Pak. J. Agri. Sci., Vol. 55(4), 761-766; 2018
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/18.6240
http://www.pakjas.com.pk

BORON APPLICATION IMPROVES THE GRAIN YIELD AND QUALITY OF FINE GRAIN RICE CULTIVARS IN PUNJAB, PAKISTAN

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Boron (B) is an important micronutrient required for plant growth. In this study, the importance of B application at different developmental stages was investigated to see its impact on grain yield, plant vigor and quality parameters of fine grain rice cultivars. The experimental soil was light textured (loam), and was very low in soil organic matter and soil B contents. Boron was applied as i) soil application (7.5 kg ha^{-1}), ii) foliar application (1.5 g B L^{-1} of water) at booting stage, and as iii) soil + foliar application, with untreated control. The results indicated that B application substantially improved the paddy yield. In this regard, dual application of boron proved to be the most effective for improvement in morphological, yield and quality parameters (milling recovery and cooking quality) of rice. Dual application of B (soil application + foliar application) improved the paddy yield by 18.5% in Super Basmati and 30.2% in Basmati 515. B application also reduced the panicle sterility in rice. In conclusion, B should be applied as basal + foliar treatment to improve the grain yield, milling recovery, cooking quality, and to reduce the panicle sterility in rice.

Keywords: Plant nutrition, rice yield, panicle sterility, head recovery, bursting

INTRODUCTION

Rice (*Oryza sativa* L.) is a major staple food of Asia, and to keep pace with the population growth, the rice yield should be increased up to 30% by 2025 (IRRI, 2008). Rice is also an important food crop of Pakistan. In 2016-17, it was grown on an area of 2.7 million hectares with production of 6.9 million tonnes (Anonymous, 2016). However, the average yield of rice in Pakistan is 2.5 t ha^{-1} which is far below the actual yield potential of locally bred rice varieties.

There are several factors which are responsible for low average yield of rice. These factors include pest pressure (insects and weeds), panicle sterility, low plant population per unit area, lodging and un-wise use of macro- and micro-nutrients in rice (Ikehashi and Araki, 1986; Maheswari *et al.*, 2007; Farooq *et al.*, 2011). Among these factors, panicle sterility is very common yield limiting factor in rice which reduces the number of grains per panicle (Nieuwenhuis *et al.*, 2002) thus resulting in low rice yields (Gowri, 2005).

The studies have correlated the panicle sterility with the B deficiency (Chaudhri and Hisiani, 1970). Indeed, the fertilizer use in Pakistan predominantly pertains to phosphorus (P), nitrogen (N) and potassium (K). The use of B fertilizers in Pakistan is almost negligible, and several rice varieties in Pakistan are vulnerable to B deficiency (Chaudhry *et al.*, 1978; Rashid and Din, 1992). Beside Pakistan, B deficiency in rice crop has also been reported in 80 countries of the world (Rashid *et al.*, 2004; Rerkasem and Jamod, 2004). The B deficiency symptoms in rice include thinner stems, shorter and fewer tillers, and failure to produce viable seeds. B deficient stems and leaves become brittle whereas leaves and stems are flaccid (Dunn *et al.*, 2005). B deficiency in rice results in white and rolled tips of emerging leaves, reduced plant height, death of growing point and failure to produce panicles (Dobermann and Fairhurst, 2000).

Thus, the wise use of B fertilizer in rice belt of Punjab, Pakistan may improve the yield and quality of rice (Rashid *et al.*, 2004; Rashid, 2006). Indeed, the B is an essential micronutrient for plant growth and reproduction with an important role in carbohydrate metabolism and translocation (Siddiky *et al.*, 2007). It also plays an indispensable role in plant cell formation, integrity of plasma membranes, pollen tube growth and increases pollination and seed development (Oosterhuis, 2001). Seed priming with B usually shows increased germination rate, greater germination uniformity, synchronized and early germination, and sometimes greater total germination percentage over a range of environmental conditions (Goldbach *et al* ., 2001; Farooq *et al* ., 2009, Farooq *et al* ., 2011b).

Foliar applied B is believed to retain significant phloem mobility of B to the flowering parts. Therefore, the foliar sprays of B provide not only a mean to apply B at a particular growth stage, but it also eliminates the B deficiency (Rashid *et al* ., 2004; Dunn *et al* ., 2005; Rashid *et al* ., 2007).

The prediction of actual B requirements of crop varieties is difficult, except after having local experimentation in various soil types, crop varieties and cropping systems. The amount of B required by rice crop is also affected by soil factors such as cation exchange capacity, soil organic matter, clay minerals, calcium carbonate contents, soil texture, and other properties (Solis and Torrent, 1989).

Thus, keeping the importance of B application in rice, the present study was conducted to evaluate the role of B application through various methods on the performance of the fine grain rice cultivars under the agro-climatic conditions of Sheikhupura, Punjab, Pakistan.

MATERIALS AND METHODS

This experiment was conducted on Engro Eximp Agri Product (EEAP) Research and Development Farm Saranwala, Muridke, Sheikhupura, Punjab, Pakistan from 2011 to 2013. This farm is situated at 74.24° E 31.81° N and 214 meters above the sea level. The soil analysis (20 cm depth) classified the soil as light textured (loam) with 0.22 mg Kg^{-1} B, 7.4 pH, 1.1 mS cm^{-1} EC, 0.69 % organic matter, 6.8 mg Kg^{-1} available P and 79 mg Kg^{-1} available K. The nursery for paddy was sown in mid-May and was transplanted to the prepared field (four ploughings followed by planking in standing water) at 28-30 days after sowing during each year. The plot size was 1.57 m × 1.57 m. The plant to plant and row to row distance was marinated at 22.5 cm.

The experiment was conducted in randomized complete block design with four replications. The experiment consisted of four treatments viz. i) soil application of B (7.5 kg ha^{-1}), ii) foliar application of B (1.5 g B L^{-1} of water) at booting stage, and as iii) soil + foliar application, along with an untreated control. The same B treatments were used in Super Basmati and Basmati-515. The soil application of B was done at the time of land preparation for nursery transplanting. The foliage application of B was done at booting stage. Borax was used as source of B. Nitrogen (200 kg ha^{-1}), phosphorus (150 kg ha^{-1}), potassium (100 kg ha^{-1}) and zinc (15 kg ha^{-1}) were applied according to recommendations in the form of urea, diammonium phospahte, potassium sulphate and zinc sulphate, respectively. Phosphorus and potassium was applied as a basal dose along with 50% of total nitrogen. Remaining 50% nitrogen was applied at panicle initiation stage. The Zn was applied 15 days after transplantation using zinc sulphate as source of zinc. The other agronomic practices were kept uniform for all the experimental plots for the control of insects, weeds and diseases. During each year, the crop was harvested in the last week of October.

Data on panicle length, filled grains, unfilled grains, and panicle sterility were measured at maturity. Paddy yield and 1000 grains weight were taken after harvesting the rice crop. The parameters related to milling recovery like brown rice (BR) percentage, total milled rice (TMR) and head rice (HR) percentage was determined following the standard procedures. The grain dimensions i.e. grain length, grain width and grain thickness was measured with the help of vernier caliper and was averaged for each treatment. The cooking quality was analyzed for selected samples, focusing upon cooked grain length (CGL), bursting percentage and elongation ratio (E/R) using the standard procedures (Rehman, 2012; Rehman *et al.*, 2012, 2014 a, b, 2016).

The collected data were subjected to the analysis of variance using statistical software 'MSTATC' for a randomized complete block design. The treatment means were separated by using the least significant difference (LSD) test at 5% probability. The differences between the years were non-significant for all the three years, so the data was pooled for all the three years and mean values of all the parameters has been presented in tables (Steel *et al* ., 1996).

RESULTS

This study indicated that application of boron significantly affected the panicle length, 1000-grain weight and paddy yield of rice in both rice varieties (Table 1). Likewise, brown rice percentage, total milled rice percentage, bursting percentage, head rice percentage, number of filled grain and unfilled grains, panicle sterility, average grain length, average grain weight, cooked grain length and elongation ratio was significantly affected by boron application in both rice varieties except the average grain thickness (Table 1, 2; Fig. 1, 2).

Table 1. Influence of boron application on panicle length (cm), 1000 grains weight and paddy yield of two rice varieties.

Treatments	Panicle length (cm)		1000 grain weight (g)		Paddy yield (t ha^{-1})	
	Super Basmati	Basmati 515	Super Basmati	Basmati 515	Super Basmati	Basmati 515
Control (no boron)	26.8b	24.2c	19d	18c	3.84c	3.44d
Soil application (7.5 kg ha^{-1})	27.9a	26.1b	21c	22b	4.22b	4.15c
Foliar application (1.5 g B L^{-1} of water)	28.0a	27.3a	23b	24b	4.40a	4.30b
Soil application + foliar application	28.6a	28.1a	25a	27a	4.55a	4.48a

Table 2. Influence of boron application on quality parameters (milling recovery, grain measurements and cooking quality) of rice (Super Basmati).

Treatments	Milling recovery			Grain measurements			Cooking quality		
	BR (%)	TMR (%)	HR (%)	L (cm)	W (mm)	T (mm)	CGL (mm)	Bursting (%)	E/R
Control (no boron)	79.5b	70.0b	50.9b	7.21ab	1.53b	1.41	13.4b	6.0a	1.859b
Soil application (7.5 kg ha^{-1})	80.8a	71.0a	51.5b	7.30a	1.57a	1.42	13.8a	3.7b	1.896a
Foliar application (1.5 g B L^{-1} of water)	79.8b	70.8a	51.3b	7.26a	1.54b	1.42	13.6b	5.0a	1.873a
Soil application + foliar application	81.0a	71.3a	53.0a	7.31a	1.59a	1.43	13.9a	3.3b	1.896a

BR= brown rice; TMR= total milled rice= HR: head rice; L: average grain length; W= average grain weight; T= average grain thickness; CGL= cooked grain length; E/R= elongation ratio.

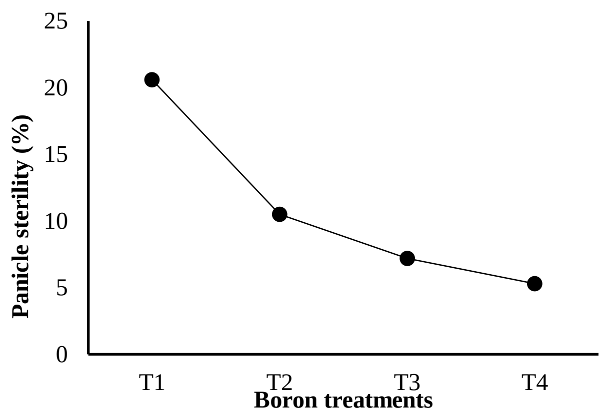

Figure 1. Influence of B application on the panicle sterility in rice. T_1= no application of boron; T_2= soil application of boron at 7.5 kg ha^{-1}; T_3= foliar application of B at 1.5 g B L^{-1} of water at booting stage; T_4= dual application of boron (soil application + foliar application)

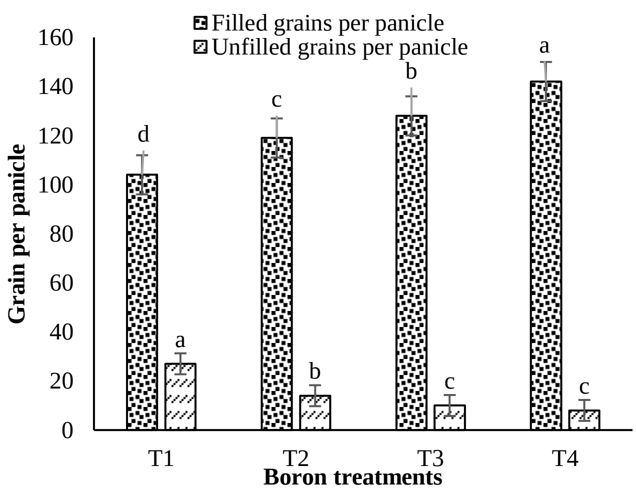

Figure 2. Influence of B application on the number of filled grains and unfilled grains per panicle in rice. T_1= no application of boron; T_2= soil application of boron at 7.5 kg ha^{-1}; T_3= foliar application of B at 1.5 g B L^{-1} of water at booting stage; T_4= dual application of boron (soil application + foliar application)

The highest panicle length was recorded with the dual application of B (soil application + foliar application) and that was statistically similar with the soil application of B in Super Basmati and with the soil as well as foliar application in Basmati 515 (Table 1). The 1000-grain weight and paddy yield in both rice varieties was the highest with the dual application of B (soil application + foliar application) and that was statistically similar with the foliar application of boron in Super Basmati for paddy yield (Table 1). Dual application of B (soil application + foliar application) improved the paddy yield by 18.5% in Super Basmati and 30.2% in Basmati 515 (Table 1).

In Super Basmati, the brown rice percentage, total milled rice percentage, and head rice percentage was the highest with dual application of B (soil application + foliar application) and that was statistically similar with soil application of B for brown rice percentage and with the soil as well as foliar application for total milled rice percentage (Table 2). Average grain length and average grain weight was also highest with dual application of B (soil application + foliar application) and that was statistically similar with soil as well foliar application for average grain length and with soil application for the average grain weight for Super Basmati (Table 2). The cooked grain length and elongation ratio was the highest for dual application of B (soil application + foliar application) and that was statistically similar with soil application of B for cooked grain length and with soil as well as foliar application for elongation ratio in Super Basmati (Table 2). The bursting percentage was the highest with no boron application followed by B foliar application in Super Basmati (Table 2).

In Basmati 515, the brown rice percentage, total milled rice percentage, and head rice percentage was the highest with dual application of B (soil application + foliar application) and that was statistically similar with soil application of B for brown rice percentage and head rice percentage, and with the soil as well as foliar application for total milled rice percentage (Table 3). Average grain length and average grain weight was also highest with the dual application of B (soil application + foliar application) and that was statistically similar with soil application of B for the average grain length and with the soil as well as foliar application of B for the

Table 3. Influence of boron application on quality parameters (milling recovery, grain measurements and cooking quality) of rice (Basmati 515).

Treatments	Milling recovery			Grain measurements			Cooking data		
	BR (%)	TMR (%)	HR (%)	L (cm)	W (mm)	T (mm)	CGL (mm)	Bursting (%)	E/R
Control (no boron)	79.7c	70.6b	51.7b	7.34b	1.53b	1.41	13.9b	6.0a	1.893b
Soil application (7.5 kg ha^{-1})	81.2a	71.3a	52.8a	7.37a	1.57a	1.43	14.1b	3.3b	1.914a
Foliar application (1.5 g B L^{-1} of water)	80.5b	71.0a	52.0b	7.36b	1.58a	1.43	14.0b	5.0a	1.898b
Soil application + foliar application	81.3a	71.3a	53.0a	7.38a	1.59a	1.42	14.4a	3.3b	1.920a

BR= brown rice; TMR= total milled rice= HR: head rice; L: average grain length; W= average grain weight; T= average grain thickness; CGL= cooked grain length; E/R= elongation ratio.

average grain weight for Basmati 515 (Table 3). The cooked grain length and elongation ratio was the highest for dual application of B (soil application + foliar application) and that was statistically similar with soil application of B for elongation ratio in Basmati 515 (Table 3). The bursting percentage was the highest with no boron application followed by B foliar application in Basmati 515 (Table 3).

The lowest panicle sterility was recorded with dual application of B (soil application + foliar application) followed by foliar and soil application of B respectively (Fig. 1). The highest number of filled grains per panicle and lowest number of unfilled grains per panicle were recorded with the dual application of B (soil application + foliar application) (Fig. 2).

DISCUSSION

This study indicated that B application by either method improved the rice yield. This improvement in rice yield was attributed to the improvement in 1000-grain weight and reduction in panicle sterility due to B application. Indeed, the B is an essential micronutrient for plant growth and reproduction with an important role in carbohydrate metabolism and translocation (Siddiky *et al.,* 2007). It also plays an indispensable role in plant cell formation, integrity of plasma membranes, pollen tube growth and increases pollination and seed development (Oosterhuis, 2001) which reduces the panicle sterility as was observed in this study. Various studies have reported that exogenous application of B usually shows increased germination rate, greater germination uniformity, synchronized and early germination, and sometimes greater total germination percentage over a range of environmental conditions (Goldbach *et al.,* 2001; Farooq *et al.,* 2009, 2011b; Rehman *et al.,* 2012, 2014ab, 2016).

In this study, the foliage application of B in both rice varieties was more beneficial than the soil application. Indeed, foliar applied B is believed to retain significant phloem mobility of B to the flowering parts which ultimately improves the grain partitioning and the grain yield (Rashid *et al.,* 2004; Dunn *et al.,* 2005; Hussain, 2006; Khan *et al.,* 2006; Rashid *et al.,* 2007). On the other soil application of B may cause the fixation of B in various soil types thus limiting its availability to plants. In another study, Rashid *et al.* (2004) reported an increase of 14-25% in rice grown in rice belt of Punjab and Sindh provinces of Pakistan. Other long-term research on rice-wheat system on four major soil types in Punjab province revealed that the average increase in first rice crop's paddy yield with B application (1.0 kg B ha^{-1}) was 25% over control. The residual effect of B on the succeeding wheat crop was also appreciable, and the mean grain yield was increased by 22-24% over control (Rashid, 2006). In another study, B application increased the size, weight and number of spikelets in the rice panicle (Khan *et al.,* 2006). In field experiments, Khan *et al.* (2006) observed that the paddy yield was significantly increased by the B application, which ranged from 3.51-6.00 t ha^{-1}, while the maximum grain yield was observed with B application at 2 kg B ha^{-1}. Rashid *et al.* (2007) also reported an increase of 14-23% in the paddy yield with B application. Renukadevi *et al.* (2002) observed a significant increase in sunflower yield as well as B accumulation with the application of B, while the highest (16%) increase in seed yield and stalk yield (19%) was recorded with the soil application of 2 kg B ha^{-1}. Yang *et al.* (2009) also reported an increase of 46% in the seed yield due to B application in sandy soils; B also increased the quality and quantity of rapeseed.

The application of the B fertilizer also improved the quality parameters of both fine grain rice varieties viz. basmati super and basmati 515. This improvement in quality was visible through improvement in milling recovery, grain size and cooking quality due to application of B. Among all the treatments, B application twice in a season (basal application at the time of land preparation and foliar application at booting stage) showed the best results. This accretion in milling recovery and grain size will draw the attention of millers toward the use of B in paddy fields.

***Conclusion*:** The application of B through either method improved the grain weight, paddy yield, milling recovery, and cooking quality of both the fine rice varieties. This improvement in paddy yield and grain quality was attributed to reduced panicle sterility in rice. The dual application of B (as basal dose at land preparation and foliage application at booting) proved to be more beneficial as compared to their sole application. Thus, it is recommended that the farmers of rice zone should apply B to rice crop to improve the grain weight, paddy yield, milling recovery, and the cooking quality of fine grain aromatic rice.

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