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BORON NUTRITION UNDER INTERMITTENT FLOODING AND DRYING CONDITION SEEMS SUSTAINABLE NUTRIENT MANAGEMENT TECHNIQUE IN RICE

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ABSTRACT. Water saving rice cultivation is emerging technique to couple with irrigation water shortage due to climate change all over the world. Major issue in these techniques is to compromise yield and quality fatalities because of higher unfilled grain due to nutrients deficiency. Boron fertilization seems to be big management technique to improve rice agriculture due to having imperative role in pollen viability. Thus, a field experiment was conducted to see the impact of boron fertilization both with basal and foliar application methods in water saving rice cultivation systems. Boron, with basal (3 kg borax/acre) and foliar (2% boron) was applied at different growth stages in rice crop grown under various rice cultivation systems; flooded rice, intermittent flooding and drying and aerobic rice. Boron fertilization both with basal and foliar application technique resulted in improved crop performance in all cultivation systems. Rice plants recorded highest yield, yield attributing parameters like productive tillers, panicle length and grain weight with boron fertilization. Quality parameters like sterile kernels, abortive kernels, opaque kernels were significantly reduced with boron fertilization in all rice cultivation systems. Furthermore, normal kernels were enhanced with basal and foliar application of boron nutrition. Likewise, maximum water use efficiency was recorded in foliar application of boron at panicle stage under intermittent flooding and drying condition. Foliar application of boron nutrition at panicle initiation stage was found to be most appropriate in water saving rice cultivation systems.

Key words: Boron; growth; Quality; Rice; Yield.

INTRODUCTION

Rice is one of the most important cereal crop as well as staple food for the majority of people on earth. In Pakistan, rice is grown as second staple food after wheat crop. It is also

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a source of foreign exchange as basmati rice is famous all over the world due to its specific fragrance. Pakistan is considered as a leading producer and exporter of Basmati rice throughout the world. In Pakistan, rice crop accounts 2.7% of the value added in agriculture and 0.6% of GDP (GOP, 2013-'14).

Due to increasing population, food demand is also increasing while the available water resources are declining, creating challenges for food security (Kreye *et al.*, 2009). It is however believed that irrigation water for agriculture purpose is becoming intensively scarce and it is estimated that up to 2025, 15-20 million ha of irrigated rice will suffer some degree of water scarcity (Tuong and Bouman, 2003). When we made a comparison between rice and others cereals it seems that to produce 1 kg of rice, it takes 3,000-5,000 L water, which demands huge amount of water for cultivation (Bouman *et al.*, 2002). Due to shrinkage of water resources farmers are forced to grow rice within this limited available water. Lot off water saving techniques are under discussion like aerobic rice (Bouman *et al.*, 2005), saturated soil culture (Borell *et al.*, 1997), alternative wetting drying (Tabbal *et al.*, 2002) and system of rice intensification (Stoop, 2002).

In case of aerobic rice systems, specific adapted cultivars are direct seeded in non-puddled soil and irrigation is applied only to keep the soil moist. This method save water by following ways: (1) eliminating continuous seepage and percolation (2), reducing evaporation and (3), eliminating wet-land preparation (Castaneda *et al.*, 2002). When we compare flooded lowland rice with aerobic rice systems, the aerobic rice systems can reduce water use upto 50%, while realizing yields of up to 6 t/ha under optimum conditions (Bouman *et al.*, 2007a,b; Yang *et al.*, 2005; Wang *et al.*, 2002). The change in cultivation from flooded to aerobic soil condition causes changes in soil water contents, soil aeration and nutrient availability (Timsina and Connor 2001).

Most of soils in Pakistan are alkaline-calcareous in nature, low organic matter content, nutrient mining with intensive cropping and inadequate and imbalance fertilizer use, containing multiple deficiencies, including of boron (Rashid *et al*, 2002a). Boron is an essential nutrient for development and growth of plants, like most of other nutrients. As required, in small amounts by plants so considered as micronutrient. Boron deficiency is wide spread in Pakistan (Sillanpaa, 1990; Rashid and Raffique, 1992) and prevailed up to 50% in cotton belt (Rashid, 1995; Rashid and Raffique, 1997) and 10-45% in rice fields (Tahir *et al.*, 1990; Zia, 1993). Rashid *et al*. (2004) perceived the effect of boron on different rice verieties, like Super Basmati, Basmati-385 and KS-282 and concluded that 14-25% increase in paddy yield, as compared with control.

For efficient uptake of boron, application technique plays a vital role. Soil and foliar applications are the most prevalent methods of boron addition in developing world. Foliar application of boron is most suitable method due to rapidly availability of nutrients, as compared with soil application. However, transport of boron is different among various plant parts and also among different species. It is however, believed that species with poor phloem mobility show boron deficiency and need multiple foliar applications to overcome the deficiency instead of single application (Gupta, 1979). This method of application is also a cost effective because reasonable crop yield can be increased with a little extra cost on micronutrients application on most appropriate stage. The present study was therefore carried out to see best method of boron fertilization under water saving rice cultivation and its impact on rice growth, yield and quality.

MATERIALS AND METHODS

The experiment was conducted at agronomic research farm, Department of agronomy BZU Multan (71.43 E^{o}, 30.2 N^{o}) Pakistan, during kharif season 2013. The climate of the region was subtropical to semiarid. The soil was silty clay and alkaline with organic matter of 0.56 % (*Table. 1*).

Table 1 - Analysis of air dried soil of the experimental area

Determination	Value
Physical analysis	
Sand (%)	22
Silt (%)	45
Clay (%)	31
Textural class	silt clay
Chemical analysis	
Ph	7.9
Boron (mg/kg)	0.24
Organic matter (%)	0.56
Total nitrogen (%)	0.03
Available phosphorus (mg/kg)	4
Available potassium (mg/kg)	86

Crop husbandry

Rice cultivar Super Basmati was used as experimental material. Experiment was layout under RCBD split plot arrangement and replicated thrice. Net area of experimental was adjusted as 4 m and 2.20 m (Length x Width). The experiment was composed of two factors. First factor included different rice cultivation systems, like aerobic rice (direct seeded), flooded rice and alternate wetting and drying. In second factor, we evaluated different boron application methods (basal and foliar). Boron fertilization treatments were: B_0 (no application), B_1 (basal), B_2 (2% foliar application at seedling), B_3 (foliar (2%) at tillerling) and B_4 (foliar at panicle initiation). Nursery was raised on 5th June by using wet method with recommended seed rate of 2 kg/Marla. The aerobic rice was sown on the same date of nursery sowing with recommended seed rate of 75 kg per hectare keeping row to row distance of 20 cm by using hand drill. The nursery was irrigated weekly and prevented from weeds. For weed control recommended dose of Ryzelan was applied as pre-emergence herbicide. After 25 days of sowing nursery plants were uprooted and were transplanted in main field.

Water was maintained at standing condition throughout the growth period, in case of flooded rice. While in case of alternate wetting and drying we maintained flooded condition for two weeks after transplanting, then supplement irrigation up to panicle initiation and lastly field was saturated with water up to physiological maturity. The recommended dose of NPK (140 kg N ha^{-1}, 80 kg P ha^{-1} and 60 kg K ha^{-1}) fertilizer was applied. Full dose of all the nutrients were applied, except for nitrogen before transplanting. Nitrogen was applied in three splits in the form of urea fertilizer: one third before transplanting, 21 days after transplanting and 45 days after transplanting. The calculated amount of water was applied as per treatment.

Before one week of harvesting, when the sign of physiological maturity appears we stopped the irrigation. In transplanted rice for effective weed control we used Butachlor 800 mL ha^{-1}, after one week of transplanting in standing water. Whereas in direct seeded rice, Ryzelan 75 mL ha^{-1} as pre-emergence herbicide was applied to control weeds. Harvesting was done manually at harvest maturity and threshing was done separately for each plot.

For observing growth behavior of rice crop, plant sample were collected after every 15 days interval. We cut out two plants from each treatment in case of transplanted rice and fresh weight was measured. While for aerobic rice, a row of 25 cm was cut from the base of plants and fresh weight was taken. Leaves were separated from each sample and then leaf and stem weight was taken separately. For the calculation of leaf area leaf sample of 5g from each treatment was taken and leaf area was calculated by using leaf area meter. The following growth parameters, LAI, LAD and TDM were calculated by Hunt procedure, 1978.

$$LAI = \text{Leaf Area/Land area}$$
$$LAD = (LAI_1 + LAI_2) \times (T_2 - T_1)/2$$

The different yield parameters were also calculated. The parameters were included productive tillers, total tillers, thousand kernel weight, kernel yield plant height, panicle length, numbers of panicles and quality parameters (normal kernels, abortive kernels, opaque kernels and sterile kernels) were also measured. The productive tillers were measured by using square meter. Firstly we calculated productive tillers with square meter, which were healthy tillers that contains full spike while unproductive tillers were dead tillers that contains partial spike and sometimes no spike. Plant height was measured by using meter rod from bottom of plant to the tip of panicle. Final yield was calculated at end of experiment of each plot and also thousand grain weight for each plot was calculated separately.

RESULTS

Leaf area index, leaf area duration, net assimilation rate and total dry matter

Leaf area index was progressively increased from first harvest to 4th harvest, after that it was decreased linearly (*Figs. 1 and 2*). Mean comparison for growth parameters showed that minimum LAI (4.9), LAD (70.3), NAR (22.6) and TDM (2083.8) were recorded in treatment where boron application was missed. All these growth parameters were enhanced with boron fertilization either with basal or foliar application. Plants showed accelerated growth, when were fertilized at tillering as well as panicle initiation stage. In comparison with cultivation systems, there was no significant difference was recorded (*Table. 2*).

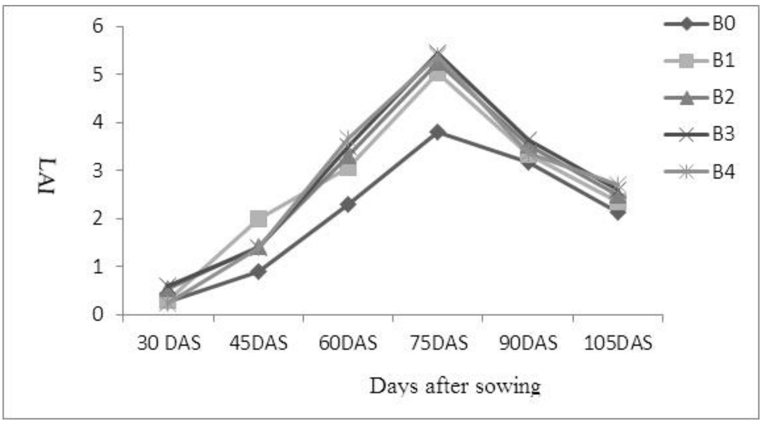

Figure 1 - Effect of boron application on leaf area index of rice crop

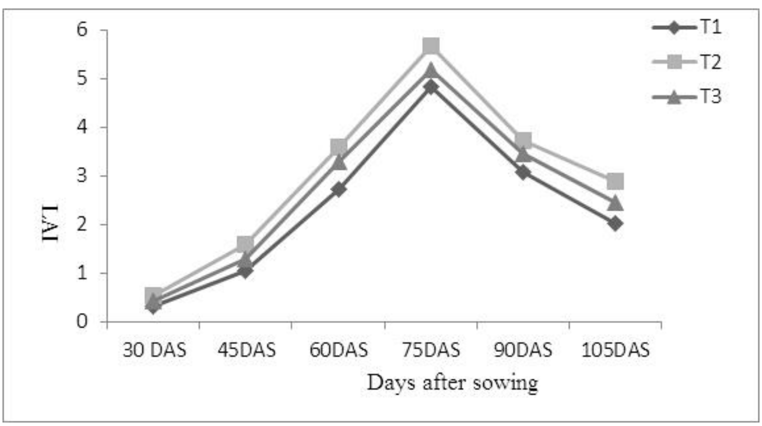

Figure 2 - Effect of rice cultivation systems on leaf area index of rice crop

Table 2 - Effect of boron fertilization on different growth parameters of rice under different cultivation systems

Treatments	LAI	LAD (days)	NAR ($g\ m^{-2} day^{-1)}$)	TDM ($g\ m^{-2}$)
Rice cultivation systems				
T_1	4.8 C	80.4 N.S	28.8 N.S	2417.4 N.S
T_2	5.6 A	85.0	29.8	2670.2
T_3	5.1 B	79.6	27.8	2478.03
	0.11	20.67		
Boron application				
B_0	4.9 E	70.3 B	22.6 B	2083.8 B
B_1	5.0 D	82.5 A	29.7 A	2425.2 AB
B_2	5.2 C	83.9 A	29.8 A	2406.1 AB
B_3	5.4 B	86.3 A	31.7 A	2616.3 A
B_4	5.5 A	85.4 A	30.3 A	2660.0 A
LSD	0.07	9.5	4.05	367.7

Yield attributes

Plant height (cm)

Plant height is an important morphological attribute; it is a function of combined effects of genetic makeup of a plant, soil nutrient status, seedling vigor and the environmental conditions under which it is grown. The interactive effect of boron fertilization and rice cultivation systems showed the maximum plant height in T_3B_1, that was similar with T_3B_2, T_3B_3, T_2B_2, and minimum value was found in T_1B_0 without boron fertilization under aerobic rice cultivation system (*Table 3*).

Productive tillers (m^{-2})

Total yield of any crop depend on cumulative effect of total plants producing grains. More the productive tillers more will be the spikes and final yield. Experimental data revealed that the maximum productive tillers (442.8) were observed in T_2B_4, which was similar with T_2B_2, T_2B_3, T_3B_4 and T_3B_3. However T_1B_0 showed the numbers of productive tillers were reduced due to no boron application (*Table 3*).

Panicle length and 1000-grain weight (g)

The maximum panicle length was observed in T_2B_4, that was similar with T_2B_3 and minimum were observed in T_1B_0 without boron application in aerobic rice cultivation. Similarly, heavier grains were observed in flooded or in intermittent flooding and drying condition, when foliar fertilization of boron was done at panicle initiation stage (T_2B_4, T_3B_4) while the minimum value was found at T_1B_0 under aerobic rice without boron fertilization (*Table 3*).

Table 3 - Effect of boron fertilization on yield and yield attributes of rice under different cultivation systems

Treatments	Plant height (cm)	Productive tillers (m^{-2})	1000-grain weight (g)	Panicle length (cm)	Yield (kg/ha)	WUE
B_0T_1	94.0f	240.9e	12.0j	18.7h	2119 h	0.19g
B_0T_2	99.7d-f	325.6d	22.7ef	32.7c-e	3165b-d	0.35de
B_0T_3	97.6e	319.3d	22.0fg	31.1e	2470f-h	0.33e
B_1T_1	100.5b-f	308.3d	16.7i	24.2g	2352g-h	0.22g
B_1T_2	105.8a-e	392.6c	23.3d-f	32.5c-e	3255a-c	0.35de
B_1T_3	113.2a	405.3bc	23.0ef	32.0de	2625e-g	0.33e
B_2T_1	100.3	302.3d	19.7h	26.4fg	2636e-g	0.25g
B_2T_2	110a-d	433.6ab	24.8b-d	33.4b-d	3475ab	0.37b-d
B_2T_3	110.7a-c	404.3bc	23.7c-e	33.2c-e	2920c-e	0.36cd
B_3T_1	101.7b-f	299.3d	20.5gh	27.2f	2766 d-f	0.27g
B_3T_2	105.4a-e	423.6ab	25.2b	35.4ab	3549 ab	0.39a-c
B_3T_3	111.2ab	409.3abc	25.2b	33.4b-d	3197bc	0.36cd
B_4T_1	103.5a-f	301.3d	20.7gh	28.5f	3443 ab	0.35de
B_4T_2	106.2a-e	442.8a	27.6a	36.6a	3388 ab	0.42a
B_4T_3	106.5a-e	410.3abc	26.8a	34.2bc	3599a	0.40ab
LSD	10.8	20.6	1.5	2.3	400	0.03

Grain yield (kg ha^{-1})

Grain yield is the cumulative effect of all yield attributes. It is obvious from the data that rice yield was significantly affected with rice cultivation system and boron application. Interactive effect of rice cultivation systems and boron fertilization showed that maximum yield were observed in T_3B_4, similar with T_1B_4, T_2B_4, T_2B_3, T_2B_2 and T_2B_1, and minimum value was observed in control T_1B_0 where boron fertilization was missed in aerobic rice (*Table 3*).

Water use efficiency (g L^{-1})

The interactive effect among rice cultivation systems and boron application showed that plants grown under flooded or with intermittent flooding and drying condition and with boron fertilization at panicle initiation stage were found more efficient in water used. Maximum water use efficiency was observed at T_2B_4, similar with T_3B_3 treatment combinations. The minimum water use efficiency was observed at T_1B_0, i.e., without boron application in aerobic rice culture (*Table 3*).

Kernel quality parameters

Sterile grain (%)

Sterility is considered as one of the important factors for the hindrance of crop yield. Sterility reduction always helps to increase in crop yield. The data showed that sterile grain (%) was affected significantly by rice cultivation system and boron fertilizer application. The interactive effect showed that the maximum sterile grain (%) was observed in T_1B_0, while minimum was observed in foliar applied boron in flooded or in intermittent flooding and drying condition (T_2B_4, T_3B_4, T_3B_3 and T_2B_3) (*Table 4*).

Normal grain (%)

The rice kernel with full size and through which light can pass is considered as normal kernel. The interaction values showed that maximum normal kernel (%) was observed in T_2B_4, where foliar boron was applied while minimum value was found at T_1B_0 with no boron application in aerobic rice fields (*Table 4*).

Table 4 - Effect of boron fertilization on quality parameters of rice under different cultivation systems

Treatments	Sterile kernels (%)	Normal kernels (%)	Abortive kernels (%)	Opaque kernels (%)
B_0T_1	69.6a	19.81k	12.2a	11.4a
B_0T_2	23.3f	45.17gh	8.9de	7.1de
B_0T_3	33.2cd	51.26fg	9.8c	7.9c
B_1T_1	40.0b	25.80k	11.6a	8.5b
B_1T_2	19.9f	59.10e	7.2g	6.5f
B_1T_3	22.9f	57.29ef	9.3cd	7.1de
B_2T_1	34.6c	34.10j	10.6a	7.6cd
B_2T_2	11.2gh	67.17c	6.9g	5.9g
B_2T_3	13.0g	61.79de	8.1f	5.7g
B_3T_1	28.7de	36.87ij	9.8c	7.3c-e
B_3T_2	9.1h	75.73b	5.6hi	5.3gh
B_3T_3	7.2h	65.36cd	6.4gh	5.4gh
B_4T_1	24.1ef	41.61hi	8.4ef	6.7ef
B_4T_2	6.7h	83.63a	4.6j	4.6i
B_4T_3	6.7h	67.96c	6.0gi	4.9hi
LSD	4.9	6.1	0.8	0.6

Opaque kernel (%)

The values of interaction showed that maximum opaque kernel % age was observed in T_1B_0 that lacks boron fertilizer or where boron application was missed. However, minimum opaque kernel was recorded in treatment T_2B_4, where boron was foliarly applied at panicle initiation stage (*Table 4*).

Abortive kernel (%)

The interactive effect showed that maximum abortive kernels (%) were observed in T_1B_0, where we missed boron application in aerobic rice cultivation system. However, minimum abortive kernels were recorded in treatment T_2B_4, where foliar boron application was done under flooded rice cultivation system (*Table 4*).

DISCUSSION

The intensive cropping system results in continuous removal of nutrients, which create imbalance among micro and macro nutrients. In Pakistan, most of the farmers are just focusing on macronutrients application because they are ignorant about the importance of micronutrients fertilization. Balance application of macro and micro nutrients obviously will have great impact on crop productivity. Most of the soils in the country is alkaline with high pH, which needs high concentration for balance nutrient application to fulfill crop need. Due to shrinkage of water resources, many farmers are shifting cultivation from flooded to aerobic condition on this calcareous or micronutrient deficient soil. This shift in cultivation will change the dynamics of nutrients in the soil, which needs to explore and to re-evaluate the already established package of crop production.

With reference to growth performance, crop showed accelerated growth with boron application either with basal or foliar method. In comparison with control treatment in which we did not apply the boron, all other boron application treatments significantly enhanced growth parameters, like LAI, LAD, TDM and NAR. Data of leaf area index showed that crop enhanced LAI from 30 days after sowing to 75 days, after that crop declined LAI. In comparison with different boron application methods, data showed that there were little different found on growth parameters. Both methods given similar performance related with crop growth. Poor performance in control treatment might be due to imbalance nutrient application. In boron application treatment, crop up taken more nutrients and improved the crop vigor. Healthy and vigorous plants will ultimately have great impact on crop growth.

The foliar application of boron enhanced the total number of tillers in different rice cultivation systems and resulted in more number of tillers. As a result of rapid growth, more the number of leaves emerged both the plant height and number of tillers increases. It was found that adding boron in growing media results in enhancement in number of leaves and also the number of tillers. It was observed that due to boron fertilizer application there was improvement in number of tillers either the application methods would be different i.e., seed priming or foliar application or soil application (Rashid *et al.*, 2007; Farooq *et al.*, 2011).

Boron application improved the water use efficiency (WUE) in different rice cultivation systems. The improvement in water use efficiency (WUE) showed that boron application has potential to enhance the rice yield with less water and it was evident from the results of aerobic rice.

It seems from the experimental result that foliar application of boron showed its impact on the quality of rice. There was reduction in sterility percentage due to boron application. The foliar application method improved the percentage of normal kernels in different rice cultivation systems, as compared to control were we missed the boron application. There was improvement in the percentage of abortive kernels due to foliar application of boron at later stages of crop growth. Similarly, there was reduction in the percentage of opaque and sterile kernels due to boron application at reproductive stages of growth of rice crop, as compared to control with no boron application. The results showed that boron application in rice crop not only enhanced the yield, but also improved rice grain quality.

CONCLUSION

Foliar application of boron nutrition at panicle initiation stage was found to be most appropriate in water saving rice cultivation systems. Rice growers can maximize the crop output with little extra cost involved on boron fertilization under limited water resources for sustainable rice agriculture.

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