



## Effect of planting density and micronutrient application on growth, physiological parameters and yield of rice (*Oryza sativa*)

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Received: 05 April 2021; Accepted: 04 September 2023

### ABSTRACT

The field experiments were conducted during the rainy (*kharif*) seasons of 2019 and 2020 at crop research centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh to study the effect of seedling density and micronutrient application on growth, physiological parameters and yield of basmati rice (*Oryza sativa* L.). Three planting densities, viz. 1 seedling per hill, 2 seedlings per hill and 3 seedlings per hill and 5 foliar application of micronutrient [MN<sub>0</sub>-control; MN<sub>1</sub>, B @0.04% and Fe @0.1% at maximum tillering (MT) stage; MN<sub>2</sub>, B @0.04% and Fe @0.1% at panicle initiation (PI) stage; MN<sub>3</sub>, Fe @0.1% at maximum tillering stage (MT) and B @0.04% at panicle initiation (PI) stage and MN<sub>4</sub>, B @0.04% and Fe @0.1% at maximum tillering (MT) and panicle initiation (PI) stages] were tested in a split plot design, keeping as main plots and sub plots, respectively with 3 replications. The growth, physiological traits and yield of basmati rice were significantly influenced by varying planting density and micronutrients application through leaves, as indicated by the outcomes of the experiments. Growth and physiological parameters such as dry matter accumulation, leaf area index, plant height, chlorophyll content, crop growth rate and relative growth rate increased through the application of boron and iron, being highest in foliar spray of 0.04% B and 0.1% Fe at both the stages (MT and PI). Of the different seedling densities, 3 seedlings per hill resulted in significantly higher grain yield (5.0 and 5.1 t/ha) during 1<sup>st</sup> and 2<sup>nd</sup> year, respectively. In both the years, the highest grain and straw yield were observed by using 3 seedlings per hill along with a foliar application of 0.04% B and 0.1% Fe during the MT and PI stages.

**Keyword:** Biofortification, Crop growth rate (CGR), Growth, Relative growth rate (RGR), Yield

Rice (*Oryza sativa* L.) holds a position of utmost significance as a staple food crop in Asia. To align with the escalating population growth, there is a need to increase its yield approximately 30% by 2025, as indicated by IRRI (2008). India, rice cultivation spans an area of roughly 43.8 million hectares, yielding 118.9 million metric tonnes at an average productivity rate of 2715 kg/ha, as reported in Anonymous (2021). It occupies a prominent position among the major cereals due to its wider adaptability to climatic, cultural and edaphic conditions. In the present era, there is a growing necessity for agricultural methods in crop cultivation that are environmentally sustainable, economically viable and demand fewer inputs such as the quantity of seedlings per hill. These techniques offer economic efficiency, allowing farmers to seamlessly adopt them without altering their input prerequisites. Tillers per unit area are greatly affected by both qualitatively and quantitatively to the number of seedlings per hill. Having the ideal number of seedlings per hill ensures that plants

can effectively utilize solar radiation, water, and nutrients to facilitate growth in both their aerial and underground parts. If proper attention is given, these factors can be utilized efficiently, ultimately resulting in a significant increase in crop production. Barua *et al.* (2014) stated that the number of plants/hill was an important factor as it affected plant population/unit area, proper utilization of nutrients, sunlight, respiration and photosynthesis, which eventually affected the yield of rice. Both developed and developing nations face challenges related to mineral deficiencies among their populations. Furthermore, approximately one-third of the global population experiences greater impact as a result of consuming food with lower nutritional content (Stein 2010). The prevalence of micronutrient malnutrition is on the rise in numerous countries. To illustrate, the worldwide prevalence of Fe deficiency has escalated from roughly 35% of the global population in 1960 to exceeding 50% by 2000. Furthermore, the occurrence of iron deficiency among impoverished women is undergoing a worrisome increase in numerous developing nations. Presently, our rice supply is adequate for sustenance, presenting an opportunity to focus on cultivating high-quality rice that contains essential nutrients like iron and vitamin B within the grains.

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Given that agriculture serves as the primary resources of micronutrients for human utilization, it is imperative for agricultural systems to play a pivotal role in addressing this shortfall in meeting nutritional requirements. With this background an experiment was conducted to study the effect of seedling density and micronutrient application on growth, physiological parameters and yield of basmati rice.

## MATERIALS AND METHODS

The field experiments were conducted during the rainy (*kharif*) seasons of 2019 and 2020 at crop research centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (29°40' N and 77°42' E, with an elevation of 237 meters amsl), Uttar Pradesh. The area received a total rainfall of 587.6 mm in the 1<sup>st</sup> year and 369.6 mm in the 2<sup>nd</sup> year. Additionally, the cumulative evaporation amounted to 495.6 mm in the 1<sup>st</sup> year and 510.3 mm in the 2<sup>nd</sup> year. The average minimum and maximum temperatures during the first and second years ranged from 23.0 to 34.5°C and 23.5 to 34.2°C, respectively. The soil was sandy loam containing 0.323% organic carbon, 192.4 kg/ha available N, 11.1 kg/ha available P and 130.2 kg/ha available K and pH 8.68. The treatments comprising 3 planting densities [1 seedling per hill, 2 seedlings per hill and 3 seedlings per hill] in the main plot and 5 foliar application of boron and iron [MN<sub>0</sub>-control; MN<sub>1</sub>, B @0.04% and Fe @0.1% at maximum tillering (MT) stage; MN<sub>2</sub>, B @0.04% and Fe @0.1% at panicle initiation (PI) stage; MN<sub>3</sub>, Fe @0.1% at maximum tillering stage (MT) and B @0.04% at panicle initiation (PI) stage and MN<sub>4</sub>, B @0.04% and Fe @0.1% at maximum tillering (MT) and panicle initiation (PI) stages] in the sub plot were laid out in a split plot design (SPD) with 3 replications. The gross plot of 5.0 m × 3.6 m size was used for the experimentation. Boron and Iron were applied as foliar mean, after neutralizing with slaked lime [Ca (OH)<sub>2</sub>]. The suggested dose of NPK was applied at 100:60:40 kg per ha in the form of Urea, Di-ammonium phosphate (DAP) and Muriate of potash (MOP). Nitrogen was applied in 3 equal splits, viz. as basal, at MT and at PI stage. For dry matter production, plant samples were initially sun-dried and then oven dried at 65°C until stable weight was obtained. The crop growth rate (CGR) and relative growth rate (RGR) of rice were calculated on dry weight basis. Average CGR of plants/hill for a time "t" is define as the enhance in dry weight "w" of plants/hill from a unit area per unit time. It was calculated using the periodic dry matter recorded at different stages as (Radford 1967):

$$\text{CGR (g/m}^2\text{/day)} = 1/A \times \frac{W_2 - W_1}{t_2 - t_1}$$

The immediate RGR of plants or a hill within a specific time interval "t" is precisely defined as the growth in dry biomass of the plants or hill/unit of material present/unit of time. The RGR of the crop was computed as (Radford 1967):

$$\text{RGR (g/g/day)} = \frac{\log W_2 - \log W_1}{t_2 - t_1}$$

Leaf area was assessed using the leaf area meter (LA-3100). The leaf area index (LAI) was determined by multiplying the measured leaf area by a correction factor (0.67), with the LAI calculated for each as (Watson 1952):

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

A SPAD meter (SPAD-502, Soil-Plant Analysis Development Section, Minolta Camera Co., Ltd., Japan) was employed to measure SPAD values on the topmost, fully extended leaf of each plant.

## RESULTS AND DISCUSSION

*Growth and physiological parameters:* At harvesting stage, planting density of 3 seedlings per hill exhibited significantly better performance (Table 1) with respect to variation in dry matter accumulation (g/m<sup>2</sup>) and leaf area index than 1 and 2 seedlings per hill during both the years. However, planting density of 2 seedlings per hill resulted in the maximum plant height and found at par with 1 seedling per hill. But the highest chlorophyll content as reflected by SPAD values was found in 1 seedling per hill during 1<sup>st</sup> and 2<sup>nd</sup> year. The positive effect on dry matter accumulation might be due to higher LAI with high photosynthetic efficiency of crop plant leading to improved photosynthates accumulation and their translocation which jointly accounted for higher dry matter production. Our findings confirm the results of Asmamaw (2017) and Dhungana *et al.* (2021).

Among the application of micronutrients at harvesting stage the treatment of MN<sub>4</sub> recorded significantly higher plant height, dry matter accumulation, leaf-area index and SPAD value than the rest of the treatments, which was found to be at par with treatment MN<sub>3</sub> during both the years. The minimum values of growth parameters were observed in control treatment (MN<sub>0</sub>). It was probably due to the fact that Fe is involved in photosynthesis and increment of chlorophyll content and B is involved in the N accumulation and thus increase the availability of nitrogen for maximum growth of plants. Similar results were also observed by Ahmad *et al.* (2011) and Meena *et al.* (2013).

Increase in dry-matter accumulation up to 60 days of growth was slow. The maximum increase in CGR was recorded between 60 and 90 days after transplanting in all the treatments and declined thereafter towards maturity due to natural leaves falls (Table 2). In general, maximum CGR and RGR were noticed under 2 seedlings per hill, while the lowest were found in 3 seedlings per hill at all the crop enlargement intervals, except between 30–60 DAT during both the years. But, between 90 DAT-harvest, CGR and RGR did not show any significant variation during 1<sup>st</sup> and 2<sup>nd</sup> years. The highest CGR and RGR at the optimum planting density (2) was found due to the proper consumption of nutrients, moisture and interception of highest solar radiation which led to faster increase of crop plants. CGR and RGR enhanced with the application of Fe and B at both the stages but they did not show any significant variation among each other in in this regard, except 30–60 DAT

Table 1 Effect of seedling density and micronutrients application on plant height, dry matter, leaf area index and chlorophyll content in basmati rice

Treatment	Plant height (cm)		Dry matter (g/m <sup>2</sup> )		Leaf area index		Chlorophyll content	
	2019	2020	2019	2020	2019	2020	2019	2020
<i>Planting density</i>								
1 Seedling/hill	109.9	110.2	1133.7	1137.0	4.02	4.13	36.3	38.1
2 Seedlings/hill	115.1	115.6	1233.6	1235.2	4.27	4.44	35.4	37.0
3 Seedlings/hill	105.1	105.5	1256.2	1259.0	4.49	4.65	34.4	34.9
SEm±	1.4	1.3	12.0	12.3	0.07	0.09	0.3	0.5
CD (P=0.05)	5.6	5.4	48.4	49.5	0.31	0.37	1.0	2.0
<i>Micronutrients Application (Fe and B)</i>								
MN <sub>0</sub>	106.1	106.5	1165.6	1166.6	3.86	3.98	34.2	35.4
MN <sub>1</sub>	108.4	109.1	1198.2	1200.6	4.24	4.36	35.6	36.8
MN <sub>2</sub>	109.3	109.4	1205.3	1210.1	4.28	4.42	35.4	36.4
MN <sub>3</sub>	112.5	112.9	1223.6	1225.5	4.42	4.58	36.4	37.6
MN <sub>4</sub>	113.7	114.2	1246.6	1249.3	4.51	4.68	37.1	38.4
SEm±	1.4	1.6	13.9	15.3	0.07	0.08	0.5	0.6
CD (P=0.05)	4.2	4.7	40.9	44.8	0.21	0.23	1.4	1.8

Treatment details are given under Materials and Methods.

during both the years. The highest CGR and RGR were recorded with the application of Fe @0.1% and B @0.04% at maximum tillering and panicle initiation stage followed by Fe @0.1% at MT stage and B @0.04% at PI stage. While, the minimum values of CGR and RGR were found in control. The higher CGR and RGR resulting from boron application may be due to the elevated leaf area index (LAI). Higher LAI means larger assimilation system resulting in more photosynthesis. More photosynthesis results in more

dry matter accumulation and higher CGR and RGR. Our results are in the close conformity with those of Mahato and Adhikari (2017) and Baruah (2022).

*Yield of rice:* Rice grown with the planting density of 3 seedlings per hill, being at par with 2 seedlings per hill resulted into significantly maximum biological, straw and grain yield which was found undesirable for getting economic yield during both the years (Table 3). Rice transplanted with 3 seedlings per hill obtained an average

Table 2 Effect of seedling density and micronutrients application on crop growth rate (CGR) and Relative growth rate (RGR) of basmati rice

Treatment	Crop growth rate (g/m <sup>2</sup> /day)						Relative growth rate (mg/g/day)					
	30–60 DAT		60–90 DAT		90 DAT- harvest		30–60 DAT		60–90 DAT		90 DAT-Harvest	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
<i>Planting density</i>												
1 Seedling/hill	7.0	7.1	16.4	17.0	10.7	11.8	25.5	25.1	27.1	27.3	10.7	10.6
2 Seedlings/hill	7.7	7.9	17.0	17.8	12.9	13.9	26.6	26.5	27.7	27.7	11.8	11.6
3 Seedlings/hill	9.0	9.2	16.2	16.6	12.8	13.8	27.6	28.1	23.8	23.7	11.7	11.2
SEm±	0.3	0.3	0.1	0.2	0.9	1.0	0.7	0.5	0.6	0.7	0.8	0.8
CD (P=0.05)	1.4	1.3	0.6	0.8	NS	NS	NS	2.1	2.5	2.6	NS	NS
<i>Micronutrients application (Fe and B)</i>												
MN <sub>0</sub>	7.2	7.2	15.3	16.4	11.3	12.1	25.4	25.3	25.3	25.2	9.9	10.0
MN <sub>1</sub>	7.8	7.8	16.7	16.7	11.5	12.3	26.4	26.3	26.0	26.0	11.9	11.6
MN <sub>2</sub>	7.2	7.3	16.8	17.3	12.6	13.4	25.6	25.5	25.9	25.8	10.1	10.2
MN <sub>3</sub>	8.4	8.5	17.1	17.5	12.8	13.6	27.2	27.3	26.4	26.7	12.5	11.8
MN <sub>4</sub>	9.3	9.1	17.9	17.6	13.3	14.1	28.2	28.3	27.5	27.4	12.6	12.1
SEm±	0.5	0.4	0.3	0.5	0.8	1.0	1.3	1.2	1.0	0.9	0.8	0.8
CD (P=0.05)	1.3	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Treatment details are given under Materials and Methods.

Table 3 Effect of seedling density and micronutrients application on yield and harvest index of basmati rice

Treatment	Yield (t/ha)						Harvest Index (%)	
	Biological		Straw		Grain		2019	2020
	2019	2020	2019	2020	2019	2020		
<i>Planting density</i>								
1 Seedling/hill	11.04	11.23	6.48	6.60	4.56	4.62	41.3	41.2
2 Seedlings/hill	12.16	12.34	7.18	7.30	4.97	5.04	40.9	40.9
3 Seedlings/hill	12.38	12.58	7.37	7.47	5.02	5.11	40.5	40.6
SEM±	0.09	0.10	0.09	0.05	0.08	0.07	0.6	0.4
CD (P=0.05)	0.38	0.39	0.39	0.20	0.32	0.30	NS	NS
<i>Micronutrients application (Fe and B)</i>								
MN <sub>0</sub>	11.60	11.77	6.94	7.06	4.66	4.71	39.3	39.4
MN <sub>1</sub>	11.79	11.98	6.99	7.09	4.80	4.89	41.0	40.7
MN <sub>2</sub>	11.87	12.05	7.01	7.12	4.83	4.91	41.1	40.9
MN <sub>3</sub>	11.98	12.12	7.04	7.15	4.97	5.04	41.6	41.7
MN <sub>4</sub>	12.06	12.23	7.08	7.20	5.02	5.16	41.7	42.0
SEM±	0.12	0.08	0.11	0.09	0.06	0.05	0.5	0.5
CD (P=0.05)	NS	0.24	NS	NS	0.18	0.15	1.6	1.4

Treatment details are given under Materials and Methods.

of 10.1 and 10.6% more grain yield than the 1 seedling per hill during 1<sup>st</sup> and 2<sup>nd</sup> years, respectively. Highest biological and straw yield was found better under triple seedlings per hill; this may be due to the easy establishment of plants after transplanting because of less root damage during uprooting, as well as minimal transplant shock and mortality. Since more number of seedlings will be used at the time of transplanting, the shock of root damage will be less and the mortality of seedlings will also be less because the 3 seedlings will jointly contribute to the recovery of the seedlings from transplanting shock, while the grain yield will be better. Kajonpho *et al.* (2018), Pokharel *et al.* (2018) and Rajput *et al.* (2020) made similar observations in the case of rice.

Rice getting application of Fe and B at maximum tillering and panicle initiation stage as foliar spray outyielded control, foliar spray of iron and boron at maximum tillering stage and foliar spray of iron and boron at panicle initiation stage by 7.70 and 9.60%, 4.6 and 5.5% and 3.3 and 5.1% during 2019 and 2020, respectively. Similarly, the pace of increment in straw yield was 2.02 and 2.00%, 1.29 and 1.55% and 1.00 and 1.12% during 1<sup>st</sup> and 2<sup>nd</sup> year, respectively. Although, foliar spray of iron at maximum tillering stage and boron at panicle initiation stage and foliar spray of iron and boron at both the stages remained on par with each other in this regard during both the years. This was probably due to higher dry matter production and its transfer to the sink due to better nutrient uptake. Rashid *et al.* (2006) reported that B application increased the yield of rice due to significant reduction in panicle sterility. Similar results were also reported by Patel *et al.* (2019). The data revealed that there was no any significant difference among different planting densities during both the years. The highest harvest index of 0.413 and 0.412 was recorded with 1 seedling per

hill, while the lowest harvest index of 0.405 and 0.406 was recorded under 3 seedlings per hill during 2019 and 2020, respectively. Among the micronutrients application, the maximum harvest index of 0.417 and 0.422 was recorded with Fe @0.1% and B @0.04% applied at both the stages, which was on par with all the micronutrients bearing treatments, while the minimum harvest index of 0.393 and 0.394 was noted under control during 2019 and 2020, respectively. The improvement in crop index as a result of boron application may be due to better starch utilization resulting in higher seed setting and transfer of assimilation to the developing grain, thereby increasing grain size and number of grains per panicle. Similar results were reported by Hussain *et al.* (2012) and Baishya *et al.* (2019).

Based on the aforementioned investigation, it can be inferred that transplanting basmati rice (PB1121) with 2 seedlings per hill, coupled with a foliar application of 0.1% Fe and 0.04% B during the maximum tillering and panicle initiation stages, resulted in notably enhanced growth, physiological characteristics, and rice yield. Following this, the application sequence of 0.1% Fe during maximum tillering and 0.04% B during panicle initiation also demonstrated improved outcomes in terms of growth and yield under the conditions of western Uttar Pradesh.

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