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Research Communication

Effect of boron on growth indices, physiological traits and productivity of rice (*Oryza sativa*) under north-west Indian conditions

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ABSTRACT

An experiment was conducted during the rainy season (*kharif*) of 2019 at the Punjab Agricultural University, Ludhiana, to explore the role of boron (B) in improving seed filling, vascularisation and yield of rice (*Oryza sativa* L.). The field experiment comprising 14 treatments, viz. foliar application of boron (B) @ 24, 28, 32 and 40 millimolar (mM) at boot-leaf stage (BL) or at 1 week after boot-leaf stage (1 WABL) as well as at both the stages (BL+1 WABL) along with foliar application of water and control (unsprayed), were laid out in randomised complete-block design, with 3 replications. Plants sprayed with 24 mM B at different stages showed improved photosynthetic efficiency in terms of chlorophyll content, carotenoid content and hill-reaction activity of leaf chloroplasts. Also, the yield-attributing traits, viz. 1,000-grain weight, panicle weight and panicles/m^2, were significantly higher in plants treated with 24 mM B at BL + 1 WABL, followed by plants treated with 24 mM B at 1 WABL, which were similar to that treated with 24 mM B at BL or at 1 WABL. Increasing B concentration above 24 mM showed negative impact on the growth and yield of rice. Thus, foliar spray of 24 mM B at BL or 1 WABL may be used to improve the productivity of rice.

***Key words*: Boron, Dry-matter partitioning, Photosynthetic efficiency, Rice, Yield**

Rice (*Oryza sativa* L.) is the world's second highest produced cereal crop after maize. About 90% of the world's rice is cultivated and consumed in Asia (FAO, 2018). Grain yield of rice is influenced by a number of factors including environmental, genetic and agronomic. The prevalence of favourable climatic conditions enhances yield of rice through its effect on yield attributes. The 2 major attributes among various yield attributes are the number of grains per panicle and 1,000-grain weight. Although the total number of grains/panicle is a characteristic feature of variety and under genetic control, sometimes there is an increase in number of unfilled grains per panicle due to which the yield is reduced. The increase in number of unfilled grains per panicle is explained by various factors such as environmental stress, deficiency of mineral nutrients and poor translocation of photo-assimilates from source to sink. Rate of grain-filling is determined by source-sink balance (Saleem *et al.,* 2020). Carbon transportation from stem to panicles and carbon assimilation in leaves affect the source ability for proper grain-filling.

Among various micronutrients, boron (B) is the essential micronutrient and its deficiency causes a reduction in final crop yield (Patil *et al.,* 2017). The main physiological roles of B in plants are translocation of sugars, synthesis of cellular walls, maintaining membrane integrity, IAA metabolism, accelerating flowering and fruit-bearing processes in head (Prasad *et al.,* 2014; Farooqi *et al.,* 2019). A large amount of biomass is locked up in the vegetative plant parts, so any practice to manipulate the remobilization of photosynthates from vegetative parts to head may improve harvest index and grain yield. Various studies have indicated an increase in productivity of rice with application of boron. It has been suggested that, the grain sterility results from several unrelated factors including poor vascular bundles differentiation and boron deciency (Farooqi *et al.,* 2019). Since limited studies have been carried out to evaluate the effectiveness of boron on the grain-filling and vascularisation of rice in North-West Indian conditions, present investigation was conducted to study the effect of foliar application of boron for improving seed-filling, vascularisation and yield of rice.

The experiment was conducted during the rainy season (*kharif*) of 2019 at Research farm and Laboratory of Department of Botany, Punjab Agricultural University,

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Ludhiana [30°56' N, 75°52' E, 247 m altitude], located in the Western Indo-Gangetic Plains (WIGPs). Climate of experimental site is characterized as subtropical, semi-arid, with an annual rainfall of 733 mm received mainly (80% of total) during June-September. The soil of the experimental field was sandy loam, high in available P and available K but low in available N and soil organic carbon (SOC) status. Boron content of soil was sufficient (0.8 ppm). The electrical conductivity and *p*H of the soil were within normal range. The experiment comprising 14 treatments was laid out in randomized complete-block design (RCBD) with 3 replications. The treatments included foliar application of boron @ 24, 28, 32 and 40 millimolar (mM) either at boot-leaf stage (BL) or 1 week after boot leaf stage (1 WABL) as well as at both the stages. Treatments of water spray and unsprayed (control) were also kept. The short-duration rice variety 'PR 126' was sown in nursery during the last week of May and transplanted during the last week of June at 15 cm × 20 cm spacing with 30-day-old seedlings. All other production and protection technologies were followed as per recommendations of the Punjab Agricultural University, Ludhiana (PAU, 2022).

Plant height, tiller count, leaf-area index (LAI) and flag-leaf area were recorded at anthesis and physiological maturity by randomly selecting 5 plants in each experimental unit. Flag-leaf area was calculated by measuring length and width of flag leaf manually and multiplying with a correction factor of 0.75 as suggested by Chanda and Singh (2002) and expressed as cm^2. Total chlorophyll and carotenoid content were determined as per the method of Hiscox and Isrealstam (1979). Hill-reaction activity was measured from randomly chosen leaves from each plot and calculated by using the equation suggested by Cherry (1973). Total and effective tillers were counted from 5 random plants and expressed as tillers/m^2 and panicles/m^2, respectively. Five panicles were randomly selected from each experimental unit for recording panicle weight and number of grains (filled and unfilled) per panicle. For recording grain yield, the grains obtained after threshing net plots (10 m^2) were sun-dried, winnowed, cleaned and weighed on an electronic balance. For valid comparison of different treatments, moisture content in grains was estimated using digital moisture meter (Kett's RICETER J Handheld grain moisture meter) and grain yield was adjusted at 14% moisture and expressed as q/ha (100 kg/ha). The weight of straw from each net plot was also recorded 3 days after harvesting for estimation of straw yield, which was expressed as q/ha. For anatomy of the peduncle, its transverse sections were hand-cut and observed under Leica Bright Field Research Microscope at 4x magnification. Data were subjected to analysis of variance (ANOVA) using Proc GLM procedure of SAS software (SAS 9.3.) as per RCBD. The multiple comparisons among treatment means were made using Tukey's test ($P \le 0.05$).

At anthesis stage, plants treated with 24 mM B at BL + 1 WABL were taller (118.7 cm) than those of the control (Table 1). But at physiological maturity, plants treated with 24 mM B 1 WABL, though statistically at par with the plants treated with 24 mM B at BL or at BL+ 1 WABL, recorded the highest plant height (119.6 cm). Results on increased plant height due to foliar spray of B are in accordance with that reported by Rehman *et al.,* (2014). A

Table 1. Effect of boron treatments on periodic plant height, tiller count, leaf area index, flag-leaf area and number of vascular bundles of rice

Treatment	Plant height (cm)		Tiller count (number/m^2)		Leaf-area index		Flag-leaf area (cm^2)		Number of vascular bundles
	Anthesis stage	Physiological maturity	Anthesis stage	Physiological maturity	Anthesis stage	Physiological maturity	Anthesis stage	Physiological maturity	
T_1, 24 mM B at BL	115.2 ^{bd}	118.8 ^{a}	367.9^{a}	364.3^{a}	8.1^{d}	6.9^{c}	40.4^{d}	29.8^{d}	15
T_2, 28 mM B at BL	114.3 ^{ce}	117.9 ^{ab}	364.8^{a}	362.2 ^{a}	7.9^{e}	6.7 ^{d}	40.1^{de}	28.2 ^{bd}	15
T_3, 32 mM B at BL	111 ^{fh}	110.8 ^{eg}	361.4^{a}	360.9^{a}	7.5 ^{f}	6.0 ^{I}	37.2 ^{f}	27.5^{cd}	16
T_4, 40 mM B at BL	109.7 ^{gh}	110.6 ^{fg}	361.3a	360.1^{a}	7.5 ^{g}	6.0^{h}	37.6 ^{f}	27.6^{cd}	16
T_5, 24 mM B at 1WABL	117.2 ^{ab}	119.6 ^{a}	368.8 ^{a}	366.8^{a}	8.3 ^{c}	7.4^{a}	45.3^{b}	30.3^{b}	16
T_6, 28 mM B at 1WABL	116.3 ^{ac}	118.1 ^{ad}	365.8^{a}	365.3^{a}	8.2^{c}	7.3^{a}	44.8 ^{c}	30.3^{b}	15
T_7, 32 mM B at 1WABL	111.8 ^{eh}	112.8 ^{ef}	360.4^{a}	360.1 ^{a}	7.3^{I}	5.9^{f}	37.6^{f}	26.9 ^{d}	16
T_8, 40 mM B at 1WABL	112 ^{eg}	113.4 ^{cd}	360.2^{a}	359.1^{a}	7.4^{hi}	5.9 ^{j}	37.3^{f}	26.9^{d}	15
T_9, 24 mM B at BL + 1WABL	118.7 ^{a}	119.3 ^{a}	369.2^{a}	368.8 ^{a}	8.9^{a}	7.7^{b}	48.9^{a}	36.5 ^{a}	16
T_{10}, 28 mM B at BL + 1WABL	112.7 ^{df}	113.3 ^{ce}	368.2^{a}	366.7^{a}	8.6^{b}	7.5^{c}	47.0^{b}	34.1^{a}	14
T_{11}, 32 mM B at BL + 1WABL	109.3 ^{h}	109.6 ^{gh}	359.1^{a}	359.8^{a}	7.2 ^{j}	5.6^{j}	36.7^{f}	26.2 ^{d}	14
T_{12}, 40 mM B at BL + 1WABL	109.3 ^{h}	107.6 ^{h}	358.2^{a}	357.1^{a}	7.1 ^{k}	5.6 ^{k}	36.5^{f}	26.3^{d}	15
T_{13}, Water sprayed	112.7 ^{df}	115.6 ^{bc}	360.2^{a}	359.7^{a}	7.4^{h}	6.2^{e}	38.4^{ef}	27.8 ^{cd}	15
T_{14}, Control	112 ^{eg}	114.2 ^{cd}	358.3^{a}	358.2^{a}	7.1^{k}	5.9^{g}	37.9^{f}	26.6^{d}	12
SEm±	0.5	0.6	3.9	4.7	0.1	0.2	0.65	0.5	-

B, Boron; BL, boot-leaf stage; WABL, week after boot leaf stage.
Within column, Means followed by the same letter are not significantly different.

decrease in leaf-area index and flag-leaf area was observed from anthesis to physiological maturity stage but plants treated with boron maintained higher values of these parameters than the control plants. Plants treated with 24 mM B at BL + 1 WABL showed the highest leaf-area index both at anthesis (8.9) and physiological maturity (7.7). However, this treatment was at par with 28 mM B at BL + 1 WABL in respect of the flag-leaf area at physiological maturity (Table 1). The higher leaf-area index owing to application of B as observed in our study might be because of more cell division (hyperlasia) and elongation (hypertrophy) that led to vigorous leaf production and ultimately higher leaf-area index in individual rice plants. Similar results were reported by Dhillon *et al.,* (2018b) in sunflower.

The total chlorophyll content, carotenoid content and hill-reaction activity of leaf chloroplast decreased from anthesis to physiological maturity stage which might be due to onset of senescence, resulting in chlorophyll degradation (Fig. 1). Maximum total chlorophyll and carotenoid content were observed in plants treated with 24 mM B at BL+ 1 WABL both at anthesis (7.76 mg/g fresh weight) and at physiological maturity (3.64 mg/g fresh weight) stages. Maximum hill-reaction activity at anthesis (0.860 mg/chl/h) and at physiological maturity (0.085 mg/chl/h) was observed in plants treated with 24 mM B at BL + 1 WABL, followed by plants sprayed with 24 mM B 1 WABL (0.844 and 0.061 mg/chl/h at anthesis and physiological maturity respectively). Rehman *et al.,* (2014) also reported increase in chlorophyll content with B application.

Variation in number of vascular bundles was observed in all the treatments as compared to the control (unsprayed). Plants treated with 24 mM B at BL + 1 WABL showed the maximum number of vascular bundles in their peduncles (Fig. 2). The increase in number of vascular bundles led to an increase in area of conducting tissues which might be responsible for increased translocation of

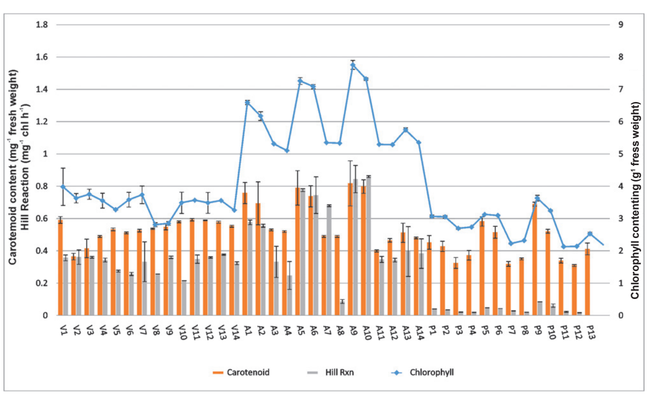

Fig. 1. Effect of boron treatments on photosynthetic parameters
V, A, P indicate the values of photosynthetic parameters at vegetative, anthesis and physiological maturity stages, respectively.
1, 2, 3,……14 indicate treatment number.

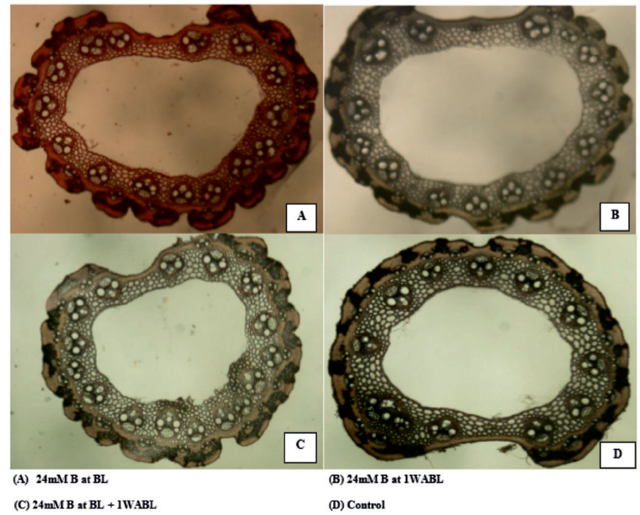

Fig. 2. Transverse section of rice peduncle showing vasculature under boron treatment and control

assimilates to the grains. Dhillon *et al.,* (2018a) also reported improvement on vasculature of sunflower in response to B application.

The highest value of grain weight/panicle (4.83 g) and filled grains/panicle (181.3) was observed in plants sprayed with 24 mM B at BL + 1 WABL, which was statistically similar to the treatments wherein B was applied @ 24 mM at BL or at 1 WABL (Table 2). Likewise, these treatments exhibited higher panicle fertility. The plants under unsprayed (control) treatment exhibited the least values of these parameters. Increment of 7.4% in filled grains/panicle increased by 7.4% in plants treated with 24 mM B at BL+ 1 WABL than in the untreated (control) plants which might be because of the favourable effect of boron application on translocation of assimilates and grain-filling. Ali *et al.,* (2016) also reported that, supplemental application of B during panicle-formation stage increased the number of filled grains/panicle. The poor yield attributes under higher levels of B application (28, 32 and 40 mM B) may be ascribed to the phytotoxic effect of higher concentration of boron (Roessner *et al.*, 2006). Increase in panicle weight with B application might be owing to higher number of filled grains/panicle or improvement in individual grain weight, which might be the consequence of improved source-sink relationship that ensured better assimilate translocation during grain development. Similarly, 6.13% higher 1,000-grain weight under 24 mM B at BL + 1 WABL than the control treatment might be owing to positive role of boron in translocation of assimilates to grains. Increase in spikelet (grain) number following boron application was also reported by Farooqi *et al.,* (2019) in wheat.

Application of 24 mM B at BL + 1 WABL resulted in the highest grain yield (86.46 q/ha) owing to higher value of the yield attributes (Table 2). However, this treatment

Table 2. Effect of boron treatments on yield attributes and yields of rice

Treatment	Panicle number (m^2)	Grain weight/ panicle (g)	Filled grains/ panicle	Panicle fertility (%)	1,000-grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
T_1, 24 mM B at BL	364 ^{a}	4.7 ^{a}	182.3 ^{a}	91.1 ^{a}	21.3 ^{bc}	84.0 ^{ab}	112.8 ^{ab}	42.7 ^{a}
T_2, 28 mM B at BL	362 ^{a}	4.1 ^{c}	160.6 ^{c}	81.5 ^{de}	21.2 ^{bd}	80.2 ^{bc}	110.3 ^{ac}	42.1 ^{a}
T_3, 32 mM B at BL	361 ^{a}	3.2 ^{ef}	158.1 ^{c}	79.1 ^{e}	20.4^{fg}	76.0 ^{de}	105.4 ^{c}	41.7 ^{abc}
T_4, 40 mM B at BL	360 ^{a}	3.2 ^{ef}	159.5 ^{c}	79.1 ^{e}	20.9 ^{ce}	76.0^{de}	110.5 ^{ac}	40.6 ^{bd}
T_5, 24 mM B at 1 WABL	367 ^{a}	4.7 ^{ab}	180.4 ^{a}	89.3 ^{ab}	21.4 ^{ab}	84.0^{ab}	113.0 ^{ab}	42.6 ^{a}
T_6, 28 mM B at 1 WABL	365 ^{a}	4.3 ^{c}	161.4 ^{bc}	81.0 ^{de}	21.1 ^{bd}	81.1 ^{bc}	110.9 ^{ac}	42.2 ^{ab}
T_7, 32 mM B at 1 WABL	360 ^{a}	3.1 ^{f}	162.9 ^{bc}	80.8 ^{de}	20.6 ^{eg}	75.7 ^{de}	106.4 ^{bc}	41.6^{ad}
T_8, 40 mM B at 1 WABL	359^{a}	3.2 ^{ef}	159.9 ^{c}	80.0 ^{e}	20.1 ^{g}	75.3 ^{e}	104.3 ^{c}	41.9^{ac}
T_9, 24 mM B at BL + 1 WABL	369 ^{a}	4.8 ^{a}	181.3 ^{a}	88.0 ^{b}	21.8 ^{a}	86.5 ^{a}	114.3 ^{a}	43.0 ^{a}
T_{10}, 28 mM B at BL + 1 WABL	367 ^{a}	4.6 ^{b}	163.4^{bc}	81.2 ^{ce}	21.2 ^{bd}	82.2 ^{bc}	112.9 ^{ab}	42.1 ^{ac}
T_{11}, 32 mM B at BL + 1 WABL	360 ^{a}	3.2 ^{ef}	161.6 ^{bc}	80.6 ^{de}	20.6 ^{eg}	74.6 ^{e}	110.2 ^{ac}	40.3 ^{cd}
T_{12}, 40 mM B at BL + 1 WABL	357 ^{a}	3.3 ^{e}	161.4 ^{bc}	80.3 ^{e}	20.9 ^{ce}	73.5 ^{e}	110.1 ^{ac}	40.0 ^{d}
T_{13}, Water sprayed	360 ^{a}	3.6 ^{d}	168.9 ^{b}	83.8^{cd}	20.8 ^{df}	79.0 ^{cd}	110.4 ^{ac}	41.7 ^{ad}
T_{14}, Control	358 ^{a}	3.3 ^{e}	168.8 ^{b}	84.2^{c}	20.5 ^{cg}	78.8 ^{cd}	110.3 ^{ac}	41.7 ^{ad}
SEm±	4.6	0.03	1.49	0.57	0.1	0.73	1.33	0.35

B, Boron; BL, boot-leaf stage; WABL, week after boot leaf stage.
Within column, Means followed by the same letter are not significantly different.

was at par with application of 24 mM B at BL or at 1 WABL. Similarly, straw yield was also higher in plants treated with 24 mM B at BL + 1 WABL. The grain and straw yield decreased significantly when B was applied at higher concentration (28, 32 or 40 mM) both at BL and 1 WABL. According to Binhafiz (2017), rice straw yield increased with boron application because boron improved the membrane function which favoured the activities of membrane-bound enzymes that attributed to higher straw yield of rice. The plants treated with 24 mM B at BL or at 1 WABL or at BL + 1 WABL had the highest harvest index. Improvement in harvest index in boron-treated plants can be attributed to better assimilate utilization that resulted in improvement in seed setting and translocation of photo-assimilates to developing grains which may increase the grain size and number of grains/panicle (Farooqi *et al.,* 2019; Lenka *et al.,* 2019).

It may be concluded that, foliar spray of B @ 24 mM at boot-leaf stage or at 1 week after boot-leaf stage may be done for higher yield of rice crop which is ascribed to improvement in photosynthetic efficiency and yield attributes of rice on account of improved vasculature.

REFERENCES

Ali, S., Raza, S.A., Butt, S.J. and Sarwar, Z. 2016. Effect of foliar boron application on rice (*Oryza sativa* L.) growth and final crop harvest. *Agricultural and Food Science Research* **3**(2): 49–52.

Binhafiz, R.A.S.M. 2017. Influence of foliar boron application on improvement of yield of hybrid rice. Ph.D. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh pp. 27–68.

Chanda, S.V. and Singh, Y.D. 2002. Estimation of leaf area in wheat using linear measurements. *Plant Breeding and Seed Science* **46**(2): 75–79.

Cherry, J.H. 1973. *Molecular Biology of Plant*: *Text Manual,* pp. 46–49. Columbia University press, London, UK.

Dhillon, B.S., Sharma, P.K. and Sardana, V. 2018a. Productivity of spring sunflower (*Helianthus annuus*) in response to sowing dates and foliar application of boron and TIBA. *Indian Journal of Agronomy* **63**(3): 342–349.

Dhillon, B. S., Sharma, P.K. and Dhingra, M. 2018b. Boron and TIBA induced physiological and anatomical changes in relation to dry matter partitioning in spring sunflower (*Helianthus annuus* L.) under delayed sowing. *Indian Journal of Plant Physiology* https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.1007%2Fs40502-018-0362-z.

FAO. 2018. Rice market monitor. FAO, Rome **21**(1): 4.

Farooqi, M.U., Tahir, M., Saleem, A.M. and Ahmad, T. 2019. Effect of foliar application of nitrogen and boron on growth, yield and quality of wheat (*Triticum aestivum* L.). *Pakistan Journal of Life and Social Sciences* **17**(2): 93–99.

Hiscox, J.D. and Israelstam, G.F. 1979. A method for extraction of chlorophyll from leaf tissue without macerartion.*Canadian Journal of Botany* **57**: 1,332–1,334.

Lenka, S., Mohanty, A.K., Mohapatra, S. and Panygrahy, N. 2019. Effect of irrigation scheduling and different levels of zinc and boron on yield, economics, water productivity and nutrient uptake in aerobic rice (*Oryza sativa*). *Indian Journal of Agronomy* **64**: 330–335.

Patil, Y.J., Patil, H.M., Bodake, P.S., Lende, N.S. and Patil, V.S. 2017. Effect of soil application of boron on growth, yield and soil properties of lowland paddy. *International Journal of Chemical Studies* **5**(5): 972–975.

PAU. 2022. *Package of practices for kharif crops in Punjab*. Punjab Agricultural University, Ludhiana, pp. 1–20.

Prasad, R., Kumar, D., Shivay, Y. and Rana, D. 2014. Boron in

Indian agriculture–A review. *Indian Journal of Agronomy* **59**: 511–517.

Rehman, A., Farooq, M., Cheema, Z.A., Nawaz, A. and Wahid, A. 2014. Foliage applied boron improves the panicle fertility, yield and bio-fortification of fine grain aromatic rice. *Journal of Soil Science and Plant Nutrition* **14**(3): 723–733.

Roessner, U., Patterson J.H., Forbes, M.G., Fincher, G.B., Langridge, P. and Bacic, A. 2006. An investigation of boron toxicity in barley using metabolomics. *Plant Physiology* **142**: 1,087–1,101.

Saleem, M.A., Tahir, M., Ahmad, T. and Tahir, M.N. 2020. Foliar application of boron improved the yield and quality of wheat (*Triticum aestivum* L.) in calcareous field. *Soil Environment* **39**(1): 59–66.