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Growth and productivity of basmati rice (*Oryza sativa* L.) as influenced by seedling density and iron and boron biofortification

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Abstract
The field experiments were conducted during the rainy (*kharif*) season of 2019 and 2020 at Meerut, Uttar Pradesh (INDIA), to evaluate the growth and productivity of basmati rice (*Oryza sativa* L.) as influenced by seedling density and iron and boron Biofortification. Three planting density, *viz*. 1 seedling/hill, 2 seedlings/hill and 3 seedlings/hill and five foliar application Iron and Boron (control, Fe @ 0.1% and B @ 0.04% at Maximum tillering stage, Fe @ 0.1% and B @ 0.04% at Panicle initiation stage, Fe @ 0.1% at Maximum tillering stage and B @ 0.04% at Panicle initiation stage and Fe @ 0.1% and B @ 0.04% at both stages) were tested in a split-plot design (SPD), keeping as main and subplots, respectively, with 3 replications. The total rainfall receipt during the experimental period was 587.6 mm (10 rainy days) during 2019 and 369.6 mm (10 rainy days) during 2020. The experimental result revealed that different planting density and foliar application of Fe and B had a remarkable influence on the Growth, Yield and yield Attributes, and Profitability of rice. In general, among the 1 seedlings/hill had the highest Growth and yield Attributes which were statically superior over rest of the planting density during both the years. While in case of yield *viz*., grain, straw and harvest index, was highest in 3 seedling/hill. Of the different planting density, 3 seedlings/hill resulted in significantly the highest grain yield (5.02 and 5.11 t/ha) during 2019 and 2020, respectively. Among them, highest grain and straw yields were recorded with the treatment of 3 seedlings/hill and foliar spray of Fe @ 0.1% and B @0.04% at MT and PI.

Keywords: Biofortification, growth, fertility ratio, panicle density, hulling percent, yield and rice

Introduction
Rice is a most important cereal crop of rainy season, grown under semi-aquatic condition and mostly under submergence condition. It is a major staple food for more than 60% population and considered as the "global grain''. In India rice is being cultivated on an area of 44 million ha with total production of 109.7 million tonnes and average productivity of 2.49 tonnes/ha (FAI, Fertilizer Statistics 2017–18). In Uttar Pradesh, area under rice is 1.53 million ha, with 2.63 million tonnes production and with an average productivity of 1.714 tonnes/ha in 2016 (Jagtap *et al*., 2018). Rice is a nutritious cereal crop, mainly used for human consumption. It is the main source of energy and is an important source of protein, providing substantial amount of the recommended nutrients intake of zinc and niacin. Enhance production of rice is an important requirement to meet the needs of ever-increasing population in World with limited cultivated area thus, it is necessary to enhance the productivity per unit area. Among the improved Agronomic management practices such as seedling density and Biofortification of Fe and B play important role in enhancing the yield of Basmati rice. India has exported around 4.5 million metric tonnes of Basmati rice to the world worth Rs 32.8 thousand crores during 2018–19 (APEDA 2019).

The saying "Rice is life line" is the most adoptable for country like India as rice crop has been playing a vital part to our national food security. Now a day's we need techniques of crop production those are environmentally sound, cost effective and requires low inputs such as number of seedlings/hill (seedlings density). Because such techniques are cost effective i.e. farmers can easily adopt without changing in input requirement. The optimum seedlings/hill ensures the plants to grow in their both aerial and underground parts through efficient utilization of solar radiation, water and nutrients. All these factors can be efficiently utilized and ultimately they would lead to bumper crop production if proper care is taken. Excess number of seedlings/hill may produce higher number of tillers/hill resulting in mutual shading and lodging and thus favors the production of more straw instead of grain.

While the least number of seedlings/hill may cause insufficient number of tillers growth thus keeping air, space and nutrients unutilized in soils and at the end, total panicles/unit area will be reduced resulting in poor yield. The highest cumulative dry matter weight of stem and leaf sheath/m^2 (51.83 g) area was obtained from 3seedlings/hill. The second highest cumulative dry matter weight of stem and leaf sheath/m^2 (49.08 g) was obtained from 2seedlings/hill (Mahamud *et al*., 2013) [11]. Crop planted with 3seedlings/hill recorded maximum dry matter accumulation per hill (19.08g) as compared to 1 and 2 seedlings/hill (Chauhan, 2005) [3].

Today we have sufficient quantity of rice for diet, now the time of producing quality rice which grain have sufficient amount of nutrients like Fe and B. Micronutrient malnutrition continues to increase in many nations. For example, the global burden of iron deficiency has risen from about 35% of the world's population in 1960 to over 50% in 2000, and iron deficiency among poor women is increasing at an alarming rate in many developing countries. This global crisis in micronutrient malnutrition is the result of dysfunctional food systems that cannot deliver enough micronutrients to meet the nutritional requirements of all. Because agriculture is the primary source of all micronutrients for human consumption, agricultural systems must be contributing to this failure to meet nutritional needs. How can agriculture be changed in ways that will result in enough micronutrient output from farming systems to ensure adequate nutrition for all, if agricultural technologies are directed at improving the nutritional quality of food crops, they must encompass a holistic food system perspective to ensure that such interventions will be sustainable and adopted by farmers and consumers. Biofortification of micronutrients is, thus, one of the most effective and safest approaches to enrich those micronutrients in crop grain (Fang *et al.* 2008; Jin *et al.* 2008) [5, 7]. Fe deficiency decreases chlorophyll production, leading to interveinal chlorosis, which is exhibited as sharp distinctions between veins and chlorotic areas in young leaves (Kobayashi *et al*., 2003) [10]. Therefore, the present study was undertaken to find out the increase in Growth, Yield and yield Attributes, NUE and Profitability of rice with foliar application of Fe and B.

Material and Methods

The present investigation was conducted at the Crop Research Center, Meerut, during (*kharif)* rainy season of 2019 and 2020. The University farm is located at the latitude of 29°40′ N and longitude of 77°42′ E at an altitude of 237 meters above the mean sea level. The total rainfall receipt during the experimental period was 587.6 mm and 369.6 mm and total evaporation were 495.6 mm and 510.3 during 2019 and 2020, respectively. The mean minimum and maximum temperatures were 23 °C, 34.4 °C and 23.6 °C, 34.1 °C during 2019 and 2020, respectively. The soil was sandy loam, low in organic carbon, moderately alkaline with pH 8.68 and 8.71 during 2019 and 2020, respectively. It was medium in available nitrogen 192.36 and 201.03 kg/ha, low in available phosphorus 11.08 and 10.58 kg/ha and fairly medium in available potassium 130.21 and 142.20 kg/ha. The experiment was laid out in a split-plot design (SPD), comprising 15 treatment combinations, replicated thrice. The main-plot treatment consisted of 3 planting density *viz*., 1 seedling/hill, 2seedlings/hill and 3seedlings/hill. The subplot treatment consisted of five foliar application of Fe and B, namely Control (Water spray) MN_0, Fe @ 0.1% and B @ 0.04% at Maximum tillering stage MN_1, Fe @ 0.1% and B @ 0.04% at Panicle initiation stage MN_2, Fe @ 0.1% at Maximum tillering stage and B @ 0.04% at Panicle initiation stage MN_3 and Fe @ 0.1% and B @ 0.04% at both stages MN_4. The gross plot of 3.60 m × 5.00 m size and net plot 2.80 m × 4.10 m size were used for the experimentation. Iron and Boron was applied as foliar mean, after neutralizing with Slaked lime, through $FeSO_4$ and Solubor, respectively as per treatments. The recommended dose of N: P_2O_5:K_2O was applied at 100:60:40 kg/ha in the form of urea, Diammonium phosphate, and Murate of potash. Nitrogen was applied in 3 split as 1/3rd as basal, 1/3rd at 50% tillering and rest 1/3rd at the panicle initiation stage. Five hills were tagged randomly in each net plot and recorded height and tillers. The day on which 50% panicles of tagged hills emerges from each plot was carefully recorded and thus total number of days from transplanting, upto 50% panicle emergence was considered as days taken to 50% panicle emergence. Total number of days taken from transplanting to the maturity of the experimental crop was judged carefully and thus total number of days from transplanting, upto maturity was considered as days taken to maturity.

Fertility ratio and Panicle density was calculated by the following formula as

$$\text{Fertility ratio} = \frac{\text{Total number of filled grains/Panicle}}{\text{Total number of filled and unfilled grains/Panicle}}$$

$$\text{Panicle density} = \frac{\text{Number of grains/panicle}}{\text{length of panicle (cm)}}$$

Harvesting of basmati rice was carried out when it attained physiological maturity. Rice grain yield and straw yield were taken from the net plot demarcated. The grain yield of rice was recorded with moisture content adjusted to 14%. Harvest index was calculated using grain yield divided by biological yield and multiplied by 100. Statistical analysis was performed by an OPSTAT program. Least significant difference (LSD) values at a 5% level of significance were used to determine the significance of differences between treatment means.

Results and Discussion

Plant height (cm)

Plant height increased with the advancement of the crop age and reached to maximum at harvest, irrespective of the treatments, but the rate of increment was highest between 30 to 60 DAT during both the years (Table 1, Fig. 1). Plant height of rice differed significantly due to different planting density and micronutrients application (Fe and B) at various stages of crop growth, except 30 DAT during the both years (Appendix-II).

Table 1: Effect of seedling density and foliar application of Fe and B on plant height (cm) of rice

Treatment	Plant height (cm)							
	30 DAT		60 DAT		90 DAT		At Harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
Planting Density								
1 Seedling/hill	67.1	68.6	97.5	98.5	107.2	108.6	109.9	110.2
2 Seedlings/hill	66.7	67.7	99.2	102.0	112.4	113.7	115.1	115.6
3 Seedlings/hill	66.4	68.3	89.4	91.4	103.0	104.4	105.1	105.5
S.Em±	1.8	1.4	1.3	2.0	1.6	1.3	1.4	1.3
C.D. (P=0.05)	NS	NS	5.4	8.0	6.5	5.2	5.6	5.4
Micronutrients Application (Fe and B)								
MN_0	65.4	68.3	92.6	94.2	104.4	105.2	106.1	106.5
MN_1	67.0	67.9	95.0	97.2	106.0	107.9	108.4	109.1
MN_2	65.7	67.2	92.8	93.7	106.4	107.8	109.6	109.7
MN_3	67.6	68.1	97.0	99.7	109.8	111.2	112.5	112.9
MN_4	68.0	69.6	99.4	101.8	111.0	112.4	113.7	114.2
S.Em±	1.3	1.0	1.6	1.8	1.3	1.5	1.4	1.6
C.D. (P=0.05)	NS	NS	4.7	5.4	3.9	4.4	4.2	4.7

MN0- Control, MN1 - Fe @ 0.1% and B @ 0.04% at Maximum tillering stage, MN2 - Fe @ 0.1% and B @ 0.04% at Panicle initiation stage, MN3 - Fe @ 0.1% at Maximum tillering stage and B @ 0.04% at Panicle initiation stage, MN4 - Fe @ 0.1% and B @ 0.04% at both stages.

At 30 DAT, the plant height varied between 66.4 to 67.1 cm and 68.3 to 68.6 cm, being highest with 1 seedling/hill and the minimum under 3 seedlings/hill during 2019 and 2020, respectively. At 60 and 90 DAT, significantly tallest plants (99.2, 112.4 cm and 102.0, 113.7cm) were recorded with 2 seedlings/hill, being *on par* with 1 seedling/hill, while the shortest plants (89.4, 103.0 and 91.4, 104.4 cm) were recorded under 3 seedlings/hill during first and second year, respectively. However, the difference between 1 and 3 seedlings/hill was found to be non significant at 60, 90 DAT and at harvest during both the years, except at 60 DAT in 2019. Although at harvest stage, maximum plant height of 115.1 and 115.6 cm, which was *on par* with 1 seedling/hill was observed with 2 seedlings/hill, while the minimum plant height of 105.1 and 105.5 cm was observed with 3 seedlings/hill during 2019 and 2020, respectively. Moreover, rice transplanted with 2 seedlings/hill resulted into 9.5 and 9.6% more plant height over 3 seedlings/hill during 2019 and 2020, respectively. Similar results were reported by Dhungana *et al.* (2021) [4].

Among the micronutrients application at 30 DAT, the maximum (68.0 and 69.6 cm) and minimum plant height (65.4 and 68.3 cm) during 2019 and 2020 was noticed with iron and boron applied at both the stages and control, respectively. Moreover, Fe @ 0.1% and B @ 0.04% applied at both the stages (MN_4), being *on par* with MN_3 and MN_1 at 60 DAT during both the years resulted into statistically taller plants as compared to rest of the treatments. However, the difference between MN_1 and MN_2 treatments was also found to be non significant at 60, 90 DAT and at harvest stage during both the years. Although at 90 DAT and harvest stage, the maximum plant height (111.0 and 112.4cm and 113.7 and 114.2cm) was recorded with the application of Fe @ 0.1% and B @ 0.04% at both stages, which was *on par* with MN_3, while the lowest plant height (107.2 and 108.6cm and 106.1 and 106.5cm) was recorded under control followed by MN_1 and MN_2 during first and second year, respectively. Further at harvest stage, the crop fortified with Fe @ 0.1% and B @ 0.04% at both the stages experienced an increase of 7.16 and 7.23% over control during 2019 and 2020, respectively. Similar results were reported by Sonam *et al.* (2018) [14].

Days taken to 50% panicle emergence and days taken to maturity

The data pertaining to days taken to 50% panicle emergence and maturity of rice as influenced by seedling densities and Fe and B application is presented in Fig. 1.

Different seedling densities and micronutrients application (Fe and B) did not being any significant variation days taken to 50% panicle emergence and maturity. Although, the crop took 90 to 93 days in 2019 and 88 to 91 days in 2020 to attain the 50% panicle emergence and 129 to 134 days in 2019 and 128 to 131 days in 2020 for maturity from 3 to 1 seedling/hill, being highest under 1 seedling/hill.

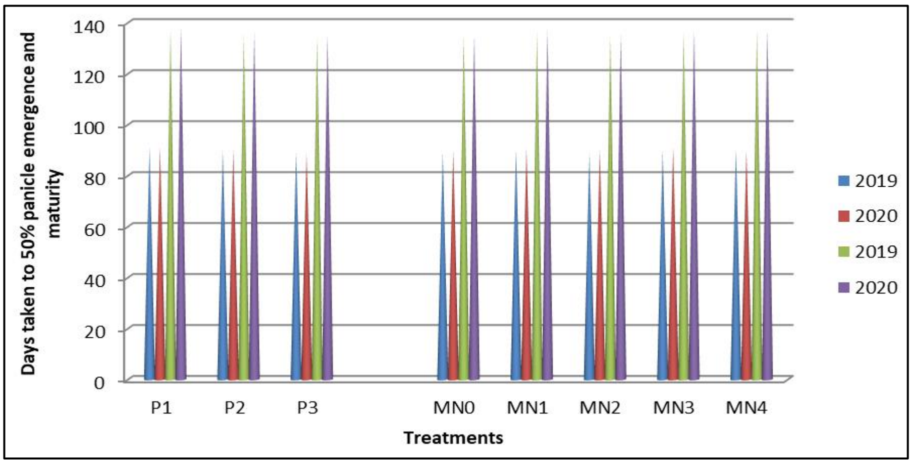

Fig 1: Effect of seedling density and foliar application of Fe and B on days taken to 50% panicle emergence and maturity

The crop fertilized with Fe @ 0.1% and B @ 0.04% at both the stages delayed in days taken to 50% panicle emergence and maturity in basmati rice slightly i.e., 2-3 days over control during both the years. However, the minimum and maximum days were taken to attain the 50% panicle emergence and maturity with (MN_0) control and MN_4, respectively.

Yield and Yield Attributes

Fertility ratio

The data revealed that there was significant difference among different planting densities and iron and boron application during both the years (Table 2).

The highest fertility ratio (0.843 and 0.830) was recorded in 1 seedling/hill in 2019 and 2020, respectively, being at par with the 2 seedlings/hill in both of the years. Though, the lowest fertility ratio (0.795 and 0.789) was recorded in 3 seedlings/hill during 2019 and 2020, respectively. Among the different Fe and B application, the highest fertility ratio (0.832 and 0.823), being at par with MN_1 and MN_2 was recorded with foliar spray of Fe @ 0.1% and B @ 0.04% at maximum tillering (MT) stage and foliar spray of Fe @ 0.1% and B @ 0.04% at panicle initiation (PI) stage, remaining all the treatments was statically superior over rest of the treatments during 2019 and 2020, respectively. However, the lowest fertility ratio (0.808 and 0.797) was recorded under foliar spray of Fe @ 0.1% and B @ 0.04% at maximum tillering (MT) stage and panicle initiation (PI) stage during 2019 and 2020, respectively.

Table 2: Effect of seedling density and foliar application of Fe and B on amylose content, volume expansion and protein content in grains

Treatment	Fertility ratio		Panicle density		Hulling %	
	2019	2020	2019	2020	2019	2020
Planting Density						
1 Seedling/hill	0.843	0.830	2.58	2.60	0.696	0.719
2 Seedlings/hill	0.831	0.820	2.49	2.51	0.680	0.691
3 Seedlings/hill	0.795	0.789	2.47	2.46	0.663	0.667
S.Em±	0.005	0.005	0.03	0.05	0.008	0.009
C.D. (P=0.05)	0.019	0.020	NS	NS	NS	0.035
Micronutrients Application (Fe and B)						
MN_0	0.832	0.823	2.52	2.52	0.683	0.681
MN_1	0.829	0.820	2.51	2.52	0.686	0.684
MN_2	0.829	0.820	2.49	2.50	0.685	0.689
MN_3	0.817	0.806	2.52	2.53	0.674	0.699
MN_4	0.808	0.797	2.52	2.53	0.671	0.708
S.Em±	0.006	0.005	0.05	0.03	0.008	0.010
C.D. (P=0.05)	0.017	0.015	NS	NS	NS	NS

MN_0- Control, MN_1 - Fe @ 0.1% and B @ 0.04% at Maximum tillering stage, MN_2 - Fe @ 0.1% and B @ 0.04% at Panicle initiation stage, MN_3 - Fe @ 0.1% at Maximum tillering stage and B @ 0.04% at Panicle initiation stage, MN_4 - Fe @ 0.1% and B @ 0.04% at both stages

Panicle density

There was non-significant difference among different planting densities during both the years (Table 2). The highest panicle density of 2.58 and 2.60 was recorded with 1 seedling/hill during 2019 and 2020, respectively. However, the lowest panicle density 2.47 and 2.46 recorded fewer than 3 seedlings/hill during 2019 and 2020, respectively. Among the panicle density was non-significant the different Fe and B application during both the years. The highest panicle density of 2.52 and 2.53 was recorded with foliar spray of $FeSO_4$ @ 0.5% and Solubor @ 0.2% at maximum tillering (MT) stage and panicle initiation (PI) stage during 2019 and 2020, respectively. However, the lowest panicle density 2.52 and 2.52 under control during 2019 and 2020, respectively.

Hulling (%)

It is clear from the table.2 that hulling percent differed significantly among the different seedling densities during 2020 and no significant in 2019. Significantly highest hulling percent (0.696 and 0.719%) was recorded in 1 seedling/hill, followed by 2 seedlings per hill during 2019 and 2020, respectively. The lowest hulling percent was recorded in 3 seedlings per hill during both of the years. There was non-significant different Fe and B application during both the years. The highest hulling percent (0.686 and 0.6874) was recorded in $FeSO_4$ @ 0.5% and Solubor @0.2% at MT stage MN_1, in 2019 and 2020, respectively. Though, the lowest hulling percent (0.671 and 0.708) was recorded during 2019 and 2020, respectively. Similar results were reported by Kamali *et al.* (2020) [9]

Yield of Rice

Rice grown with a planting density of 3 seedlings/hill, being *at par* with 2 seedlings/hill resulted into significantly higher biological yield (12.38 and 12.58 t/ha), straw yield (7.37 and 7.47 t/ha) and grain yield (5.02 and 5.11 t/ha) than 1 seedling/hill which was found undesirable for getting economic yield during 2019 and 2020, respectively (Table 1). The highest biological and straw yield under this treatment were mainly owing to the more DMA coupled with the growth and physiological parameters, while the grain yield due to better photosynthetic efficiency and their translocation towards sink. Although, the lowest biological (11.04 and 11.23 t/ha), straw (6.48 and 6.60t/ha) and grain yield (4.56 and 4.62 t/ha) was recorded under 1 seedling/hill during 2019 and 2020, respectively. Rajput *et al.* (2020) and Kajonpho *et al.* (2018) [8] also made similar observations in rice. Rice receiving applications of $FeSO_4$ @ 0.5% and Solubor @0.2% at MT and PI stage as foliar spray outyielded control, foliar spray of $FeSO_4$ @ 0.5% and Solubor @0.2% at MT stage and foliar spray of $FeSO_4$ @ 0.5% and Solubor @0.2% at PI stage by 7.73 and 9.55%, 4.58 and 5.52% and 3.29 and 5.09% during 2019 and 2020, respectively. Similarly, the pace of increment in straw yield was 2.02 and 2.0%, 1.29 and 1.55% and 1.0 and 1.12%, respectively. Although, foliar spray of $FeSO_4$ @ 0.5% at MT stage and Solubor @0.2% at PI stage and foliar spray of $FeSO_4$ @ 0.5% and Solubor @0.2% at both the stages remained *on par* with each other in this regard during both the years. It was probably due to better nutrient uptake leading to higher dry-matter production and its translocation towards sink. Similar results were reported by Patel *et al.* (2019) [12].

The harvest index in rice was significantly influenced by foliar application of Fe and B only during both the years. Although, the highest (0.413 and 0.412) and lowest (0.405 and 0.406) HI was recorded under 1 and 3 seedlings/hill during both the years. Among the foliar applied Fe and B, the highest HI was noticed under foliar spray of $FeSO_4$ @ 0.5% and Solubor @ 0.2% at both the stages followed by PI only. However, all the foliar applied Fe and B treatments were also statistically alike to each other and significantly superior over control during both the years, except 2020 where foliar spray of $FeSO_4$ @ 0.5% and Solubor @ 0.2% at MT stage remained on par with control. Similar results were reported by Baishya *et al.* (2019) [2].

Table 3: Effect of different Seedling density and foliar application of Fe and B on biological, straw, grain yield and harvest index

Treatments	Yield (q/ha)						Harvest Index	
	Biological		Straw yield		Grain yield			
	2019	2020	2019	2020	2019	2020	2019	2020
Planting Density								
1 Seedling/hill	110.4	112.3	64.8	66.0	45.6	46.2	0.413	0.412
2 Seedlings/hill	121.6	123.4	71.8	73.0	49.7	50.4	0.409	0.409
3 Seedlings/hill	123.8	125.8	73.7	74.7	50.2	51.1	0.405	0.406
S.Em±	0.94	0.96	0.96	0.50	0.80	0.74	0.006	0.004
C.D. (P=0.05)	3.79	3.86	3.86	2.01	3.21	2.98	NS	NS
Micronutrients Application (Fe and B)								
MN_0	116.0	117.7	69.4	70.6	46.6	47.1	0.393	0.393
MN_1	117.9	119.8	69.9	70.9	48.0	48.9	0.410	0.405
MN_2	118.7	120.5	70.1	71.2	48.6	49.1	0.410	0.407
MN_3	119.8	121.2	70.4	71.5	49.7	50.4	0.416	0.416
MN_4	120.6	122.3	70.8	72.0	50.2	51.6	0.417	0.422
S.Em±	1.16	0.80	1.09	0.92	0.61	0.50	0.005	0.005
C.D. (P=0.05)	NS	2.36	NS	NS	1.79	1.47	0.016	0.014

MN_0- Control, MN_1 - Fe @ 0.1% and B @ 0.04% at Maximum tillering stage, MN_2 - Fe @ 0.1% and B @ 0.04% at Panicle initiation stage, MN_3 - Fe @ 0.1% at Maximum tillering stage and B @ 0.04% at Panicle initiation stage, MN_4 - Fe @ 0.1% and B @ 0.04% at both stages

Conclusion

From the above study it can be concluded that the 3 seedlings/hill is better as compared to rest of the treatments, during both the years. Further, foliar application of Fe @ 0.1% and B @ 0.04% at both stages recorded increase in rice yield (7.73 and 9.55%) over control (water spray) during 2019 and 2020, respectively. The above mentioned practices may be recommended for enhancing productivity and quality of rice at western Uttar Pradesh.

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