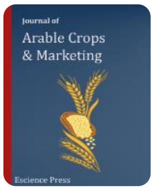

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SEED COATED BY BORIC ACID ENHANCES GROWTH, YIELD AND KERNEL QUALITY OF BOTH FINE AND COARSE RICE (ORYZA SATIVA L.) UNDER SEMI-ARID ENVIRONMENTAL CONDITION

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ABSTRACT

Currently, more than half of the world's population relies on rice as a primary crop, making it a crucial cereal crop in the struggle against food security. Sustainable rice production is under great threat because of poor soil productivity and fertility because of nutrient losses due to temperature stress under semiarid conditions. Boron (B) is a vital micronutrient and plays an eminent role in plant proliferation and development. The Super Basmati and KS-282 seeds were coated with boric acid at dosages of 0.25, 0.50, 0.75 and 1.00 g kg^{-1} in this experiment. Both rice cultivars exhibited the following traits when boric acid was applied at a rate of 0.75g kg^{-1} seed: plant height, maximum number of productive tillers, number of kernels per panicle, grain weight in the thousand, biological yield, paddy yield and straw yield. When boric acid was applied at 0.75 g kg^{-1} seed, the physiological characteristics of Super Basmati and KS-282 rice cultivars, such as crop growth rate, leaf area index, leaf area duration and net absorption rate were significantly greater yielding values of 11.08 $gm^{-2}d^{-1}$ and 11.96 gm^{-2} d^{-1}, 4.28 and 4.32, 67.52 and 68.94, 7.33 g m^{-2} d^{-1}, and 8.93 gm When both the super basmati and KS-282 rice cultivars were treated with boric acid at 0.75 g kg-1 seed, considerably higher paddy yields (3.95 t ha^{-1}) and (5.02 t) were obtained. The kernel quality parameters show maximum results when boric acid applied at 0.75g kg^{-1} seed. Current research shows that coating seed with micro nano-nutrients are highly effective procedure for increasing rice production and fertilizer use efficiency under semiarid climatic conditions

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INTRODUCTION

The requirement for genuine and exact input resource use such as fertilizers, in feeding the world's population must be given more consideration (Ghafoor *et al*., 2021). About 1/2 of the global population, approximately 3.5 billion people fulfill their 20% daily energy requirement from rice crop (Rossi *et al*., 2020). Food security is biggest threat because of lower crops yields and quality of staple crops like wheat, rice maize etc. (FAO, 2016). In addition to carbohydrates, fat and protein, rice also includes a respectable quantity of iron, calcium, thiamine, riboflavin and niacin (Sufyan *et al*., 2022). Pakistan supplies high-quality rice to Saudi Arabia, West African nations, Malaysia, Bangladesh, Iran and Indonesia. Raising nursery plants in a nursery bed and transferring one-month-old seedlings into a damp field are the traditional ways that Pakistanis grow rice (Ehsanullah *et al*., 2007). The crop production is reduced because of different variables like nutrition stress, drought stress, poor sowing methods, damaged seeds, climate change, but precise use of fertilizers is more significant for rice production to maintain food security (Hochman and Horan, 2018; Ghafoor *et al*., 2021; Ghafoor *et al*., 2022). Alike fertilizers seeding technology also influenced on rice yield under higher temperature environment. As opposed to transplanting seedlings from the nursery, direct seeding of rice refers to the method of starting the rice crop from seeds put in the field. Water sowing, wet seeding, and dry seeding are the three primary methods used for direct seeding of rice (DSR).

In the last two decades, seed coating technology has advanced quickly and offers an affordable means of improving seeds, particularly for larger-seeded agronomic and horticultural crops. The benefit of seed coating is that it allows for the direct application of seed-improving agents such as fungicides, insecticides, and micronutrients to the seed without changing its structure (Ehsanfar and Mdarre, 2005). Technology for seed coating can be utilised for two purposes: either as a pesticide carrier for plants or to assist with mechanical sowing to generate consistent plant spacing. Materials can be used in the target region with minimal influence on the environment and soil ecology (Taylor *et al*., 1998). Several staple crops have also used seed coating to enhance appropriate establishment in nutrient-poor soil (Sainio *et al*., 1997). A seed coating provides nutritional assistance throughout the early stages of crop development by creating a nutrient-rich environment surrounding germinating seeds (Taylor and Herman, 1990). To control rice illnesses, seed coating agents can be utilised. Seed treatments serve two purposes: to incorporate insecticides into the seed coat or to lessen the seed's vulnerability to disease for the duration of germination in soil (Freeborn *et al*., 2001).

The B is a micronutrient and important for normal rice crop development and growth (Farooq *et al*., 2018; Riaz *et al*., 2021). B has a number of roles such as the transportation of sugar, the production and maintenance of cell walls, the integrity of membranes, and the metabolism of phenol and indole acetic acid (IAA) (Farooq *et al*., 2018). B is more necessary for the production of seeds and grains than for vegetative growth (Vaughan, 1977; Riaz *et al*., 2021). The mineral nutrient B is essential for the growth of cell walls and RNA metabolism in vascular plants, as well as for a number of physiological activities that it stimulates (Herrera-Rodriguez *et al*., 2010). Research indicates that the B is necessary for pollen germination, pollen tube growth, promoting the plasma membrane, floret fertility and seed development (Wang *et al*., 2003). According to a study, the use of B increased rice output in several parts of Pakistan's Punjab and Sindh by 14 to 23% (Rashid *et al*., 2007). Low grain set or poor seed quality occur from a lack of the B, which is necessary for the proper development of reproductive tissues (Dell, 2006; Riaz *et al*., 2021). Though, B needs different among crop species and based on variables like soil physical and chemical characteristics, B contents and crop species. Its deficiency has been showed in rice cropping areas and become strong cause of yield reduction (Rashid *et al*., 2007; Rashid *et al*., 2017). Both Basmati-grain, fine and coarse-rice varieties are negatively affected by B scarcity (Rashid *et al*., 2004; Riaz *et al*., 2021). White necrotic streaks on the youngest leaf, which subsequently create a sizable white irregular area, are signs of B shortage in rice crops (Tandon, 1995; Farooq *et al*., 2018). In light of the aforementioned, an experiment was conducted to find the effects of boric acid on the production and growth of both coarse and fine rice varieties as well as to determine the best seed coating for both types of rice cultivated in aerobic environments.

MATERIAL AND METHODS

Experimental Area, Design and Treatments

Super Basmati and KS-282 cultivars of fine-grained aromatic rice seeds were received from the Rice Research Institute in Kala Shah Kaku, Pakistan and the Soil Salinity Research Institute in Pindi Bhattian, Hafizabad, Pakistan, respectively, for use in this study. The B seed was coated with an inert and sticky substance called Arabic gum. The B coating treatments are B0 (control), B1 @ 0.25, B2 @ 0.50, B3 @ 0.75 and B4 @ 1.00 g kg-1 seed of coating.

During the kharif season, the coarse and fine rice types were seeded at rates of 100 kg ha^{-1} and 75 kg ha^{-1}, respectively. The study was performed in triplicate using a factorial arrangement and a randomized complete block design (RCBD). The 3 m 5 m net plot size was maintained.

Agronomic Characteristics

At harvest time, the maximum numbers of productive tillers, panicle weight, 1000-grain weight, biological yield, paddy yield and straw yield were noted. At the time of harvest, the highest amounts of productive tillers, panicle weight, the number of kernels per panicle, biological yield, paddy yield and straw yield were noted.

Harvest Index

Using the formula below, harvest index (HI) was determined as the proportion of grain yield to total (above ground) biological yield (Ghafoor *et al.*, 2021).

$$\mathrm{HI} = \frac{\text{Kernel yield}}{\text{Biological yield}} \times 100 \quad \text{(i)}$$

Crop Growth Rate

Crop growth rate was calculated using Hunt's formula (Robert *et al.*, 1978). Whereas the first dry matter (T_1), the second dry matter (T_2), the first harvest's (W_1) dry weight (D W) m^{-2} land area and the second harvest's (W_2) dry weight (D W) m^{-2} land area (T_2).

$$CGR = (w_2 - w_1)/(t_2 - t_1) \quad \text{(ii)}$$

Leaf Area Index

For the purpose of calculating the leaf area index, plant samples from each plot were collected over the length of the crop's growing season at intervals of 15 days. The plants were cut off from the green foliage. Using a leaf area metre, the areas of 5 leaves were calculated. Using the area-weight relationship, LAI was calculated (Watson, 1958). The Hunt formula was used to estimate the leaf area duration (LAD) (1978). Where, first harvest time (t_1), second harvest time (t_2), leaf area index at first harvest (LAI_1) and leaf area index at second harvest (LAI_2) are concerned (t_2).

$$LAD = (LAI_1+LAI_2)\,(t_2-t_1)/2 \quad \text{(iii)}$$

Net Assimilation Rate

The following formula, as reported by Hunt, was used to get the net assimilation rate (Robert *et al.*, 1978).

$$NAR = TDM/LAD \quad \text{(iv)}$$

Kernel Quality Characterizes

20 panicles from primary tillers, chosen at random from each plot, were counted to determine the proportion of abnormal, opaque, chalky and normal kernels. In order to distinguish between sterile spikelet, abortive, opaque and normal kernels, the whole panicles were meticulously sketched (Nagato and Chaudhry, 1969). Lighting was provided via a lamp on a movable stand. In order to discern between different types of kernel formation, a panicle was placed in front of the bulb so that light could travel through it. We separated the opaque, sterile and abortive spikelet.

RESULTS AND DISCUSSION

This study raises the possibility of applying micronutrients through seed coating. The study does suggest, however, that before using on a big scale, the nutrient to seed ratio should be improved. B can greatly enhance the stand establishment of rice cultivars when applied to rice seed coating, especially at low concentrations. The plant height, tillers per square metre, productive tillers, panicle length and the quantity of kernels per panicle were all considerably increased when rice seeds were coated with B. In T3, where boric acid was applied at a rate of 0.75 g per kg of seed, seed coating with B significantly (P 0.05) affected the plant height of the rice crop, which increased from 88.69 cm (in the control treatment) to a statistically significant level of 96.10 cm. A similar trend was also seen in the number of tillers, productive tillers, panicle length, and the number of kernels per panicle (Table 1). Boric acid coating of rice seeds, especially at low concentrations, presents a significant opportunity to enhance the agronomic characteristics of rice cultivars.

B may also play a role in vegetative growth producing and fertilizing pollen tubes and pollen grains while not causing plants to grow taller. The outcomes are consistent with Furlani *et al.* (2003) that found plant height varied little with increasing B concentrations but varied between cultivars, suggesting that this property may be a genetic characteristic of the plant. Utilizing micronutrients increased growth parameters, chlorophyll content, biochemical profiles and yield components and was discovered to be dose dependent. This dose-dependent pattern was consistent with earlier research (Ali *et al.*, 2011). Low B availability according to Rerkasem and Jamjod (2004), may cause a decrease in the quantity of wheat tillers. B however, is crucial in hastening the development of panicles in rice plants. According to Dobermann and Fairhurst (2000) a B deficit will significantly slow the development of panicles in rice plants, especially during the panicle formation stage.

Table 1. Analysis of variance for B seed coating's effect on growth characteristics of rice.

Source of Variation	DF	Mean sum of square				
		Plant height	NO of Tillers m^{-1}	Productive Tillersm^{-1}	Panicle Length (cm)	Number of Kernels per panicle
Rice cultivar (C)	1	15125.6**	160.53**	2.49 ns	419.14**	1.22ns
B (B)	4	12.24**	27.75**	15.78*	24.25**	35.73**
C × B	4	2.02ns	3.08*	1.80 ns	2.87*	0.39ns
Error	18	0.47	16.05	8.45	0.259	16.19

DF stands for degree of freedom; * indicates significance at 0.05; ** indicates significance at 0.01

The 1000-kernel weight is one of many factors that affect the production of tiny grain crops (cereals) and it is crucial. The yield will increase the heavier the kernel. Table 02 provides information on two rice cultivars, Super Basmati and KS-282, based on their 1000-kernel weights and they demonstrate a considerable increase in 1000-kernel weight as compared to the control treatment after seed coating with boric acid @ 0.75g kg^{-1}. With each rise in the level of the boric acid seed coating, however, this increase became more pronounced. In Super basmati and KS-282, respectively, maximum 1000-kernel weights of 21.33 g and 22.40 g were obtained using boric acid at 0.75 g kg^{-1} seed. Boric acid seed coating and rice cultivars had a strong interaction. In comparison to Super basmati, the KS-282 often had a heavier 1000-kernel weight (21.65 g) (20.65 g). The weight of the kernel decreased as a result of the higher boric acid rates than 1.0g kg^{-1} seed (Table 2). The control treatment led to the production of lighter grains.

The plots treated with boric acid at 0.75 g per kg of seed responded maximally with biological yields ranging from 10.41 to 11.49 t ha^{-1} respectively (Table 2). The use of boric acid at 0.75 and 1.0 g per kg of seed considerably increased the Super Basmati straw production by 8.20 t ha^{-1}. Similar to this, applying boric acid at a rate of 0.75 g per kg of seed greatly enhanced the straw production of KS-282 by 6.76 t ha^{-1}. Boric acid seed coating and rice cultivars had a strong interaction. Compared to KS-282, the super basmati has a higher yield of straw (7.61 t ha^{-1}) (6.21 t ha^{-1}). When compared to the control treatment, paddy yield was dramatically boosted by the application of boric acid at 0.75g kg^{-1} seed coating. Both rice cultivars (Super Basmati and KS-282) produced higher paddy yields of 3.95 t ha^{-1} and 5.02 t ha^{-1} when seed was treated with B @ 0.75g kg^{-1} seed. The H.I was greatly improved after the application of boric acid, reaching a maximum of 35.02 in Super Basmati and KS-282 and a minimum of 31.63 and 40.83, respectively (Table 2).

The findings of the current study also lined with Khan *et al.* (2006) who found that applying B significantly increased paddy output. According to Rashid *et al.* (2004), there was a considerable improvement in grain production of rice types due to decreased panicle sterility and higher 1000-grain weight after B application, which may explain why there were more grains per panicle than in control plots and appropriate grain filling. According to Ehsan *et al.* (2009) B treatment increased all growth metrics. Our findings concur with those of Riaz *et al.* (2021) who showed that the usage of B improved rice yield and kernel quality. The B may also play a function in vegetative growth, forming and fertilizing pollen tubes and pollen grains while not causing plants to grow taller. The results are in line with Furlani *et al.* (2003) discovered that while cultivar differences in this trait suggested that this trait may be a genetic trait of the plant, plant height did not change appreciably with increasing B concentrations.

The presence of B in the soil before to planting undoubtedly boosted paddy yields. The investigations of Jana *et al.* (2005) and Rashid *et al.* (2006), which stated that B usage not only increased paddy output but also decreased panicle sterility, are consistent with these outcomes. Improved B plant nutrition is credited with better grain filling and more consistent crop maturity (Rashid *et al.*, 2004). The rise in H.I. caused by the administration of boric acid may be the consequence of improved starch consumption, which enhances seed germination and cause assimilates to be transferred to growing grains, increasing grain size and number of grains per panicle. In cereals like rice, boric acid is responsible for better pollination, seed laying, low spike sterility and higher grain formation (Aslam *et al.*, 2002). It is denoted that the application of boric acid increases the H.I. and seed yield, as well as the paddy and productive tillers plant-1 yields in rice. Our results agree with those of Farooq *et al.* (2018) who demonstrated the beneficial effects of boron on rice crop.

Table 2. Plant yield traits of rice as affected by B seed coating.

Treatments	1000-Kernel Weight (t ha^{-1})			Biological yield (t ha^{-1})			Straw Weight (t ha^{-1})			Kernel yield (t ha^{-1})			Harvest Index (%)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Control	19.50F	20.70E	20.10D	10.41D	9.29G	9.85D	7.14D	5.39H	6.26D	3.36G	3.87D	3.61E	31.63	40.83	36.23D
0.25g B kg^{-1} seed	20.66E	21.70BC	21.18C	10.85B	9.82F	10.33C	7.44C	6.13G	6.78C	3.55F	4.19C	3.87D	32.55	42.06	37.30C
0.50g B kg^{-1} seed	20.99DE	21.91B	21.45B	10.97B	9.96E	10.47B	7.69B	6.49F	7.09B	3.65EF	4.56B	4.10C	33.64	43.23	38.43B
0.75g B kg^{-1} seed	21.33CD	22.40A	21.86A	11.49A	10.55C	11.02A	8.20A	6.76E	7.48A	3.95D	5.02A	4.48A	35.02	44.16	39.59A
1.0g B kg^{-1} seed	20.80E	21.53C	21.16C	10.63C	10.32D	10.47B	7.60BC	6.28FG	6.94BC	3.67E	4.95A	4.31B	33.29	43.26	38.28B
Mean	20.65B	21.65A		10.87A	9.99B		7.61A	6.21B		3.63B	4.52A		33.23B	42.71A	

The physiological parameters of both rice cultivars, Super Basmati and KS-282 including crop growth rate, leaf area index, leaf area duration, and net assimilation rate, increased significantly when boric acid was applied at 0.75 g kg^{-1} seed, with values of 11.08 gm^{-2}d^{-1} and 11.96 gm^{-2} d^{-1}, 4.28 and 4.32, 67.52 and 68.94, 7.33 g m^{-2} d^{-1} and 8 (Fig 1,2,3 and 4).

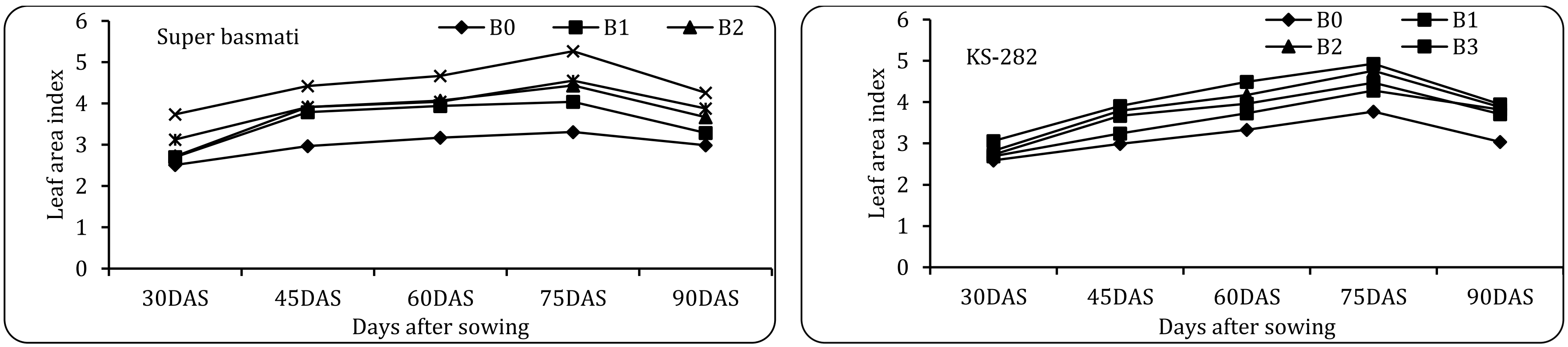

Figure 1. Influence of B seed coating on leaf area index of rice.

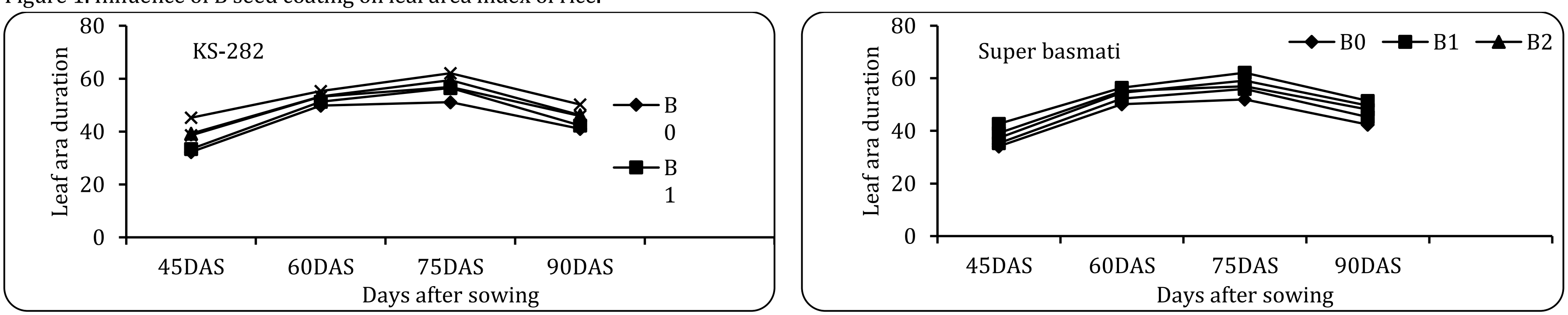

Figure 2. Influence of B seed coating on leaf area duration of rice.

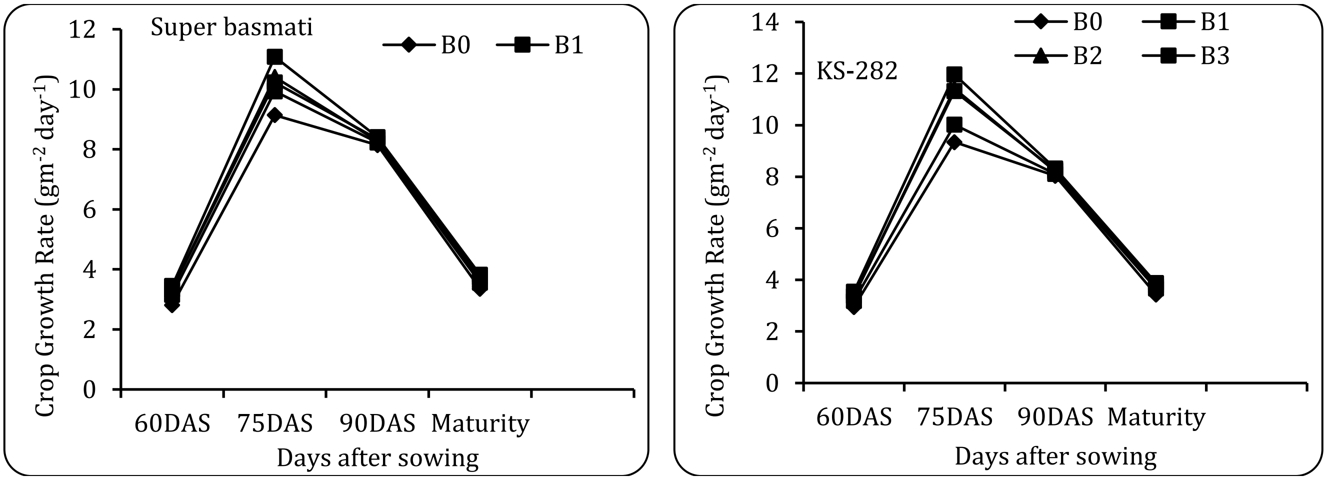

Figure 3. Influence of B seed coating on crop growth rate of rice.

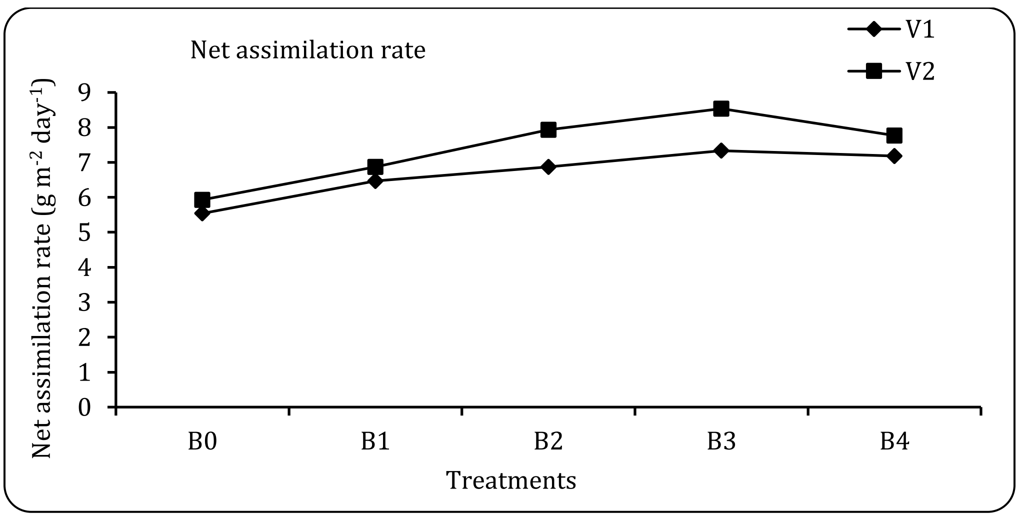

Figure 4. Influence of B seed coating net assimilation rate of rice.

Greater assimilatory capacity brought on by increased LAI leads to more photosynthesis, which in turn leads to greater accumulation of dry matter and higher CGR. High CGR resulting from B application may be caused by improved LAI (Rashid *et al.*, 2004). In all cases, administration of B enhanced the translocation of photo assimilates. B controls the formation of cell walls, assimilate translocation, cell division, and cell elongation, among other crucial physiological functions (Herrera-Rodriguez *et al.*, 2010). By increasing leaf area, boosting photosynthesis, and accumulating dry matter, B helped plants more effectively employ the nutrients that were already available. This accelerated crop growth. These outcomes support the investigations of Asad and Rafique (2002) who claimed that B boosted wheat's ability to produce dry matter. The plant's ability to grow dry weight in relation to the size of its assimilatory surface reflects the assimilation rate's net contribution. In Super basmati and KS-282, respectively, the maximum normal kernel percentages (62.23% and 62.54%) were seen when boric acid was given at 0.75g kg^{-1} seed as opposed to (50.98%) and (50.60%) without boric acid treatment (Table 3). In comparison to the other control treatments under study, the seeds coated with boric acid produced grains of higher quality, with normal kernel percentages, lower percentages of abortive, sterile and chalky kernel percentages.

Table 3. Analysis of variance for influence of B seed coating on kernel quality of rice.

Source of Variation	DF	Mean sum of square				
		Sterile Kernel (%)	Opaque Kernel (%)	Abortive kernels (%)	Chalky Kernel (%)	Normal Kernel (%)
Rice cultivar (C)	1	4103.95**	4.07*	0.20ns	4.07ns	4.84*
Boron (B)	4	111.76**	34.61**	5.13*	34.61**	66.56**
C × B	4	19.72*	2.49ns	0.04ns	2.49ns	1.17ns
Error	18	0.0168	1.0071	17.52	18.1	18.09

DF = Degree of freedom; * = Significant at p 0.05; ** = Significant at p 0.01

B-coated rice seed coating offers a wonderful chance to enhance the quality of the kernel in rice cultivars, especially at low concentrations. B is a crucial nutrient that is required for plants to successfully transform sunshine, water and air into large yields of nutritious food and fiber. Parallel findings were reached by Jana *et al*. (2005) and Rashid *et al*. (2006) who came to the conclusion that B usage not only significantly boosted kernel milling recovery but also improved quality attributes and decreased panicle sterility. According to Cakmak *et al*. (1989) and Yilmaz *et al*. (1997) B scarcity inhibits plant development by decreasing photosynthesis through petiolar vascular bundles, leading to stunted growth and aberrant reproductive development (Wang *et al*., 1992). B successfully increased grain filling in rice. Our findings are also according with Rehman *et al.* (2018) who stated that B increased kernel quality, growth and development and yield production of rice crop. On the other hand, the effects on reproductive development vary greatly.

CONCLUSION

The results supported the hypothesis that seed coating with borates improved kernel quality and agronomic characteristics. Both rice cultivars should be coated with borates at a concentration of 0.75 g kg^{-1} seed since this will increase rice kernel yield. The B fertilizers increased the soil fertility by providing the B that plants require. The chemical makeup of rice kernels harvested from a crop grown with seeds coated in boric acid and the molecular mechanism of B in rice may be the subject of future research. The sustainability of the agricultural system may also be suggested by future experimental investigations like the modeling of B loss under various cereal circumstances and climate change scenarios.

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