6 mM thus, a consumption of 100 g zinc treated rice per day would provide us with 6 mg zinc, while on using an average of 300 g of these rice will provide us with 18 mg zinc which is in the range of daily required intake of zinc *i.e.*, 15 mg for a young adult.

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