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Evaluating Non-Aromatic Rice Varieties for Growth and Yield under Different Rates of Soil Applied Boron

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Abstract

Balanced boron (B) fertilization has prime importance to obtain maximum paddy yield. The range between B deficiency and toxicity is smaller than most plant nutrients, though B requirement among different crops varies widely. The adequate dose of B for one genotype can either be insufficient or toxic to other. Hence, without knowing the actual requirements of crop varieties, B application can be risky due to the toxicity hazards. A field experiment was undertaken at experimental farm of Nuclear Institute of Agriculture (NIA), Tandojam during 2013, to evaluate the B requirement of two non-aromatic rice varieties. The experiment was arranged in split plot design with three repeats. Two rice varieties Sarshar and Shandar were grown in main plots with four rates of B: 0.5, 1.0, 1.5 and 2.0 kg ha^{-1} and control (0 kg ha^{-1}) in sub plots. Both the varieties responded differently to B rates. Sarshar produced the highest paddy yield (5691 kg ha^{-1}) at a rate of 1.5 kg B ha^{-1} and was 18% greater than control, Shandar produced the highest yield (6075 kg ha^{-1}) at a rate of 1.0 kg B $ha^{-1}$and was 5% greater than control. B accumulation in paddy and straw of both varieties increased with the increasing B rates. Both varieties were also significantly ($p<0.05$) varied in B accumulations. Comparatively, rice variety Sarshar accumulated 9% and 22% more B in straw and paddy than the Shandar. Thus, the B requirement of Sarshar was relatively higher than the Shandar. Shandar can be grown without the additional B application, whereas, Sarshar requires additional B for its maximum harvest in B deficient soils.

Keywords: Boron rates; Non-aromatic; Rice cultivars

Introduction

Boron (B) is one of the essential micronutrient for crop growth and development [1]. It involves in many physiological, biochemical processes including respiration; formation of meristematic tissues [2], regulation of metabolic pathways [3] metaboli-zation of carbohydrate [4, 5], RNA and indole acetic acid [4, 5, 6, 7]. B bioavailability to crop is related to soil properties. Generally the soils, clay in texture, poor in organic matter, high in pH and alkaline calcareous in nature are deficient in B [8]. More than 100 crops all over the world including Pakistan are suffering from B deficiency [8, 9]. B deficiency in crop is complex to manage due to its narrow margin between deficient and toxic levels [10]. Thus frequent application of B to overcome the deficiency can simultaneously create the B toxicity problem [10].

Crop and genotypes differ in their ability to tolerate B deficiency stress. A wide genotypic variation in relation to B deficiency/toxicity tolerance has been noted in numerous crops species. Sometimes genotypic deviation within the species became so wide that position of species may alter with the genotypes being compared. Furthermore, scientists observed deviation in order that B efficiency among soybean (*Glycine max*), green gram (*Vigna radiata*) and black gram (*Vigna mungo*) by choosing various genotypes for comparison [11, 12]. Recently, inclusive difference was found among four cultivars of canola (*Brassica napus*) to soil applied B [13]. Therefore, the sufficient dose of B for one rice genotype can be insufficient or toxic to other genotype due to its possible toxic effects. Hence, without knowing the actual B requirement of the variety and soil condition its application can be risky.

Rice (*Oryza sativa*) is stable food crop in Pakistan. Beside the other nutrients, B deficiency also adversely affected the rice production. B deficiency can be managed with very low application of B, but its toxicity is more difficult to manage. Slight application of B, under B deficient conditions enhanced paddy yield by 14% [14]. Rice genotypes varied in their B requirement [15]. Rice genotype performed differently to soil applied B in calcareous and enhanced the paddy yield from 10 to 46% [8]. General recommendation of B can be in-sufficient for the maximum harvest of rice varieties (Sarshar and Shandar). Therefore, a field study was undertaken to evaluate the B requirement of two most popular non-aromatic rice genotypes of Pakistan.

Materials and Methods

A field experiment was undertaken in B deficient soil at experimental farm of Nuclear Institute of Agriculture, Tandojam, Sindh, Pakistan during Kharif 2013. The experiment was conducted in split plot design. Rice genotypes (Shandar and Sarshar) were grown in main plots and five B rates (control, 0.5, 1.0 1.5 and 2.0 kg B ha^{-1}) were applied in sub plots. All the treatments were repeated thrice. Each experimental unit was of 4m×6m ($24m^2$). The soil of experimental site was clay loam in texture, slightly alkaline in nature (pH: 7.7), free from salinity hazards (ECe: 2.1 dS m^{-1}). Additionally, the soil was low in organic matter (0.69%) available Olsen phosphorus (7.4 mg kg^{-1}), and diluted HCL-B (0.37 mg kg^{-1}) but adequate in NH_4-OAC exchangeable K (160 mg kg^{-1}). The crop received the recommended dose of nitrogen (100 kg ha^{-1}), phosphorus (60 kg ha^{-1}) and potassium (25 kg ha^{-1}) in the form of urea (46% N), single super phosphate (18% P_2O_5) and sulphate of potash (50% K_2O), respectively. The requisite five doses of B were maintained through soil application as Borax (11.5% B). All the phosphorus, potassium and boron along with one third dose of the nitrogen were applied after five days of transplantation. The remaining nitrogen was applied in two equal splits, each after thirty days of transplantation and at panicle initiation stage. All the recommended cultural and management practices including irrigation, weeding and pest control were followed during the whole crop life span, as per requirement. Randomly, five plants from each treatment were harvested at maturity and used for agronomic observations like plant height, panicle height, tillers per plant, grain per panicle, grain per plant and 1000-grain weight. Biological and paddy yields per hector were calculated. Paddy and straw samples were collected, washed with deionized water and dried in oven at 70°C till constant weight for four days [16]. The samples were ground and passed from 2 mm sieve. One gram of ground material was used for B analysis [16]. B content in grain and straw was determined by dry ashing [16] and subsequent measured by colorimetery using Azomethane-H [18]. The collected data were subjected to analysis of variance, using Statistix Ver. 8.1 [19]. The analysis of variance was carried out by involving split plot design. Tukey's Honestly Significant Difference (HSD) test at alpha 0.05 was used to separate the treatment.

Results and Discussion

B rates significantly increased almost all growth parameters except panicle length and 1000-grain weight (Table 1, 2, 3). Paddy and straw yields; and B content in paddy and straw were also enhanced with the B application (Table 4). Both rice genotypes (Shandar and Sarshar) significantly varied with each other in all growth traits, paddy and straw yields; and retention of B in paddy and straw. Moreover, the interaction of B with genotypes was significant for number of tillers per plant, paddy and straw yields; and B content in paddy and straw (Table 1).

Plant height (cm) of both rice genotypes and was significantly influenced with B application (Table 2). The highest plant height (97.7 cm) of both genotypes (mean of both varieties) was noted at 2.0 kg B ha^{-1}. Plant height of Shandar was non-significantly affected with the B rates. However, slight increase in plant height was noted with increase of B rates. Shandar produced the tallest plant height (98.3 cm) at 2.0 kg B ha^{-1}, while shortest (96.0 cm) in control. Plant height of Sarshar was significantly affected with B rates. The tallest plant height (96.9cm) in Sarshar was noted at 2.0 kg B ha^{-1}, while shortest (91.4 cm) in control. Comparatively, Shandar was taller than Sarshar. Boron rates significantly affected the production of tillers in both genotypes (Table 2). The maximum number of tillers (8.7) in both genotypes was noted with the application of 2.0 kg B $ha^{-1,}$ whereas, the minimum (6.8) in control. Shandar produced the maximum number of tillers (9.3) with the application of 1.0 kg B $ha^{-1,}$ while the Sarshar (7.9) with the application of 1.5 kg B ha^{-1}. The minimum number of tillers in both genotypes were recorded in control. Relatively, Shandar produced more tillers per plant than Sarshar. Boron application also significantly enhanced the grains per panicle and 1000-grain weight of both genotypes (Table 3). Shandar produced highest grains $panicle^{-1}$ (145.8) at 1.0 kg B ha^{-1}, while Sarshar (117.7) at 1.5 kg B ha^{-1}. The least number of grains per panicle in both genotypes was recorded in control treatment. B application could not produce the significant effects on 1000-grain weight of Shandar, whereas, the Sarshar responded to B rates. Sarshar produced heaviest 1000-grain weight of 27.0g at 1.5 kg B ha^{-1}. Both genotypes produced lightest 1000-grain weight in control. Comparatively, Shandar produced more grains $panicle^{-1}$ (135.8) and 1000-grains weight than Sarshar. However, Sarshar maintained heavier 1000-grain weight (26.1 g) than Shandar. Paddy and straw yields of both genotypes were also escalated with the increase of B rates (Table 4). Boron application produced significant effects on paddy and straw yields of both genotypes but the degree of effects varied with genotype. Shandar produced the maximum paddy yield of 6075 kg ha^{-1}at 1.0 kg B ha^{-1}, which was statistically at par to the yields, produced by other higher rates of B. Sarshar produced maximum paddy yield of 5691 kg $ha^{-1}$with the application of 1.5 kg B ha^{-1}, which was statistically equal to the higher rates of B. Moreover, the maximum straw yields of Shandar (10621 kg ha^{-1}) and Sarshar (1037 kg ha^{-1}) was noted at 1.5 kg B ha^{-1}. Relatively, Shandar produced more paddy and straw yields than Sarshar. Each increase in B rates significantly enhanced the B content of paddy and straw of both genotypes (Table 5). The highest B content in paddy (3.59 mg kg^{-1}) and straw (13.6 mg kg^{-1}) of both genotypes was noted at 2.0 kg B ha^{-1}. The maximum B content in paddy of Shandar (3.18 mg kg^{-1}) and Sarshar (4.02 mg kg^{-1}) was recorded at 2.0 kg B ha^{-1}. Similarly, maximum B content in straw of Shandar (13.1 mg kg^{-1}) and Sarshar (14.1 mg kg^{-1}) was also recorded at 2.0 kg B ha^{-1}. Comparatively, Sarshar retained more B in paddy and straw than Shandar.

B rates enhanced the paddy and straw yields of both genotypes at certain level then increase in B rates could not produce significant effects. The results showed the non-linear relationship of B rates with paddy and straw yields of both genotypes (Fig. 1 and 2). Moreover, the strong linear correlation of B rates with B content in paddy and straw of both genotypes was noted (Fig. 3 and 4).

***Table 1.* Significance of mean squares from analysis of various parameters of rice genotypes at different Boron level.**

Parameter	Boron (B) levels	Genotype (G)	B×G
Plant height	**	***	NS
Number of tillers per plant	***	***	**
Number of grain per plant	***	***	NS
1000- grain weight	NS	***	NS
Grain yield	***	***	***
Straw yield	***	***	***
Boron accumulation in straw	***	***	***
Boron accumulation in grain	***	***	***

** and ***: significant at alpha 0.01 and 0.001, respectively. NS: Non-significant

Table 2. **Plant height (cm) and tillers per plant of rice genotypes as affected by different rates of boron.**

B rates (kg ha^{-1}) level	Plant height (cm)			Tillers per plant		
	Shandar	Sarshar	Boron level Mean	Shandar	Sarshar	Boron Mean
Control	96.0c	91.4c	93.7B	7.6c	5.9d	6.8C
0.5	97.1b	93.8bc	95.4AB	7.89b	6.3c	7.1C
1.0	97.6ab	94.8ab	96.2AB	9.3a	6.8a	8.1B
1.5	98.4a	96.2ab	97.3A	9.4a	7.9a	8.6A
2.0	98.3a	96.9a	97.9A	9.4a	7.9a	8.7A
Genotype mean	97.48A	96.9A	----	8.69A	6.98B	----
$HSD_{0.05}$		Boron levels		Genotypes	Shandar	Sarshar
Plant height		3.185		1.4185	0.905	2.744
Tillers per plant		0.4048		0.1785	0.261	0.161

Values in columns or rows followed by different letters (lower case) are the significantly difference in treatments (interaction of B rates with genotypes). Values followed by different letters (upper case) are significantly difference in treatments (B rates or Genotypes).

Table 3. **Grains per panicle and 1000-grain weight of rice genotypes as affected by different levels boron.**

B rates (kg ha^{-1})	Grains per panicle			1000-grain weight (g)		
	Shandar	Sarshar	Boron level Mean	Shandar	Sarshar	Boron level Mean
Control	117.9c	91.9c	103.4A	21.1a	24.3c	22.7C
0.5	126.2b	97.5bc	111.9A	21.9a	25.5b	23.7B
1.0	145.8a	105.0b	125.4A	22.6a	26.3ab	24.5AB
1.5	145.9a	117.7a	31.8B	22.7a	27.0a	24.8A
2.0	146.3a	119.8a	133.0B	22.7a	27.2a	24.9A
Genotype mean	135.8A	106.4B	----	22.2B	26.1A	----
$HSD_{0.05}$	Boron levels	Genotypes	Shandar	Sarshar		
Grains per panicle	16.747	7.3868	8.406	11.932		
1000-grains weight	3.4677	1.5295	0.681	1.165		

Values in columns or rows followed by different letters (lower case) are the significantly difference in treatments (interaction of B rates with genotypes). Values followed by different letters (upper case) are significantly difference in treatments (B rates or Genotypes).

Table 4. **Paddy and straw yields of rice genotypes as affected by different levels of boron.**

B rates (kg ha^{-1})	Paddy yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	Shandar	Sarshar	Boron level Mean	Shandar	Sarshar	Boron level Mean
Control	5777.3 c	4842.3c	5309.8C	9774c	9955c	9864C
0.5	5900.3c	5561.7b	5731.0B	10228b	10103c	10165BC
1.0	6075.7a	5599.0 b	5837.3AB	10487ab	10015b	10251B
1.5	6087.0a	5691.3a	5889.2A	10612a	10378a	10495A
2.0	6063.3a	5700.3a	5881.8A	10623a	10366a	10493A
Genotype mean	5980.7A	5478.9B	----	10344A	10163B	----
$HSD_{0.05}$	Boron levels	Genotypes	Shandar	Sarshar		
Paddy yield	115.85	51.09	56.184	51.863		
Straw yield	166.06	7.74	358.58	69.655		

Values in columns or rows followed by different letters (lower case) are the significantly difference in treatments (interaction of B rates with genotypes). Values followed by different letters (upper case) are significantly difference in treatments (B rates or Genotypes).

Table 5. **Boron content in paddy and straw of rice genotypes as affected by different levels of boron.**

B rates (kg ha^{-1})	Boron content in paddy (mg kg^{1}) Shandar	Sarshar	Boron level Mean	Boron content in straw (mg kg^{1}) Shandar	Sarshar	Boron level Mean
Control	1.29c	1.24d	1.27D	3.3e	3.5e	3.4E
0.5	1.41dc	1.29d	1.35D	5.1d	5.4d	5.3D
1.0	1.95bc	2.75c	2.35C	7.2c	8.3c	7.8C
1.5	2.70ab	3.68b	3.19B	11.0b	12.3b	11.7B
2.0	3.18a	4.02a	3.59A	13.1a	14.1a	13.6A
Genotype mean	2.11B	2.59A	----	7.98B	8.75A	----

$HSD_{0.05}$	Boron levels	Genotypes	Shandar	Sarshar
B in paddy	0.3539	0.1561	0.769	0.123
B in straw	0.2192	0.096	0.367	0.337

Values in columns or rows followed by different letters (lower case) are the significantly difference in treatments (interaction of B rates with genotypes). Values followed by different letters (upper case) are significantly difference in treatments (B rates or Genotypes).

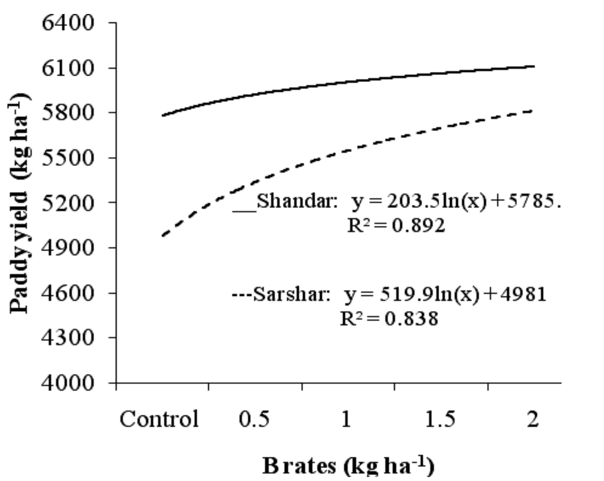

Figure 1. **Relationship between B rates and paddy yields of rice genotypes (Srashar and Shandar)**

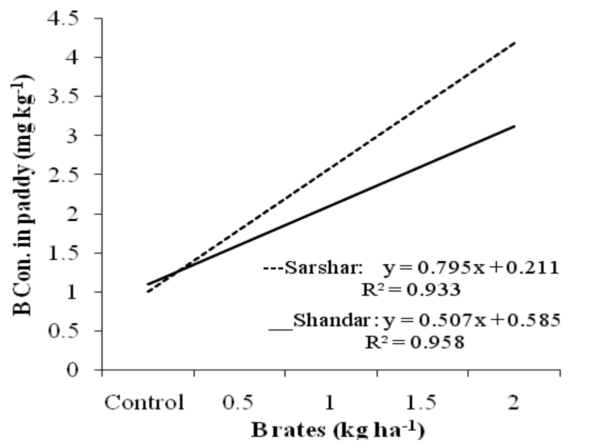

Figure 2. **Relationship between B rates and B content of paddy rice genotypes (Srashar and Shandar)**

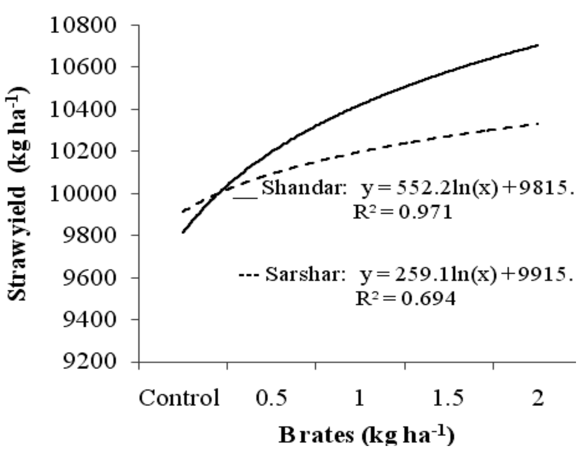

Figure 3. **Relationship between B rates and straw yields of rice genotypes (Srashar and Shandar)**

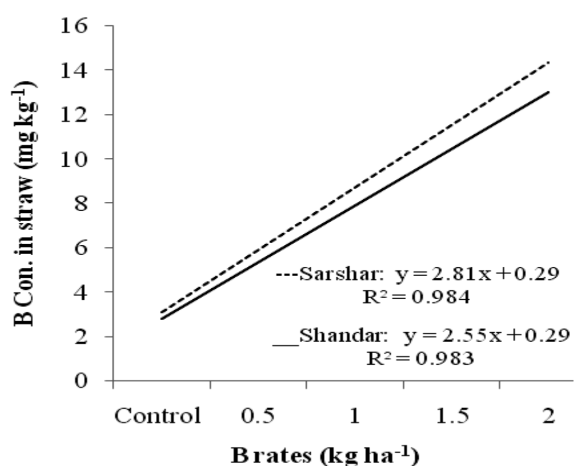

Figure 4. **Relationship between B rates and B content of straw rice genotypes (Srashar and Shandar)**

B application enhanced the growth traits like plant height, tillers per plant, grains per panicle and 1000-grain weight. These effects confirm the significance of B in plant nutrition. Boron is involved in many biochemical and metabolic functions such as cell wall growth, respiration, formation of meristematic tissues, regulation of metabolic pathways, metabolization of carbohydrate, RNA; and indole acetic acid [5, 6, 7, 8, 3, 2]. Adequate application of B not only improves fresh vegetative growth but also affected the reproductive development of plant. Hence, B must remain available for plant uptake during the whole growth phase but for it can be translocated from older to fresh tissues in the plant [1]. B application increased paddy and straw yields and also B content of paddy and straw of both rice genotypes, but the degree of increase varied with genotype. Shandar produced more number of tillers, number of grains per panicle and 1000-grain weight than Sarshar, thus produced more paddy and straw yields. However, Sarshar retained more B in paddy and straw than Shandar. Both genotypes responded different to different rates of B. Shandar produced maximum paddy yield at 1.0 kg B ha^{-1}, while Sarshar at 1.5 B ha^{-1}. It indicates that Shandar utilized B more efficiently than Sarshar and comparatively requires less B for maximum harvest. The results are in agreement with findings different scientists, who reported that adequate B application enhanced growth parameters i.e., tillering capacity, panicle length, straw and paddy yields, length and dry weight of shoot and root [20, 21, 22]. Moreover, about 9 to 32 % reduction in grain yields, and 2 to 44 % decrease in straw yields were found in different rice varieties of Pakistan [22]. It was reported that increase in B supply enhanced the B accumulation in root and shoot of rice crop [23, 24, 25]. Crop genotypes highly differ in their B requirement. Number of scientists found wide variation in growth and yield of soybean (*Glycine max*), green gram (*Vigna radiata*) and black gram (*Vigna mungo*) genotypes under different levels of B [12, 13]. Recently, found inclusive variation in yield and yield attributes of four canola cultivars to soil applied B [14]. Both rice genotypes varied in their growth and yield under different levels of B. Comparatively, Shandar is more B-efficient and utilized the limited soil B for maximum production. However, Sarshar is B in-efficient genotype, thus it requires additional B application for maximum production.

Conclusion

Both genotypes varied in their B requirement. Relatively, B requirement of Shandar is less than Sarshar. B at 1.0 kg B ha^{-1} is the best economical boron dose for Shandar, while, 1.5 kg B ha^{-1} is the best suitable dose for maximum harvest of Sarshar.

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