P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2020; 8(2): 1973.-1979

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Received: 08-01-2020

Accepted: 12-02-2020

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Direct and residual effect of boron on growth parameters and yield of rice-wheat grown under the Inceptisol of Varanasi

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DOI: <https://doi.org/10.22271/chemi.2020.v8.i2ad.9043>

Abstract

A pot experiment was conducted in net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during kharif 2017 and rabi 2017-18 to evaluate the direct effect boron (B) fertilizers on plant growth parameters of rice and their residual effect on subsequent wheat crop grown in B deficient soil (0.42 mg kg^{-1}). The experiment comprised of 9 B levels i.e., 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kg B ha^{-1} in soil as borax (B:11%) along with basal dose of nitrogen, phosphorus and potassium as treatments in a completely randomized design (CRD) with three replications. The result showed that among the levels of boron the direct application of 1.5 kg B ha^{-1} soil along with RDF to rice was most beneficial and brought highest improvement in growth parameters and on succeeding wheat crop the most beneficial and highest yield was in residual B of 3.0 kg B ha^{-1} . The yield increased due to residual effect of B was statistically lower than the direct effect of B. Boron concentration in soils ranged from 0.54 to 0.43 mg kg^{-1} in rice and 0.29 to 1.25 mg kg^{-1} in wheat. The plant growth attributes like plant height, Greenness index, and number of tillers along with yield were increased by the direct and residual effect of B levels. The application of boron did not increase grain yield of rice and wheat significantly over RDF. However, application of B @ 2 kg ha^{-1} or higher doses significantly decreased the rice grain yield. In, wheat, the grain yield was at par in all the treatments. A significant residual effect of B application in rice was noticed even after the harvest of wheat crop particularly at highest doses of application.

Keywords: Direct effect, boron fertilizers, growth parameters, residual effect, boron deficient soil

Introduction

To fulfil the demand of ever-increasing population, the present day agriculture has become more intensive and is resulting in mining of available nutrients including micronutrients from soil over the years. Boron is an essential micronutrient element required by the plants for their normal physiological processes and growth. Among all essential micronutrient, boron is the only Non- metal (metalloid) in nature. Boron is associated with one or more of the following processes: cell division, calcium utilization, flowering and fruiting, carbohydrate and nitrogen metabolism, water relations, disease resistance, and catalyst for certain reactions (Berger, 1949; Sprague, 1951) [4, 43]. Boron stabilizes the structure of plasma membrane by complexing membrane compounds containing cis-diol groups such as glycoproteins and glycolipids to keep channels and enzymes at optimum conformation within the membrane. IAA levels is regulated by the B via IAA oxidase activity. Synthesis of N-bases such as uracil requires boron. Hence, needful and careful B fertilization is the key for sustainable production of crops in intensive cropping systems in Indian soil. Micronutrient deficiency in soil including that of B is distributed over a large area in Asian countries including India due to prevalent soil and environmental conditions. There is a narrow range of concentration between deficiency and toxicity of B in soil - plant systems. Boron is essential for the development of reproductive tissues and its deficiency results in low grain set or poor quality seeds and fruits. Due to widespread deficiencies of boron in soils of Uttar Pradesh (Singh *et al.*, 2015) [39] and their direct influence on the growth and yield of cereals and other crops (Sakal *et al.*, 1996) [37] its importance increased considerably. Deficiencies of B emerge due to intensive cropping, use of high analysis fertilizers and adoption of high yielding varieties (Rashid and Fox, 1992;

Rafique *et al.*, 2006^[34, 31]. Boron is found to have its residual impact on the successive crops, it is imperative that application of B containing fertilizers are needed to exploit the production potential of crops under cropping systems and also to mitigate the deficiencies of this nutrient. Adequate B nutrition is reported to reduce incidence of some diseases in plants. Boron (B) plays an important role in the development and differentiation of sugar in plant. It helps in the normal growth of plant and in absorption of nitrogen (N) in soil and also makes up the calcium (Ca) deficiency to some extent. Boron also helps in root development, flower and pollen grain formation. Among micronutrients, zinc and boron deficiency accounts about 49% and 33% respectively in Indian soils, which reduce not only the yield but also the nutritional quality of the produce. About one-third of the cultivated soils, especially in the eastern and north-eastern states of India are deficient in B (Gupta *et al.*, 2008)^[11]. Boron deficiency is the second most important micronutrient constraint in crops after that of Zn on global scale. Its deficiency has been widely found in highly calcareous soils of Bihar, Eastern Uttar Pradesh, Tamil Nadu and Saurashtra, sandy soils of Haryana and Rajasthan, hill and sub-mountainous soils of north Himalayan and NEH States and in red and lateritic soils of Orissa, Karnataka, Andhra Pradesh and Kokan region (Behera *et al.*, 2009)^[3]. Rice-wheat is grown in the Indo-Gangatic Plains with an estimated area of 13.5 million hectares in South Asia (Jackson, 2009)^[16]. Rice-wheat is a nutrient exhaustive system and nutrient removal from the soil is much higher than fertilizer input. As a result, wide spread boron deficiency occurred in rice-wheat system. In India rice is cultivated in western Coastal strip, eastern Coastal strip, all primary deltas, Assam plains and surrounding low hills, foothills and Tarai region along the Himalayas and states like west Bangal, Bihar, Eastern Uttar Pradesh, Eastern Madhya Pradesh, North Andhra Pradesh, and Odisha. Uttar Pradesh ranks second in rice production after west Bangal in country accounting 11.5% of country production (2014-15). In Uttar Pradesh, rice is cultivated in 70 districts out of which 7 districts (Bijnour, Kushinagar, Pilibheet, Chandauli, Bagpat, Ambedkar and Varanasi) are under high productivity group. The total area under rice cultivation is 56.96 M ha with average productivity of 2,042 kg/ha. Wheat is the second most cultivated food grain in the world after maize. India is the second largest producer of wheat after china. Boron is important micronutrient that is essential for plant growth and improves the production efficiency of wheat. The micro nutrients have important role in improvement of growth and yield attributes of rice as well as wheat. Among micronutrients Boron found to be essential not only for obtaining greater number of tillers and proper seed setting but it is observed playing markable role for improvement in plant height and Greenness Index (SPAD value). Plant height is

considered as main attribute for indication of vegetative growth potential of plants which is an outcome of proper uptake of almost all essential nutrients. A healthy plant removes more amounts of nutrients from soil than weak plants and develops well and plant health is likely to be influenced by nutrient uptake. Keeping these facts in view, an experiment was conducted to assess the direct and residual effect of boron and on rice and wheat in terms of plant growth parameters and crop yield in boron deficient soils of eastern Uttar Pradesh.

Materials and Methods

A pot experiment was conducted in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between 25014' and 25023'N latitude and 82056' and 83030'E longitude and falls in a semi-arid to sub humid climate. The boron deficient soils were collected from Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Soil samples were taken from each pot after completion of the pot experiment for the determination of physico-chemical properties of the soils. The initial physico-chemical properties of experimental soils (table 2) were analyzed by following standard laboratory methods (table 1). A pot experiment was conducted taking rice (ARIZE-6444) as a test crop in kharif 2017-18 and wheat (HUW468) crop in rabi season 2017-18 in the net house of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, B.H.U., Varanasi, U.P. To conduct the pot experiment, bulk surface soil sample (0-15 cm) was collected from the Dry Land Agricultural Research Farm that was deficient in B. The soil was air dried and ground to pass through 2 mm sieve. Then processed 10 kg soil was filled in each polythene lined pots. The experiment comprised of 9 B levels i.e., 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kg B ha⁻¹ in soil as borax (B: 11%) along with basal dose of nitrogen, phosphorus and potassium as treatments in a completely randomized design (CRD) with three replications. Required quantities of fertilizers for 10 kg soil were calculated and applied in liquid form using urea, KH₂PO₄ and muriate of potash as source of N, P and K, respectively. The recommended N, P₂O₅ and K₂O were 150, 60 and 60 kg ha⁻¹ respectively for Rice and 120, 60 and 60 kg ha⁻¹ for wheat respectively. Nitrogen @ 60 kg ha⁻¹ and P₂O₅ and K₂O at full dose was applied as basal. Left over doses of nitrogen was added in two equal splits at 30 and 60 days after transplanting in each pot. Borex (Na₂B₄O₇.10H₂O) was applied in liquid form as basal. The growth parameters were recorded at 30 days, 60 days and 90 days after transplanting/sowing the crops. All the data arising out of experiment were statistically analyzed

Table 1: Analytical methods followed during investigation are as under.

Parameters	Procedures applied	References
pH (1:2.5)	Glass electrode (pH meter)	. (Sparks 1996) ^[42]
EC (1:2.5)	Conductivity meter	(Sparks 1996) ^[42]
Texture	Hydrometer	Bouyoucos (1962) ^[8]
Organic C	Titrimetric method	Walkley and Black (1934) ^[46]
Available nitrogen	Alkaline KMnO ₄	Subbiah and Asija (1956) ^[44]
Available phosphorus	Olsen's Method for alluvial soil	Olsen <i>et al.</i> (1954) ^[26]
Available potassium	Flame photometer	Hanway and Heidel (1952) ^[12]
Available boron	Azomethine-H by spectrophotometer	(Aitken <i>et al.</i> , 1987) ^[2]

Table 2: Initial physicochemical properties of composite soils.

Properties	Alluvial soil
Sand (%)	55.8%
Silt (%)	18.4%
Clay (%)	25.8%
pH (1:2.5)	7.05
EC (1:2.5) (dSm ⁻¹)	0.504
Organic carbon (%)	0.60
Available nitrogen (kg ha ⁻¹)	112
Available phosphorus (kg ha ⁻¹)	37
Available potassium(kg ha ⁻¹)	157.70
Available sulphur (mg kg ⁻¹)	15.43
Available boron (mg kg ⁻¹)	0.42

Table 3: Treatment details.

Treatments		
Rice		Wheat
T ₁ :	Absolute control (without fertilizer)	Absolute control (without fertilizer)
T ₂ :	Control: RDF (N: P ₂ O ₅ : K ₂ O @ 150:60:60 kg ha ⁻¹)	Control: RDF (N: P ₂ O ₅ : K ₂ O @ 120:60:60 kg ha ⁻¹)
T ₃ :	RDF + 0.5 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₄ :	RDF + 1.0 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₅ :	RDF + 1.5 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₆ :	RDF + 2.0 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₇ :	RDF + 2.5 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₈ :	RDF + 3.0 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₉ :	RDF + 3.5 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice
T ₁₀ :	RDF+4.0 kg B ha ⁻¹ soil application	RDF + Residual Effect of Boron Applied in Rice

*RDF – Recommended dose of fertilizer

Results and Discussion

Plant height

The plant height at 90 DAT in rice significantly varied from 37.2 to 41.6 cm whereas in wheat it ranges between 17.28 to 25.93 cm (Table 4.). The maximum plant height (41.60 cm) was recorded in treatment T₅ (RDF + 1.5 kg B ha⁻¹) at 90 DAT in rice and in wheat it was in treatment in T₈ (RDF + 3 kg B ha⁻¹) 25.93 cm and both were significantly superior to their respective absolute control (T₁) and RDF (T₂). Almost similar trend were noted with respect to plant height at 30 and 60 DAT/DAS. Gour *et al.* (2015) [10] also found the maximum plant height in rice @ 1.5 kg B ha⁻¹. Ram *et al* (2014) [32] reported that plant height significantly increased by 27.7 and 21.6% with application of S, Zn, and B with RDF over control at 30 and 60 days after transplanting (DAT), respectively. Application of higher dose of B gave higher response, but indiscriminate use of B may cause toxicity in plants and may also cause deleterious effect of growth of several crops (Kushwaha *et al.*, 1999) [22]. The middle rate of B concentration gave the highest plant height (Khalifa *et al.*, 2009) [19]. Hosseini *et al.* (2007) [14] reported that high levels of B decreased plant height and dry matter production of corn (*Zea mays* L.). The presented results are similar with the findings of BINA (1993) [6] who reported that plant height varied significantly by application of 1 kg B ha⁻¹. In wheat, the residual effect of B on plant height showed a significant (p<0.05) response along with a fresh dose of RDF. Soyly *et al.* (2004) [41] and Soyly *et al.* (2005) [40] reported that B application considerably improved the growth and yield parameters of wheat. Many studies had reported a significant increase in plant height (Pradhan and Sarkar, 1993; Rana *et al.*, 2005 and Patel and Ghosh, 2013) [30, 33, 27]. The reasons for increase in plant heights may be attributed to better plant nutrition and balanced interaction among all macro and micronutrients, which may result into better plant growth in terms of plant height. Furthermore, growth inhibition with B deficiency might be due to impairment of plasma membrane

functions by reactive quinines or decreased levels of diffusible auxins (IAA), caused by enhanced IAA oxidize activity. The inhibition of growth of the plant in boron deficiency has been attributed to the accumulation of phenolic compounds (Shkolnik, 1974) [38]. Khan *et al.* (2011) [20] were found that, Plant height significantly increased with B application over control. Maximum plant height was achieved with the application of B applied to wheat at 2 kg ha⁻¹ (T₄) that was statistically non-significant with the application of B applied both to wheat and rice at the same level of B (T₇) in rice-wheat system.

Greenness index (SPAD)

Data pertaining to greenness index in leave as influenced by direct and residual effect of different doses of B with RDF, are presented in Table 4. The greenness index (30 DAT) in rice and wheat were ranged from 37.82 to 44.36 and 32.01 to 37.73 SPAD, respectively. The maximum greenness index was recorded in T₅ (RDF+1.5 kg B ha⁻¹) in rice, whereas in wheat it was in T₈ (RDF+3 kg B ha⁻¹) and the minimum was recorded in absolute control (T₁) for both the crops. Almost similar trend was observed with the leaf greenness index at 60 and 90 DAT/DAS except a slight decrease was noticed as compared to observation at 30 DAT/DAS. Chlorophyll is one of the major components of plants for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. Bhutto *et al.* (2013) [5] reported that application Zn and B also showed increased chlorophyll content. The chlorophyll contents in plants may increase or decrease by the effects of micronutrients level in plant and soil (Manivasgaperumal *et al.*, (2011) [24]. Muhammad *et al.*, (2012) [25] revealed that the chlorophyll contents of rice plant increased significantly with the application of B and Zn as compared to the control. The improvement in growth attributes as a result of B application may be due to the enhanced photosynthetic and metabolic activity which leads to an increase in various plant metabolic pathways responsible for

cell division and elongation (Hatwar *et al.*, 2003) ^[13] because the chlorophyll contents increased considerably in Zn and B treated plants. The photosynthesis enhanced in the presence of B indicates that it helps to activate the synthesis of tryptophan and precursor of indole acetic acid (IAA) which is responsible for stimulation of plant growth and accumulation of biomass. The micronutrient is a component of ferredoxin and electron transport are also associated with chloroplast. The acceleration in photosynthesis is evident for better vegetative growth (Patil *et al.*, 2010) ^[28].

Number of Tillers

Data recorded on total number of tillers per pot in rice and wheat has been presented in Table 4. The total number of tillers at 90 DAT in rice ranged between 3.0 to 4.76. The

maximum number of tillers (4.76) was recorded in treatment T₅ (RDF+1.5kg B ha⁻¹). Residual effect of RDF + 3kg B ha⁻¹ and RDF+3.5kg B ha⁻¹ (T₈, T₉) increased the number of Tillers at 90 DAS wheat by 25 and 23% respectively over RDF. Almost similar trend was noted with respect to number of tiller at 30 and 60 DAS. The increase in number of tiller of rice might be attributed to balanced fertilization (Latere and Singh, 2013) ^[23]. Hussain *et al.* (2012) ^[15] found the maximum number of tiller per m² in the plot where B was applied in soil at 1.5 kg ha⁻¹ at flowering stage. Gour *et al.* (2015) ^[10] also found the maximum no of tiller in rice @ 1.5 kg B ha⁻¹. Hussain *et al.* (2012) ^[15] found maximum number of tillers per m² in the plot where B was applied in soil at 1.5 kg ha⁻¹ at flowering stage.

Table 4: Direct and residual effect of boron application on plant height, tiller number, and greenness Index in rice and wheat

Treatment	Plant Height (cm)					
	30 DAT/DAS		60 DAT/DAS		90 DAT/DAS	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
T ₁	26.66±.66 a	12.90±0.15 a	37.23±.43 bcd	17.14±0.52 a	37.40±.43 bc	17.28±0.60 a
T ₂	29.33±1.20 abc	14.90±0.38 a	39.33±.72 cde	22.03±0.09 b	39.50±.64 cd	22.03±0.22 b
T ₃	29.33±.88 abc	15.50±0.46 a	40.66±.92 e	21.97±0.20 b	39.56±.34 cd	22.10±0.15 b
T ₄	30.33±1.20 abc	16.00±0.58 ab	39.50±.28 de	22.07±0.24 b	39.93±.21 d	22.30±0.26 b
T ₅	31.66±1.20 c	16.23±0.39 ab	41.00±1.00 e	21.37±0.96 b	41.60±.83 d	22.40±0.55 bc
T ₆	30.66±.88 bc	16.33±1.20 ab	36.16±2.33 bc	22.30±0.64 b	37.20±1.45 b	22.47±0.44 bc
T ₇	29.66±.88 abc	16.40±0.31 ab	36.16±.16 bc	22.40±0.70 bc	36.60±.26 b	22.73±0.76 bc
T ₈	29.66±1.20 abc	20.07±3.58 b	35.00±.76 b	25.90±3.10 c	35.50±.64 b	25.93±3.08 c
T ₉	29.66±1.20 abc	17.20±0.42 ab	34.83±1.09 b	23.70±0.26 bc	35.30±.91 b	23.73±0.26 bc
T ₁₀	27.66±1.76 ab	16.20±0.99 ab	31.66±.16 a	22.40±0.42 bc	32.06±.51 b	21.63±0.87 b
Greenness Index (SPAD)						
T ₁	37.83±1.10a	32.01±0.30 a	32.06±2.72 a	37.79±0.88 a	18.48±6.29 ab	10.27±0.61 a
T ₂	40.03±4.39ab	33.22±0.99 ab	36.86±3.69 bc	39.22±0.57 ab	14.65±2.96 ab	11.21±0.72 a
T ₃	40.46±1.59ab	33.57±0.81 ab	36.40±.91 bc	39.48±0.61 ab	12.66±4.25 a	11.37±0.58 ab
T ₄	39.93±1.15ab	33.94±0.81 ab	35.80±1.32 ab	39.83±1.61 ab	18.40±7.60 ab	11.54±0.96 ab
T ₅	44.36±1.42b	33.98±0.43 ab	40.10±3.05 c	40.17±1.08 ab	17.36±1.70 ab	11.66±0.57 ab
T ₆	42.60±1.57b	34.05±0.79 ab	38.20±1.99 bc	40.83±0.22 b	28.70±7.88 b	12.09±0.32 ab
T ₇	42.06±2.75ab	34.55±0.43 b	35.90±1.17 abc	40.88±0.95 b	28.46±6.78 b	13.59±0.64 bc
T ₈	42.36±1.10ab	34.73±0.21 b	35.33±2.56 ab	41.36±0.98 b	21.40±14.55 ab	18.72±0.95 d
T ₉	40.93±3.36ab	34.26±0.52 b	37.63±.87 bc	41.88±0.80 b	18.80±6.59 ab	14.67±0.89 c
T ₁₀	40.63±2.91ab	34.14±0.58 b	38.90±1.68 bc	40.77±0.40 b	51.06±8.45 c	12.44±0.55 ab
Number of tillers pot ⁻¹						
T ₁	2.66±.33 abc	1.30±0.15 a	2.76±.23 a	1.30±0.15 a	3.00±0.00 a	1.30±0.15 a
T ₂	2.66±.33 abc	1.90±0.15 b	3.56±.29 ab	1.97±0.09 b	3.60±.26 abcd	1.90±0.10 b
T ₃	3.16±.16 bc	1.90±0.10 b	3.66±.33 bc	2.00±0.00 bc	3.76±.23 bcd	1.93±0.18 bc
T ₄	3.16±.16 bc	2.03±0.03 bc	3.66±.33 bc	2.07±0.03 bc	4.06±.06 d	2.03±0.03 bcd
T ₅	3.33±.33 c	2.03±0.03 bc	4.40±.30 c	2.07±0.03 bc	4.76±.28 e	2.10±0.00 bcd
T ₆	2.83±.16 abc	2.07±0.03 bc	3.66±.33 bc	2.10±0.10 bc	3.86±.35 cd	2.07±0.07 bcd
T ₇	2.66±.33 abc	2.27±0.17 bc	3.06±.06 ab	2.27±0.17 bc	3.13±.03 a	2.27±0.17 bcd
T ₈	2.33±.33 ab	2.30±0.15 c	3.06±.03 bc	2.33±0.12 c	3.13±.03 a	2.37±0.18 d
T ₉	2.16±.16 a	2.13±0.09 bc	3.26±.12 bc	2.20±0.10 bc	3.30±.11 abc	2.33±0.12 cd
T ₁₀	2.16±.16 a	2.07±0.07 bc	2.96±.14 bc	2.17±0.09 bc	3.20±0.00 ab	2.17±0.09 bcd

Rice: T₁-absolute control (without fertilizer); T₂-RDF (N:P₂O₅:K₂O::150:60:60 kg ha⁻¹); T₃-RDF+0.5 kg B ha⁻¹; T₄-RDF+1 kg B ha⁻¹; T₅-RDF+1.5 kg B ha⁻¹; T₆-RDF+2 kg B ha⁻¹; T₇-RDF+2.5 kg B ha⁻¹; T₈-RDF+3 kg B ha⁻¹; T₉-RDF+3.5 kg B ha⁻¹; T₁₀-RDF+4 kg B ha⁻¹

Wheat: T₁-absolute control (without fertilizer); T₂- control + RDF (N:P₂O₅:K₂O::120:60:60 kg ha⁻¹); T₃ to T₁₀ – RDF+ Residual effect of boron.

Grain yield

Examination of data (Table.5. and Fig.1.) clearly showed that the grain yield in rice as well as wheat significantly increased. The direct application of B in rice and its residual effect on wheat, the grain yield varied from 15.33 to 44.07 g pot⁻¹ and 7.76 to 19.70g pot⁻¹ respectively. The maximum grain yield in rice was recorded in T₅ (RDF+1.5kg ha⁻¹) whereas in wheat, it was observed in T₈ (RDF+3 kg B ha⁻¹). The minimum grain

yield in rice and wheat was recorded in T₁ (absolute control). Application of 1.5 kg B ha⁻¹ and +2kg B ha⁻¹ along with RDF (T₄ and T₅) was statically at par with RDF+1kg B ha⁻¹ (T₃) in rice. The residual effect of RDF+3kg B ha⁻¹ (T₈) was recorded the maximum (19.70g) grain yield followed by T₇ and T₆ which increased by 37, 26 and 24% over RDF (T₂). This increase in yield of rice might be due to the fact that micronutrients exerted a beneficial effect on chlorophyll

content in the leaves and dry matter in plant which increased the productivity. Gour *et al.* (2015) ^[10] and Ram *et al.* (2014) ^[32] reported that grain yield of rice increased with application of Zn, S and B. Similar results were also reported by Keerat-kasikorn *et al.* (1991) ^[18]. The pronounced effect of B on grain yield of rice agrees well with the findings of Jahiruddin. (1992) ^[17] and Abedin *et al.* (1994) ^[1]. Boron has many physiological functions in plants which include sugar transport, cell wall synthesis, reproduction, pollen tube growth, pollen germination, lignification, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid metabolism (IAA), phenol metabolism, membrane integrity, ascorbate metabolism and oxygen activation (Blevins and Lukaszewski, 1998; Cakmak and Romheld, 1997) ^[7, 9]. Khan *et al.* (2011) ^[20] were found that spike length significantly increased with the application of B applied to wheat alone and both to wheat and rice at 2 and 1 kg ha⁻¹ over control. Maximum spike length was observed with the application of B applied to wheat at 2 kg ha⁻¹ (T₄) which was statistically at par with the B applied both to wheat and rice at the same level of B (T₇). The number of spikes m⁻² significantly increased with B application, and ranged from 361 to 449. Maximum number of spikes was recorded with the application of B applied to wheat at 2 kg ha⁻¹ (T₄) that was at par with T₆ and T₇. The residual effect of B applied to rice at 2 kg B ha⁻¹ (T₅) and 1 kg B ha⁻¹ (T₃) on the following wheat gave grain yield of 3329 and 3244 kg ha⁻¹ respectively. These treatments differed significantly from each other. The lowest increases over control were 18 and 15% with the residual effect of B applied to rice at 2 and 1 kg ha⁻¹ respectively on the following wheat. Similarly, the application of B applied both to wheat and rice at 1 kg ha⁻¹ (T₆) gave the better results as compared

to B applied to wheat alone (T₂) and the residual effect of B at 1 kg ha⁻¹ (T₃). Khan *et al.* (2006), ^[21] observed in field experiments that paddy yield was significantly increased by the B application, which ranged from 3.51 to 6.00 t ha⁻¹ while maximum yield was observed with the cumulative application of 2 kg B ha⁻¹ of rice and wheat. Rashid *et al.* (2007) ^[35] reported that 14 to 23% increase in paddy yield was achieved with the B application.

Straw yield

Data on straw yield of rice and wheat has been presented in (Table 5 and Fig.1). It is evident that straw yield of rice and wheat significantly increased with application of different doses of boron along with RDF. The straw yield in rice and wheat ranged from 24.50 to 54.35 g per pot and 18.19 to 48.65 g per pot, respectively. The maximum straw yield in rice and wheat was recorded in T₅ (RDF +1.5 kg B ha⁻¹) and T₈ (RDF+3 kg B ha⁻¹), while the minimum was recorded in T₁ (absolute control). Application of 1.0 and 1.5 kg B ha⁻¹ along with RDF (T₄ and T₅) was significantly increased by 19 and 12% over RDF in rice. The residual effect of application of 3 kg B ha⁻¹ (T₈) and 2.5 kg B ha⁻¹ (T₇) with RDF increased straw yield by 55 and 39% over RDF (T₂) in wheat. It is evident from the results that direct application of boron and its residual effect with RDF, might have facilitated the growth of the plant, because of its involvement in many metallic enzyme system, regulatory functions and auxin production (Sachdev *et al.* 1988) ^[36] increased synthesis and transport of carbohydrates to the sink (Peda Babu *et al.* 2007) ^[29]. This is also in conformity with the results found by Uddin *et al.* (2002) ^[45] and Ram *et al.* (2014) ^[32]

Fig 1: Direct and residual effect of boron application on grain yield in rice and wheat

Table 5: Direct and residual effect of boron application on number of panicle/spike, length of panicle/spike, grain panicle⁻¹/spike⁻¹, grain yield, straw yield, harvest index and test weight in rice and wheat

Treatment	Grain yield (g pot ⁻¹)		Straw yield (g pot ⁻¹)	
	Rice	Wheat	Rice	Wheat
T ₁	15.33 ± 3.23 a	7.76 ± 0.53 a	24.50 ± 0.90 a	18.19 ± 0.54 a
T ₂	38.03 ± 2.58 c	14.36 ± 2.05 b	45.69 ± 2.58 cd	31.39 ± 3.93 b
T ₃	39.50 ± 6.19 c	15.23 ± 0.52 b	47.79 ± 4.36 de	36.80 ± 1.67 bc

T ₄	40.13 ±4.63 c	16.36 ±2.86 b	51.07 ±1.32 ef	37.88 ±5.25 bc
T ₅	44.07 ±.90 c	16.73 ±3.08 b	54.35 ±2.05 f	39.76 ±2.84 bc
T ₆	26.46 ±9.50 b	17.90 ±2.13 b	48.72 ±3.39 de	43.29 ±4.80 bc
T ₇	24.73 ±6.45 ab	18.06 ±1.21 b	42.57 ±3.30 c	43.73 ±4.16 bc
T ₈	22.83 ±5.46 ab	19.70 ±.89 b	38.05 ±2.29 b	48.65 ±3.15 c
T ₉	24.80 ±4.82ab	17.65 ±.82 b	35.64 ±1.42 b	40.73 ±6.69 bc
T ₁₀	21.43 ±4.39 ab	15.66 ±3.27 b	35.56 ±1.43 b	43.54 ±1.66 bc

Rice: T₁-absolute control (without fertilizer); T₂-RDF (N:P₂O₅:K₂O::150:60:60 kg ha⁻¹); T₃-RDF+0.5 kg B ha⁻¹; T₄-RDF+1 kg B ha⁻¹; T₅-RDF+1.5 kg B ha⁻¹; T₆-RDF+2 kg B ha⁻¹; T₇-RDF+2.5 kg B ha⁻¹; T₈-RDF+3 kg B ha⁻¹; T₉-RDF+3.5 kg B ha⁻¹; T₁₀-RDF+4 kg B ha⁻¹

Wheat: T₁-absolute control (without fertilizer); T₂- control + RDF (N:P₂O₅:K₂O::120:60:60 kg ha⁻¹); T₃ to T₁₀ – RDF+

Residual effect of boron. *panicle for rice: spike for wheat

Conclusion

The boron did not found to increase grain yield of rice and wheat significantly over RDF. However, application of B @ 2 kg ha⁻¹ or higher doses significantly decreased the rice grain yield. In, wheat, the grain yield was at par in all the treatments. Application of B @ 1.5 kg B ha⁻¹ significantly enhanced the plant growth in rice, whereas residual effect of 3 kg ha⁻¹ B application has significantly improved plant growth in wheat. A significant residual effect of B application was noticed even after the harvest of wheat crop particularly at highest doses of application.

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