Zinc fertilization improves the aerobic rice productivity

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Abstract
Malnutrition and water saving are the two biggest challenges for the rice farmers in developing countries. To produce more rice with little water seems an attractive practice for the farmers in Pakistan which may increase the problem of malnutrition on low zinc soil. Zinc as an essential nutrient needs special attention for successful management in rice crop production when transitioning from flooded to aerobic cultivation systems. In this experiment several methods of zinc fertilization were assessed: Seed priming, soil application, foliar application, seed priming + soil application, seed priming + foliar for their effect on rice productivity under aerobic culture. Results revealed that all methods of zinc fertilization improved the crop yield while the best results were found using a combination of seed priming and foliar application. Furthermore, this technique significantly enhanced the zinc bioavailability in both cultivars. We conclude that rice productivity and quality can be enhanced with zinc seed priming supplemented with foliar application grown under aerobic rice culture.

Keywords
Aerobic rice, zinc, growth, yield and quality.

Introduction
Rice is a major cash crop in Pakistan which is grown conventionally under flooded conditions which requires significant amounts of irrigation water to mature the crop. In Pakistan and globally irrigation water supply is declining and strategies are required for sustainable crop production. Farmers in Pakistan are shifting cultivation from flooded to aerobic condition to save the water but proper nutrient management is required for optimum yield and quality. Boron (B) and zinc (Zn) deficiency are limiting crop yield (Sarwar et al. 2013).

Transitioning from flooded to aerobic systems and Zn nutrition are the major concerns of the rice growers having water shortages (Bouman et al. 2007). Zinc is an essential nutrient which plays major role in human health as well as for maximising crop production but its deficiency is widely reported in various parts of the world (Alloway 2004). Developing countries are increasingly facing problems of low Zn diets leading to health and development problems in humans (Maret and Sandstead 2006). Biofortication of Zn among various crops can be achieved by agronomic practices or with the use of genetic modification, both of which may be a cost effective approach to combat malnutrition (Hotz 2009).

Yield decreases associated with the transition from flooded rice to aerobic culture have been associated with reduced zinc availability (Giordano and Mortvedt 1974; Wang et al. 2002). In this context, “bioavailability” refers to Zn availability to the crop, which is usually a small fraction of total soil Zn. Bioavailabilty of Zn may be reduced to a level where it would not become a direct production constraint to the rice crop, but the grain Zn concentration may decline, thus compromising nutritional quality. As a result, the introduction of aerobic rice on low Zn soils places the problem of Zn deficiency in rice in a new perspective (Gao et al. 2006). An experiment was conducted to evaluate zinc fertilization techniques in aerobic rice. We hypothesised that zinc nutrition can be enhanced with appropriate application method for sustainable rice agriculture.

Methods
A field experiment was carried out at experimental area of Department of Agronomy, Bahauddin Zakariya University Multan during growing seasons of year 2014 and 2015. In the first year (2014), physical and chemical analysis of soil was performed before sowing. Two fine rice Genotypes was used as test species for the response of zinc fertilization grown under aerobic condition. Five different types of application: Seed priming, soil application, foliar application, seed priming+soil application, seed priming+foliar application where compared to a control (no Zn applied) treatment under aerobic condition. Recommended rate of zinc

fertilizer in the form of $ZnSO_4$ was applied in seed priming (0.5%), soil application (12.5 kg/ha) and foliar (0.5%) application techniques. For both foliar and soil application, a half dose of each recommended fertilizer was applied to avoid toxicity. Foliar application was undertaken at different growth stages (seedling, tillering and panicle initiation) of the rice crop. Spray solution was prepared by dissolving powdered zinc ($ZnSO_4$) in distill water and applied through spray machine (900-1000 L/ha). For seed priming, seeds were soaked in 0.5% zinc solution for 12 hours. An aquarium pump was used to aerate the soaked seeds. After priming, seeds were removed from solution and dried to its original weight prior to sowing. A basal application of nitrogen, phosphorus and potassium (140:80:60 kg/ha) in the form of Urea, DAP and K_2SO_4 was applied to the experiment. One third of nitrogen with full dose of P and K was applied at the time of sowing while another two doses were applied at tillering and panicle initiation stage and a randomised complete block design (RCBD) was used for the experimental layout.

Rice genotypes were kept in main plots while the zinc application techniques were treated as subplots. The area of each subplot was 3 m x 4 m with a row spacing of 20 cm. Seed of both cultivars was direct seeded in the field soil under field capacity. Supplement irrigation was applied to maintain the field moisture. Irrigation water was applied to crop at field capacity (-8 kPa) using a tensiometer. The rice crop was sown in the first week of July, 2014.

At physiological maturity the crop was harvested manually. Various yield and yield determinants like plant height, panicle length, 1000 grain weight and grain yield were recorded at the time of harvesting. Rice grain quality was measured in term of paddy zinc concentration. Primary panicles were randomly selected from each plots and then oven dried upto constant weight. Paddy samples were grinded to powdered form by using the grinding mill (Retsch, MM-301, Germany). A sub sample of finally grounded sample was digested in mixture of HNO_3 and $HCLO_4$ (Jackson 1973). Atomic absorption spectrophotometry was used to estimate zinc contents in plants as well as in grain. Data was analysed by applying Fisher’s Analysis of Variance and the Least Significant difference (LSD) test at 5% level of probability to compare treatments means using statistical software MSTATC (Steel and Torrie 1997).

Results

Yield parameters

The interaction between cultivar and fertilization treatments was not significant ($P < 0.05$). Comparison of treatments for the plant height revealed that tallest plants were recorded in T5 in both cultivars. Shortest plants were found in the control treatments. All zinc fertilization treatments enhanced crop height as compared with the control. Similarly the maximum productive tillers were recorded in treatment of seed priming along with foliar application. This treatment also produced largest panicle length, 1000-grain weight and grain yield. Other zinc fertilization treatments also improved the crop yield and yield attributes but T_5 resulted in the best results in both cultivars. Shortest panicle length and lowest 1000 grain weight were recorded in the Control treatment.

Zinc concentration of Rice

All Zn fertilization techniques significantly improved the zinc concentration of the paddy rice as compared to control treatment. Rice cultivars grown with zinc priming supplemented with foliar application had the highest Zn concentration. Low concentrations of zinc were recorded in control. Moreover, the seed priming and soil application treatments recorded similar Zn concentrations in both cultivars. Both rice cultivars responded almost similarly to fertilization technique, so the pooled data is presented here (Figure1).

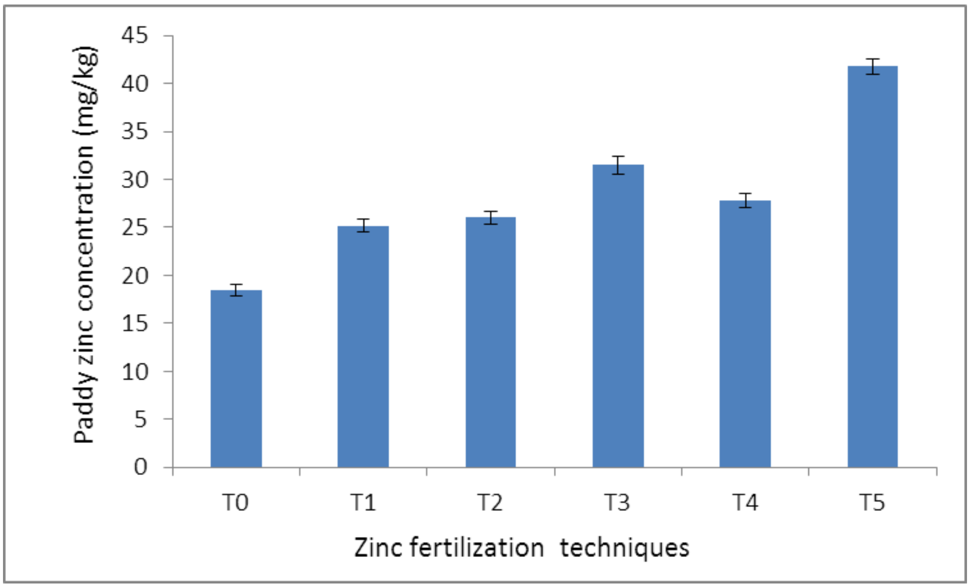

Figure1. Effect of zinc fertilization techniques on grain zinc contents in aerobic rice. T_0 (No application), T_1 (Seed priming), T_2 (soil application), T_3 (foliar application), T_4 (seed priming+soil application), T_5 (seed priming+foliar). Data represents pooled data for both rice cultivars.

Table 1. Effect of zinc fertilization techniques on various yield parameters of aerobic rice (mean of both Cultivars). T0 (No application), T1 (Seed priming), T2 (soil application), T3 (foliar application), T4 (seed priming+soil application), T5 (seed priming+foliar). Numbers followed by the same letter are not significantly different (P = 0.05).

Treat.	Plant height (cm)	Total tillers (m^{-2})	Panicle length (cm)	1000-grain weight (g)	Grain-Yield (kg/ha)
T_0	86.6f	395e	12e	16d	2.8d
T_1	88.8e	442d	15de	18c	2.9d
T_2	90.8d	501c	16cd	19bc	3.3cd
T_3	91.9c	526bc	18bc	19b	3.9bc
T_4	93.6b	550ab	20ab	21a	4.3b
T_5	94.9a	568a	22a	21a	5.2a
LSD	0.33	33.32	2.37	1.07	0.60

Discussion

Intensive cultivation of crops such as rice has resulted in the appearance of nutrient deficiencies, especially for the micronutrients like zinc. Zinc is an essential micro nutrient which plays a major role in the crop growth and yield as well as for the grain quality. These nutrient deficiencies have resulted in not only reduced grain yields but also created low nutritional food in developing countries, resulting in the need for improved crop management. Different methods can be used for the zinc fertilization like seed priming, seed coating, soil application and foliar application. In this experiment several possible methods of zinc fertilization were compared in fine rice productivity. Our results indicated that almost all of the different techniques of zinc fertilization improved the crop yield but the best results were found with seed priming supplemented with foliar application. Seed priming is an emerging and cost effective technique which seems most successful for the micronutrients as seed absorbed the nutrients which increases the seedling vigor and growth. Although soil application provided almost similar results compared to seed priming, seed priming is cost effective approach and can be used in developing countries. Soil applied zinc is less efficient technique compared to the zinc applied through foliage (Phattarakul et al. 2012). Plants requirements for zinc after germination can also be provided through foliar application at different critical growth and reproductive stages of the crop. This was possibly the major reason for higher crop productivity in T_5 treatment combination. Foliar zinc can easily absorbed through leaves and translocate in different plant parts for grain enrichment (Boonchuay et al. 2013; Haslett et al. 2001; Erenoglu et al. 2002). Our results, based on one experiment suggest that rice productivity can be enhanced with zinc seed priming supplemented with foliar application.

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