APPLICATION OF MICRONUTRIENTS FOR YIELD ENHANCEMENT IN RICE

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ABSTRACT

An experiment was conducted at the Agricultural Research Institute, Dera Ismail Khan, in 2009, to determine the effect of micronutrients viz. zinc, boron and iron on growth and yield of rice. The experiment was laid out in a randomized complete block design with four replications. The results revealed that the maximum number of tillers per square meter, spikelets per panicle and paddy yield was obtained with combined use of zinc and boron. Whereas, the highest 1000-grain weight was recorded where all three micronutrients (zinc, boron and iron) were applied in combination. The maximum normal kernel percentage was recorded where zinc was applied along with iron while the maximum number of panicles per square meter was recorded with sole iron application. Based on results obtained, it is recommended to use boron alone or combined it with zinc for obtaining higher yield of rice.

Keywords: Rice, Iron, Zinc, Manganese, Trace Elements, Pakistan

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops of the world. It is primary staple food for millions of people, more than 2 billion people in Asia and hundred millions in Africa and Latin America depend on rice for food. It is true for Pakistan too, where it is staple food and is next to wheat crop. It is annually cultivated on an area of 2.52 million hectares with total production of 5.16 million tones (Anonymous, 2008). It plays a pivotal role in the economy of Pakistan by adding foreign exchange into the natural exchequer. It clearly seems that its role in the world's trade is certain and its demand in the market would be well sustained for many years to come. Pakistan is enjoying monopoly in the international market of rice and getting considerable amount of foreign exchange through the export of rice.

There are many factors which limit the rice yield in Pakistan. Among these, plant nutrients are a major constraint in increasing rice production (Rehm and Sims, 2006). Zia *et al.* (2004) collected 329 soil samples from various depths which revealed widespread deficiencies of zinc, boron and iron in Pakistan. Imtiaz *et al*. (2010) also reported that the most widespread deficiency is of zinc as 70 % of the soils of Pakistan are zinc deficient. These micronutrients are needed in trace amounts but their adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield as well (Taiwo *et al*., 2001; Anonymous, 2009). Therefore, Fischer (1999) mentioned that the nutrient-use efficiency of rice cropping systems must be improved in order to improve profitability of rice production and prevent environmental degradation.

Zinc deficiency affects several biochemical processes in the rice plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity and growth (IRRI, 2000). Its deficiency shows dusty brown spots on upper leaves of stunted plants, uneven plant growth, decreased tillering, and increased spikelet sterility in rice (Dobberman and Fairhurst, 2000). Neue *et al.* (1998) observed that in rice, the most commonly observed micronutrient disorder is zinc deficiency. Therefore, application of zinc is felt necessary throughout the growth cycle of rice crop (Chen *et al*., 2009).

Boron affects cell wall biosynthesis and affects structure and plasma membrane integrity. Boron deficient rice plants show white and rolled leaf tips of young leaves, death of growing points and unable to produce panicles if affected at panicle formation stage (Salim *et al*., 2011). It is required for carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration, and pollen viability (Dell and Huang, 1997). Boron is not an enzyme constituent and does not affect enzyme activities. It is relatively immobile in rice plants (Yu and Bell, 1998).

Iron is required for electron transport in photosynthesis and is a constituent of iron porphyrins and ferredoxins, both of which are essential components in the light phase of photosynthesis. It is an activator for several enzymes (e.g. catalase, succinic dehydrogenase, and aconitase), but inhibits K absorption (Moril *et al*., 1991). Meng *et al.* (2005) reported that improving the iron content and bioavailability in rice is a perspective and an effective way to alleviate or even solve the widespread iron deficiency in humans.

Despite of the fact that these nutrients are actively involved in various plant growth mechanisms, their specific role for yield improvement in rice is yet to be investigated in this part of the country. Keeping this in view, the present research was undertaken to see the effect of zinc, boron and iron on growth and yield of coarse rice under the agro-climatic conditions of Dera Ismail Khan.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Institute, Dera Ismail Khan, in 2009. It was laid out in a randomized complete block design with four replications. The net plot size was $2x5m^2$ with 10 rows, 5 m long and 20 cm apart. Three micronutrients viz. Zn (8 kg ha^{-1}), B (2 kg ha^{-1}), Fe (5 kg ha^{-1}), Zn + B (8+2 kg ha^{-1}), Zn + Fe (8+5 kg ha^{-1}) and Zn + B + Fe (8+2+5 kg ha^{-1}) were applied along with recommended NPK fertilizer @ 120-90-60 kg ha^{-1}.

The land was prepared to make a fine seed bed by ploughing, harrowing and tillering once each. Cultivar IR-6 was used as test variety. Rice seedlings (30-day-old) with roots holding a small hump of soil were transplanted manually in the experimental field. Full dose of phosphorous and potassium were applied along with half dose of nitrogen at the time of transplanting, while the remaining half nitrogen was applied at panicle initiation stage after 45 days after transplantation (DAT). Soil application of zinc, boron and iron was done in the form of $ZnSo_4$, Borax and $FeSo_4$ at seedbed preparation. Furadon (3G) granules @ 30 kg ha^{-1} were applied to control rice stem borer. Soil analysis was done which showed that the experimental site was alkaline in nature with pH 7.81 and electrical conductivity (EC) 0.35 ds/m suggesting that soil had no problem of salinity and sodicity. The texture of soil was silty clay loam. It was deficient in organic matter, mineral nitrogen (N) and phosphorous (P), while adequate in potash (K) contents. The pH, EC and soluble cations were decreased after crop harvest, while available P and K were increased (Table-1).

Data were collected on number of tillers (m^{-2}), number of panicles (m^{-2}), number of spikelets ($panicle^{-1}$), 1000-grain weight (g), normal kernel (%) and paddy yield (t ha^{-1}).

The data obtained were subjected to analysis of variance technique (Steel *et al*., 1997) by using MSTATC computer software (MSTATC, 1991) and means were separated by LSD test.

RESULTS AND DISCUSSION

Number of tillers (m^{-2})

Tillering of a plant depends on the genotype, environment as well as the plant nutrition. The data showed that none of the micronutrients had significant effect on number of tillers per unit area (Table-2). However, the maximum number of tillers (380.8 m^{-2}) was recorded in treatments receiving zinc and boron @ 8 + 2 kg ha^{-1}, respectively. Hussain *et al*. (2005) also reported the same results and observed non-significant difference in total number of tillers per plant and number of fertile tillers per plant in response to applied micronutrients. However, the studies carried out in IRRI (2000) indicated that zinc application activates and increases tillering capacity in rice due to improved enzymatic activity. Dell and Huang (1997) reported that boron application increases leaf expansion and thereby the photosynthetic capacity of plants. Correa *et al*. (2006) observed that appropriate boron availability in soils favours root growth, and a sufficient supply of this micronutrient is very important for adequate rice development.

Number of panicles (m^{-2})

In rice, the final yield is mainly a function of the number of panicles bearing tillers per unit area. The data on numbers of panicles revealed significant difference among treatments (Table-2). The use of iron @ 5 kg ha^{-1} produced the highest number of panicles (377.5 m^{-2}). It was, however, statistically at par with all other treatments, except that of sole application of zinc @ 8 kg ha^{-1}, which produced the lowest number of panicles (320.5 m^{-2}). The production of higher number of panicles in iron treated plots might be due to the reason that iron is required for electron transport in photosynthesis and is a constituent of iron porphyrins and ferredoxins, both of which are essential components of photosynthetic process. Therefore, more the rate of photosynthesis more will be the production of panicles and vice-versa.

Number of spikelets ($panicle^{-1}$)

Many factors affect the spikelets per panicle such as genotype, cultural practices used (planting date, seeding rate and soil fertility) and growing conditions (air and soil temperature, etc.).The data regarding number of spikelets per panicle are presented in Table-3, which revealed that maximum number of spikelets was produced in Zn + B and Zn + Fe treatments. The minimum number of spikelets per panicle was noted where sole application of zinc was applied. In the present research, the application of zinc in combination with boron and iron produced the maximum number of spikelets per panicle. It could be attributed to adequate supply of zinc that might have increased the availability and uptake of other nutrients resulting in improvement in metabolic activities.

1000-grain weight (g)

The use of micronutrients had significant effect on grain weight (Table-3). The heavier grains were found in treatment where all micronutrients viz. zinc, boron and iron were applied in combination. The lowest grain weight was found in sole zinc application. In the mentioned case, the use of sole application of each micronutrient was not as effective as that of their combined use. It might be due to more efficient participation of all three micronutrients in various metabolic processes which enhanced accumulation of assimilates in the grains and resulted in heavier grains. Our results are supported by

Soleimani (2006) who recorded significantly increased seeds weight by integrating micronutrients like Zn, Fe, Mn and Cu. Zhang *et al*. (2008) reported that iron concentration in seed increased significantly (18.9%) when combined it with boron. Nadim *et al*. (2011) obtained higher grain weight when zinc, copper, iron, manganese and boron were applied in combination.

Normal kernel (%)

The data showed maximum normal kernel (73.90%) in treatment where zinc was applied along with iron followed by 71.59% normal kernel produced in treatment where zinc, iron and boron were used in combination. The minimum normal kernel (66.09%) was found in zinc and boron combination treatment (Table-4). The combination of zinc and boron was found not as much effective to increase percent filled grains per panicle in rice. Dobberman and Fairhurst (2000) reported that boron levels in rice plant tissue are considered toxic if concentration is > 30 mg kg^{-1}. Such boron levels may cause male sterility and induce floral abnormalities (Sharma, 2006).

Paddy yield (t ha^{-1})

Paddy yield is composed of various yield components such as number of panicles, spikelets per panicle, normal kernels and 1000-grain weight. The data showed significant effects of micronutrients on paddy yield (Table-4). The maximum paddy yield of 6.675 t ha^{-1} was obtained when zinc and boron was applied in combination. It was, however, statistically at par with paddy yield of 6.55 t ha^{-1} recorded in treatment where sole boron was applied. Minimum paddy yield (5.66 t ha^{-1}) was produced when zinc, boron and iron were used in combination. In this study, the use of zinc and boron produced the highest paddy yield due to the combined effect of many yield components including higher number of tillers m^{-2}, spikelets panicle^{-1} and statistically similar number of panicle m^{-2} and 1000-grain weight. Chaphale and Badole (1999) recorded higher paddy yield when NPK was applied with zinc in combination. Previous findings also revealed that the application of zinc fertilizer not only increased yield but also zinc concentrations in rice seed (Erdal *et al*., 2002; Hu *et al*., 2003; Genc *et al*., 2004).

The data also showed that sole application of boron produced statistically at par paddy yield to that of its combination with zinc. This is because of producing statistically similar number of panicles m^{-2}, spikelets panicle^{-1} and significantly higher percent normal kernels than the combined application of zinc and boron. Boron is basically involves in several biochemical processes including carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration, and pollen viability therefore its deficiency directly affects panicle production and hence the paddy yield. The sole application of boron is reported to be as effective as its combined use with NPK or other micronutrients. Dunn *et al.* (2005) obtained higher paddy yield with the sole application of boron. Chaudry *et al.* (2007) stated that boron application along with basal dose of NPK significantly increased the yield. Moreover, by supplying plants with micronutrients, either through soil application, foliar spray, or seed treatment, increases yield and quality as well as macronutrient use efficiency (Imtiaz *et al*., 2006). Salim *et al*. (2011) recommended that adequate boron supply is necessary for obtaining high yields and good quality of agriculture crops.

CONCLUSION

Different micronutrients were applied to achieve the highest yield of rice (cv. IR-6).

The results indicated that different micronutrients significantly affected most of the yield contributing parameters. This study emphasized the need of using micronutrients, especially boron @ 2 kg ha^{-1}, for obtaining maximum yield of rice under the agro-climatic conditions of Dera Ismail Khan or similar environmental conditions prevailing in other parts of the country.

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Table-1. Physico-chemical characteristics of soil of the experimental site.

Parameters	Unit	Pre-sowing	Post-harvesting
pH	-	7.81	7.80
Electrical conductivity	ds/m	0.35	0.20
Ca + Mg	mg/l	3.10	2.50
HCO_3	mg/l	1.20	1.60
Cl	mg/l	1.02	1.34
Organic matter	%	0.64	0.70
Nitrogen	%	0.032	0.035
Sand	%	16.2	16.4
Silt	%	47.8	47.2
Clay	%	36.0	36.4
Texture class	-	Silty clay loam	Silty clay loam
Phosphorous	mg/kg	3.2	3.5
Potassium	mg/kg	128	132

Source: Soil Chemistry Laboratory, Agricultural Research Institute, Dera Ismail Khan

Table-2. Number of tillers and panicles (m^{-2}) as affected by micronutrients application in rice.

Treatments	Dose (kg ha^{-1})	Number of tillers (m^{-2})	Number of panicles (m^{-2})
T1: Zn	8 kg	361.0^{NS}	320.5 b
T2: B	2 kg	354.8	353.0 ab
T3: Fe	5 kg	365.0	377.5 a
T4: Zn + B	8 + 2 kg	380.8	355.8 ab
T5: Zn + Fe	8 + 5 kg	365.0	356.8 ab
T6: Zn + B + Fe	8 + 2 + 5 kg	364.3	336.8 ab
$LSD_{0.05}$	---	---	49.72

NS = Non-significant

Means followed by different letter(s) in a column are statistically significant at 5% level of probability.

Table-3. Number of spikelets (panicle^{-1}) and 1000-grain weight as affected by micronutrients application in rice.

Treatments	Dose (kg ha^{-1})	Number of spikelets (panicle^{-1})	1000-grain weight (g)
T1: Zn	8 kg	132.0 b	22.98 c
T2: B	2 kg	139.5 ab	23.86 b
T3: Fe	5 kg	144.3 ab	24.19 ab
T4: Zn + B	8 + 2 kg	151.8 a	24.44 ab
T5: Zn + Fe	8 + 5 kg	150.0 a	23.94 b
T6: Zn + B + Fe	8 + 2 + 5 kg	142.3 ab	24.94 a
LSD$_{0.05}$	---	13.94	0.843

Means followed by different letter(s) in a column are statistically significant at 5% level of probability.

Table-4. Normal kernel (%) and paddy yield (t ha^{-1}) as affected by micronutrients application in rice.

Treatments	Dose (kg ha^{-1})	Normal kernel (%)	Paddy yield (t ha^{-1})
T1: Zn	8 kg	70.54 abc	6.10 bc
T2: B	2 kg	71.01 ab	6.55 a
T3: Fe	5 kg	67.82 bc	6.32 ab
T4: Zn + B	8 + 2 kg	66.09 c	6.67 a
T5: Zn + Fe	8 + 5 kg	73.90 a	6.42 ab
T6: Zn + B + Fe	8 + 2 + 5 kg	71.59 ab	5.66 c
LSD$_{0.05}$	---	4.54	0.449

Means followed by different letter(s) in a column are statistically significant at 5% level of probability.