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SUSTAINABLE SOIL MANAGEMENT FOR NUTRITION SENSITIVE AGRICULTURE THROUGH MICRONUTRIENT INCLUSION IN BORO RICE CULTIVATION

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Abstract

The experiment was conducted in *Boro* season, 2020-21 to compare the performance of fortified rice variety BRRI dhan84 with non-fortified mega variety BRRI dhan89 and their suitable combinations for maximum growth and yield. Treatments were: two rice variety viz., i) BRRI dhan84 (V_1) and ii) BRRI dhan89 (V_2) in the main plot and seven different fertilizer management viz., i) No fertilizer (F_1), ii) Recommended NPKS (RFD) with Zn as basal (F_2), iii) RFD + Zn as foliar at anthesis (F_3), iv) RFD + Zn & B as foliar at anthesis (F_4), v) 50% RFD + 50% Cowdung as basal (F_5), vi) 50% RFD + 50% Cowdung + Zn & B as basal (F_6) and vii) 50% RFD + 50% Cowdung as basal + Zn & B as foliar at anthesis (F_7) in the sub-plot. The experiment was laid out in a Split-plot design having 3 replications. No significant variations observed between the two varieties for almost all the studied characters except filled grains panicle^{-1} where the variety BRRI dhan89 showed higher number of grains (116.14) than the other variety. Foliar application of zinc and born (F_4) gave the highest plant height (102.54 cm), effective tillers hill^{-1} (12.83) that similar (13.00) with F_2 (recommended NPKS with Zn as basal), panicle length (25.91 cm), 1000-grain weight (23.58 g), grain yield (7.67 t ha^{-1}), biological yield (14.85 t ha^{-1}) and harvest index (51.69%). The interaction of V_2F_4 and V_1F_4 resulted superior response for almost all the studied parameters. Foliar application of zinc and boron (F_4) along with RFD increased 8.79 and 27.45% yield in BRRI dhan89 compared to that of foliar (F_3) and basal (F_2) application of zinc, respectively that was 17.11 and 26.77% for the other rice variety BRRI dhan84.

Introduction

Rice (*Oryza sativa* L.) is the staple food in Bangladesh and accounting for approximately 78 percent of the country's total net cropped areas cultivation. The country achieves an autarky to meet up the rice demand for its 169.04 million peoples from 11.55 million hectares of cultivated gross area (Kabir *et al*., 2020; Nasim *et al*., 2021). Rice provides about 75% of the calories and 55% of the protein in the average daily diet of the people of Bangladesh and contributes 18% to GDP (Bhuiyan *et al*., 2002). Grain quality has always been an important consideration in rice variety selection and development. Fortified rice varieties are rich in micronutrients like zinc and iron. Nutrition-sensitive agriculture is a food-based approach to agricultural development that puts nutritionally rich foods to overcome malnutrition and micronutrient deficiencies. Micronutrients provided by soils are crucial for plant development and growth. Nutrient mining occurs when crops take out a high proportion of the nutrients available in the soil, leaving a nutrient imbalance that threatens the sustained provision of food and ecosystem services. Furthermore, good nutrition is achieved through healthy and balanced diets, composed of foods with adequate nutritional composition. Exploring different soil management practices can help increase the nutritional content of crops, as many are directly affected by the nutritional status of the soil.

FAO and ITPS (2015) have demonstrated the extent of soil fertility has suffered from unsustainable management practices. Rates of malnutrition in Bangladesh are among the highest in the world. More than 54 %t of preschool-age children, equivalent to more than 9.5 million children, are stunted, 56 percent are underweight and more than 17 % wasted. Bangladeshi children also suffer from high rates of micronutrient deficiencies, particularly vitamin A, iron, iodine and zinc deficiency. Improving nutrition through soils can have a significant impact on malnutrition in Bangladesh. This population-wide zinc deficiency is one key reason why stunting affects 41% of children in Bangladesh aged under five years (Rahman *et al.*, 2016).

Cultivation of MV and hybrid varieties of different crops is deteriorating soil fertility status of most Bangladesh soil day by day due to exhaustive nature of those varieties. As a consequences new nutrient deficiency in soil is emerging. Chronologically N, P, K, S, Zn and B deficiencies have arisen in Bangladesh soils (Islam, 2008). Some reasons of micronutrient deficiency in Bangladesh were highlighted by Jahiruddin and Islam (2014) and those are organic matter depletion, unbalanced use of fertilizers, minimum or no use of manure, high cropping intensity, high pH (e.g. calcareous soils), nutrient leaching and light textured soils (Jahiruddin and Islam, 2014). Rice bio-fortified with zinc (zinc rice) could help the critical gap by delivering up to 90% of their daily dietary requirements of zinc naturally (Bashar and Miah, 2016). Rice var. BRRI dhan84 composes of zinc which may scale up its potentially-competitive agronomic characteristics along with another non-fortified variety. Kaer *et al*. (2020) also reported that the zinc enriched BRRI dhan84 is a superb variety for cultivating in the dry (*Boro*) season and farmers can be economically benefited. The study was therefore undertaken to compare the performance of fortified rice var. BRRI dhan84 with BRRI dhan89 and to determine the suitable fertilizer management.

Materials and Methods

The experiment was conducted during the December 2020 to June 2021 at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka. The seeds of *Boro* rice var. BRRI dhan84 and BRRI dhan89 were used as plant materials and the seeds were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The basal recommended dose i.e., urea, TSP, MoP, Zn and B and with cowdung were used in the experiment as per treatment. The whole amount of all fertilizers except urea along with cowdung was applied as a basal dose during final land preparation. The urea fertilizer was applied as four equal splits at 10, 20, 30 and 40 days after transplanting (DAT). The foliar application of Zn and B were applied as per treatment before anthesis. The sprouted seeds of two rice varieties were sown in the nursery bed on 05 December, 2020 from which 35 days old seedlings were transplanted in the main field on 10 January, 2021 maintaining 20 cm x 20 cm spacing.

The experiment was laid out in a Split-plot design with three replications. The treatments were two variety viz., i) BRRI dhan84 (V_1) and ii) BRRI dhan89 (V_2) in the main- plot and seven different fertilizer management viz., i) No fertilizer (F_1), ii) Recommended NPKS (RFD) with Zn as basal (F_2), iii) RFD + Zn as foliar at anthesis (F_3), iv) RFD + Zn & B as foliar at anthesis (F_4), v) 50% RFD + 50% Cowdung as basal (F_5), vi) 50% RFD + 50% Cowdung + Zn and B as basal (F_6) and vii) 50% RFD + 50% Cowdung as basal + Zn and B as foliar at anthesis (F_7) in the sub-plot. Water was ensured to the field throughout the growing season up to 10 days before harvesting. Two hand weedings were done for all the treatments on 30 and 45 DAT. The field was infested by different insects and diseases those controlled by applying appropriate ways in time. Five hills per plot was randomly selected for collecting plant height, number of tillers hill^{-1} and SPAD value at stipulated dates. The yield and yield attributes were recorded. The grain yield and straw yield were recorded at 12 % moisture level. Statistical analyses were done by using the Crop Stat computer package and the mean differences among the treatments were compared by least significant difference test at 5 % level of significance following Gomez and Gomez (1984).

Results and Discussion

Effect of variety

All the studied characters showed non-significant variation between the two varieties except number of filled grains panicle^{-1} where BRRI dhan89 (116.14) showed higher response compared to that of BRRI dhan84 (89.47) (Table 1 and Table 2). The mega var. BRRI dhan89 resulted 29.81% higher number of filled grains panicle^{-1} than the other biofortified variety BRRI dhan84. Numerically the variety BRRI dhan89 showed 7.36% higher grain yield than BRRI dhan84. Similar variation of filled grains panicle^{-1} among rice varieties was also reported by Khatun *et al*. (2020).The number of grains panicle^{-1} is mainly determined by the panicle architecture, including panicle length and the number and length of primary, secondary and higher order branches (Sakamoto and Matsuoka, 2008; Kovi *et al.,* 2011).

Table 1. Varietal and fertilizer response on different crop characters of *Boro* rice

Treatments	**Plant height (cm)**	**Effective tillers hill^{-1} (No.)**	**Panicle length (cm)**	**Filled grains panicle^{-1} (No.)**	**Unfilled grains panicle^{-1} (No.)**
Variety					
V_1	96.05	12.14	25.36	89.47b	18.43
V_2	97.60	10.86	26.09	116.14a	16.71
$LSD_{(0.05)}$	NS	NS	NS	13.394	NS
CV (%)	5.38	14.51	4.92	9.81	17.54
Fertilizer management					
F_1	86.74d	9.17c	24.75b	96.50ab	13.83c
F_2	99.40abc	13.00a	25.49ab	98.83ab	21.17ab
F_3	99.73ab	12.83a	25.75a	108.17ab	18.50abc
F_4	102.54a	12.83a	25.91a	105.67ab	22.83a
F_5	97.67bc	11.50ab	25.93a	105.33ab	16.17bc
F_6	94.44c	10.33bc	26.14a	92.33b	14.83c
F_7	97.25bc	10.83abc	25.91a	112.83a	15.67c
$LSD_{(0.05)}$	4.297	2.183	1.020	20.307	6.284
CV (%)	3.72	15.93	3.33	16.58	30.01
Interaction					
V_1F_1	84.19e	9.67cde	24.25c	85.33cde	11.33d
V_1F_2	100.14ab	14.00a	25.24bc	76.00de	26.67a
V_1F_3	97.77abc	13.00ab	25.58abc	96.67a-e	17.00bcd
V_1F_4	102.02ab	12.67abc	26.09ab	92.00b-e	24.33ab
V_1F_5	98.23abc	13.67a	25.71ab	97.00a-e	15.00cd
V_1F_6	92.81cd	10.33b-e	25.43abc	75.00e	16.33bcd
V_1F_7	97.20abc	11.67a-e	25.22bc	104.33a-d	18.33a-d
V_2F_1	89.29de	8.67e	25.66abc	107.68abc	16.33bcd
V_2F_2	98.65abc	12.00a-d	25.73ab	121.67a	15.67bcd
V_2F_3	101.70ab	12.67abc	25.92ab	119.67ab	20.00a-d
V_2F_4	103.05a	13.00ab	25.73ab	119.33ab	21.33abc
V_2F_5	97.11abc	9.33de	26.15ab	113.67abc	17.33bcd
V_2F_6	96.08bc	10.33bcde	26.84a	109.67abc	13.33cd
V_2F_7	97.29abc	10.00bcde	26.59ab	121.33a	13.00cd
$LSD_{(0.05)}$	6.077	3.088	1.442	28.719	8.887
CV (%)	3.72	15.93	3.33	16.58	30.01

V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = No fertilizer, F_2 = RFD with Zn as basal, F_3 = RFD with Zn as foliar, F_4 = RFD with Zn and B as foliar, F_5 = 50% RFD & 50% cowdung, F_6 = 50% RFD & 50% cowdung with Zn and B as basal, F_7 = 50% RFD & 50% cowdung with Zn and B as foliar

Effect of fertilizer management

The highest plant height (102.54 cm) at harvest, highest number of effective tillers hill^{-1} (12.83), 1000-grain weight (23.58 g), grain yield (7.67 t ha^{-1}), biological yield (14.85 t ha^{-1}) and harvest index (51.69 %) was recorded from the F_4 (RFD with Zn and B as foliar) treatment but the lowest result given by F_1 (No fertilizer) treatment for most of the studied parameters (Table 1 and Table 2). Application of RFD (NPKS) as per FRG (2018) but zinc and boron as foliar application during anthesis (F_4) gave 27.20 % and 74.32 % higher grain yields than F_2 (RFD with Zn as basal dose) and F_1 (No fertilizer) treatments respectively. Significant effect of zinc on plant height of rice was reported by Uddin *et al*. (1997), effective tillers hill^{-1} by Rahman *et al*. (2008), grain yield by Islam *et al*. (1997), Wasaya *et al*. (2017) and Azad (2018) and straw yield by Islam *et al*. (1997).

Interaction of variety and fertilizer management

The treatment combination of V_2F_4 (BRRI dhan89 and RFD with Zn and B as foliar application) showed the highest plant height (103.05 cm), grain yield (7.80 t ha^{-1})and biological yield (15.31 t ha^{-1}) compared to that of other interactions whereas the highest number of effective tillers hill^{-1} (14.00) by V_1F_2, panicle length (26.84 cm) by V_2F_6, number of filled grains panicle^{-1} (121.67) by V_2F_2, number of unfilled grains panicle^{-1} (26.67) by V_1F_2, 1000-grain weight (23.83 g) by V_2F_6, straw yield (8.11 t ha^{-1}) by V_2F_3 and harvest index (52.36 %) by V_1F_4 treatment combinations (Table 1 and Table 2). The lowest parameters were recorded from V_1F_1 (BRRI dhan84 and no fertilizer application) interactions.

Recommended fertilizer dose (RFD) with zinc and boron as foliar spray (F_4) gave 76.06 % and 72.71 % higher yield compared to their respective control (F_1) of BRRI dhan89 (V_2) and BRRI dhan84 (V_1) respectively whereas 27.45 % and 26.77 % higher than F_2 (RFD with zinc as basal dose). Zinc being essential nutrient plays a significant role in stomatal regulation and reducing the tensions of less water by creating ionic balance in plants system (Baybordi, 2006) and is involved in various physiological processes such as synthesis of protein and carbohydrates (Yadavi *et al*., 2014). Similarly, B application improves growth, and enhances stress tolerance in plants and improves grain production (Hussain *et al*., 2012). Both Zn and B play an important role in the basic plant functions like photosynthesis, protein and chlorophyll synthesis (Cakmak, 2008).

Table 2. Grain weight, yield and harvest index of *Boro* rice affected by variety and fertilizer management

Treatments	1000-grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Variety					
V_1	21.64	5.98	6.72	12.70	46.88
V_2	22.34	6.42	7.25	13.66	46.79
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	7.90	9.21	26.19	17.66	10.09
Fertilizer Management					
F_1	20.57d	4.40e	6.92abc	11.32e	39.05d
F_2	20.98cd	6.03c	7.31a	13.34cd	45.34c
F_3	21.42cd	6.80b	7.48a	14.28ab	47.81bc
F_4	23.58a	7.67a	7.19ab	14.85a	51.69a
F_5	23.33ab	6.86b	7.01abc	13.87bc	49.45ab

Treatments	1000-grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_6	22.13abc	6.10c	6.63bc	12.73d	47.91bc
F_7	21.92bcd	5.54d	6.37c	11.91e	46.61bc
$LSD_{(0.05)}$	1.474	0.402	0.636	0.664	2.924
CV (%)	5.62	5.45	7.65	4.23	5.24
Interaction					
V_1F_1	19.80e	4.36h	6.86bc	11.22g	39.02e
V_1F_2	21.70b-e	5.94ef	6.97bc	12.91de	46.04cd
V_1F_3	20.63de	6.43de	6.85bc	13.27d	48.45a-d
V_1F_4	23.47ab	7.53ab	6.87bc	14.40ab	52.36a
V_1F_5	23.33abc	6.60cd	6.83bc	13.42cd	49.11abc
V_1F_6	20.43de	5.73fg	6.40c	12.12efg	47.30bcd
V_1F_7	22.13a-d	5.29g	6.28c	11.57fg	45.86cd
V_2F_1	21.33cde	4.43h	6.98bc	11.41fg	39.07e
V_2F_2	20.26de	6.12def	7.65ab	13.77bcd	44.63d
V_2F_3	22.20a-d	7.17bc	8.11a	15.28a	47.17bcd
V_2F_4	23.70ab	7.80a	7.50ab	15.31a	51.02ab
V_2F_5	23.33abc	7.13bc	7.18bc	14.32bc	49.78abc
V_2F_6	23.83a	6.47de	6.86bc	13.33d	48.52a-d
V_2F_7	21.70b-e	5.79fg	6.45c	12.24ef	47.35bcd
$LSD_{(0.05)}$	2.084	0.569	0.900	0.940	4.136
CV (%)	5.62	5.45	7.65	4.23	5.24

V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control, F_2 = RFD with Zn as basal, F_3 = RFD with Zn as foliar, F_4 = RFD with Zn and B as foliar, F_5 = 50% RFD & 50% cowdung, F_6 = 50% RFD & 50% cowdung with Zn and B as basal, F_7 = 50% RFD & 50% cowdung with Zn and B as foliar

Conclusion

Based on the results of the study, it may be concluded that the fortified *Boro* rice variety BRRI dhan84 has the ability to produce similar yield to other mega variety BRRI dhan89. Foliar application of zinc and boron during anthesis along with recommended fertilizer (NPKS) showed higher yield compared to that of basal application of zinc & with NPKS. The recommended fertilizer dose (NPKS) of *Boro* rice with zinc and boron as foliar spray (F_4) during anthesis gave 76.06 % and 72.71 % higher yield compared to their respective control (F_1) of BRRI dhan89 (V_2) and BRRI dhan84 (V_1) respectively whereas 27.45 % and 26.77 % higher than F_2 (NPKS with zinc as basal dose). However, to reach a specific conclusion and recommendation, experiments with different levels of other micronutrients need to be repeated with more varieties and in different Agro-ecological zones.

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