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Effect of Different Micronutrients on Growth and Yield of Rice

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAS designed the study, wrote the protocol, analyses of the study performed and wrote the first draft of the manuscript. Author MAH managed the experimental process. Authors MJAM and TSH managed the literature searches. Author PCR identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the effect of different micronutrients including zinc (Zn), copper (Cu), manganese (Mn) and boron (B) on growth and yield of rice (BRRI dhan29).
Study Design: The study was laid out in a randomized complete block design with three replications.
Place and Duration of Study: The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the boro season of 2014-2015.
Methodology: There were altogether five treatment combinations viz. T_1: Control (NPKS), T_2: NPKS+Zn, T_3: NPKS+Zn+Cu, T_4: NPKS+Zn+Cu+Mn and T_5: NPKS+Zn+Cu+Mn+B. The total number of unit plots was 15 and the size of unit plot was 5 m × 3 m. The doses of micronutrients were 1 kg Zn ha^{-1}, 2 kg Cu ha^{-1}, 3 kg Mn ha^{-1} and 1 kg B ha^{-1}.
Results: The grain and straw yield and the yield contributing characters like plant height, panicle length, number of effective tillers $hill^{-1}$, grains $panicle^{-1}$ and dry matter yield were significantly influenced by different treatments. The treatment T_3 produced the tallest plant (44.67 cm, 61.00 cm,

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72.07 cm and 92.13 cm at 30, 45, 60 DAT and at harvest respectively), highest number of tillers (10.80, 20.90, 21.67 and 18.40 at 30, 45, 60 DAT and at harvest respectively) and dry matter yield (2.04 g, 3.70 g, 8.16 g and 8.44 g at 30, 45, 60 DAT and at harvest respectively) over the other treatments. The highest panicle length (25.00 cm), number of filled grains per panicle (105.50), grains per panicle (128.50) and thousand grain weight (22.10 g) were also observed in treatment T_3. The lowest values of all the parameters were obtained from control (T_1). Grain yield (6.13 t ha^{-1}) and straw yield (7.23 t ha^{-1}) of boro rice were also highest due to treatment T_3 followed by T_4, T_2 and T_5. Based on the overall results, treatment T_3 was found to be the best combination of micronutrients along with NPK for obtaining maximum yield and quality of boro rice.

Conclusion: Application of Zn and Cu may be recommended for better performance of rice.

Keywords: Micronutrients; BRRI dhan 29; growth and yield.

1. INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereal crops of the world, grown in a wide range of climatic zones. Bangladesh is an agro-based developing country where agriculture is the single largest sector of the economy and this sector is largely dominated by rice production [1]. Among all crops, rice is the driving force of agriculture in Bangladesh and the cropping pattern of the country is predominately rice-based. In Bangladesh, 77 percent of total cropped area is used for rice production and 93% farmers are involved in rice cultivation. The total area and production of rice in this country are about 11.7 million hectares and 31.98 million metric tons, respectively [2].

Rice is the staple dietary item for the people in Bangladesh which contributes more than 80 percent to the total food supply [2]. It is not only the main source of carbohydrate but also provides 69.61% of calories and 56.15% of the proteins in the average daily diet of the people [3]. Food security is a major concern in our country because food requirement is increasing at an alarming rate due to increasing population. Rice yield in Bangladesh is comparatively lower than that of other South East Asian countries because of poor fertilizer management. It is necessary to enhance rice production to meet the increasing food demand for the vast growing population of the country which increases at the rate of 1.32 percent per annum [4] and the increase in rice production can be achieved by efficient and good agricultural practices, water and nutrient inputs [5].

Micronutrients are as important as macronutrients in plant nutrition and the deficiency of micronutrients is considered one of the major causes of declining the productivity trends in rice growing countries including Bangladesh. Micronutrients are needed in trace amounts but their adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield as well [6]. Farmers apply N, P, K and S fertilizers widely and application of micronutrients such as Zn, Cu, Mn and B is not a usual practice. Soils deficient in their supply of micronutrients are alarmingly widespread across the globe due to intensive cropping, loss of fertile topsoil and losses of nutrients through leaching [7]. When micronutrients are in short supply, the growth and yield of crops are severely depressed [8]. The presence of micronutrient deficiency renders it impossible for the plants to gain maximum benefit from NPK fertilizers application. Micronutrient deficiency in 50% of the world's soils and many crops greatly reduces the amount and quality of food which adversely affects human health, the economic status of farmers and the environment around the world [9].

Despite the fact that these nutrients are actively involved in various plant growth mechanisms, their specific role for yield improvement in crops is still need to be investigated. The exact effects of applying micronutrients in combination with NPK to rice crop in micronutrient deficient soils and specific climate conditions need to be better established. In order to improve crop productivity, the limiting micronutrient (s) must be identified and the soils should be enriched with the addition of those nutrients in properly balanced fertilizer programme. Keeping this in view, the present research was undertaken to investigate the effect of micronutrients viz. Zn, Cu, Mn and B along with NPK on growth and yield of rice (BRRI dhan29).

2. MATERIALS AND METHODS

The study was carried out at the Soil Science Field laboratory of Bangladesh Agricultural

University, Mymensingh during the boro season of 2014-2015. The soil of the experimental site belongs to the Sonatala series under the AEZ of Old Brahmaputra Floodplain. Geographically, the experimental site is situated at the latitude of 24.74º N and longitude of 90.50º E at an elevation of 18 m above the sea level. The soil was silt loam in texture having pH 6.49, organic matter content 1.52%, total N 0.08%, available P 11.11 ppm, exchangeable K 0.24 me% and available S 16.95 ppm. There were five treatments as follows:

- T_1 : Control (NPKS)
- T_2 : NPKS+Zn
- T_3 : NPKS+Zn+Cu
- T_4 : NPKS+Zn+Cu+Mn
- T_5 : NPKS+Zn+Cu+Mn+B

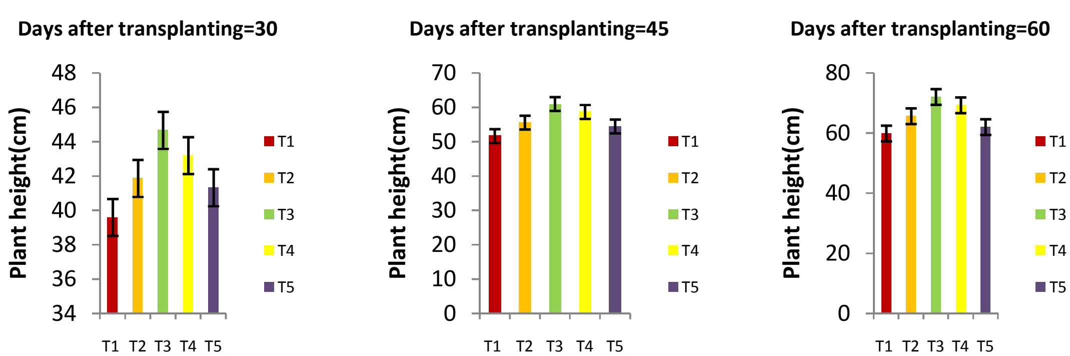
The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of unit plots was 15 and the size of unit plot was 5 m × 3 m. The experimental field had lower status of N and K, medium status of P and S and was deficient in micronutrients as described in a previous report [10]. All the treatments received 80 kg N, 20 kg P, 30 kg K and 10 kg S ha^{-1} from urea, triple super phosphte (TSP), muriate of potash (MoP) and gypsum, respectively. The full doses of TSP, MoP and gypsum were applied before transplanting as basal dose to all the experimental plots. Urea was applied in three equal splits. The first split was applied during final land preparation. Second and third splits of urea were applied as top dressing at 10 and 45 days after transplanting. The doses of micronutrients were 1 kg Zn ha^{-1}, 2 kg Cu ha^{-1}, 3 kg Mn ha^{-1} and 1 kg B ha^{-1} which were supplied from librel zinc, $CuSO_4.5H_2O$, $MnCl_2.H_2O$ and librel boron. About 35 day-old seedlings of rice (BRRI dhan29) were transplanted in the experimental plots on February 10, 2015 by maintaining a spacing of 20 cm × 20 cm. Different intercultural operations such as irrigation, weeding, pest control etc. were done as and when required. The crop was harvested at full maturity on June 5, 2015.

The data on plant parameters including plant height, number of effective tillers hill^{-1} and dry matter accumulation were observed at 30, 45, 60 DAT (days after transplanting) and at harvest. The other growth and yield parameters such as panicle length, grains panicle^{-1}, 1000-grain weight were recorded at harvest. The grain and straw yields were measured and expressed at 14% moisture basis. All the data were statistically analyzed by F-test and the mean differences were ranked by DMRT [11]. Differences at $p < 0.05$ were considered significant.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters of Rice (BRRI dhan29) at Different Growth Stages

The application of micronutrients had significant effects on the plant growth parameters viz. plant height, number of effective tillers hill^{-1} and dry matter yield at different growth stages of rice crop (Figs. 1-3). For plant height at 30, 45 and 60 DAT, the highest values of 44.67, 61.00 and 72.07 cm respectively were obtained from T_3) which were statistically similar with the values of 43.20, 58.73 and 69.33 cm found in T_4. The shortest plants at all these three stages (39.60, 51.73 and 59.93 cm) were observed in T_1 (control NPKS). Similar results were previously reported by El-Nahhal [12].



a: DAT 30 **b: DAT 45** **c: DAT 60**

Fig. 1(a,b,c). Plant height of rice (BRRI dhan29) as influenced by different micronutrients

For number of effective tillers hill^{-1} at 30, 45 and 60 DAT, the highest values of 10.80, 20.90 and 21.67 were obtained from T_3 and the lowest values of 9.07, 17.00 and 17.73 were observed in T_1. The results revealed that addition of Zn with Cu performed the best in improving plant height and number of effective tillers hill^{-1} at different growth stages followed by addition of Zn with Cu and Mn and the rates of increase were higher between 30 and 45 DAT than between 45 and 60 DAT. Narimani et al. [13] observed higher number of fertile tillers plant^{-1} in durum wheat due to combined application of Zn and Cu. Micro nutriments have been shown to increase the growth of sweet corn reported by El-Nahhal [14,15].

Dry matter yield of rice (BRRI dhan29) measured at different growth stages (30, 45 and 60 DAT) showed remarkable variation between DAT as well as treatment combinations (Fig. 1).

At 30 DAT, the highest dry matter yield of 2.05 g plant^{-1} was obtained from T_3 which was statistically identical with T_2, T_4 and T_5. Again at 45 DAT, the highest dry matter yield of 3.71 g plant^{-1} was obtained from T_3, which was statistically identical with T_2 and T_4. Furthermore, at 60 DAT, treatment T_3 produced the highest dry matter yield of 8.17 g plant^{-1} among all the treatments. At all these three stages, the lowest dry matter yields of 1.69, 3.13 and 5.13 g plant^{-1} were observed in T_1.

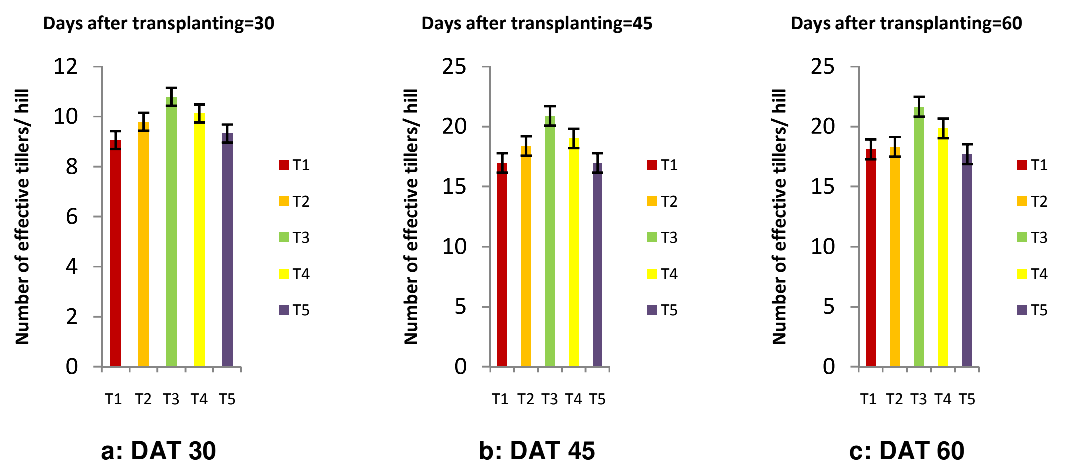


Fig. 2(a,b,c). Number of effective tillers hill^{-1} of rice (BRRI dhan29) as influenced by different micronutrients

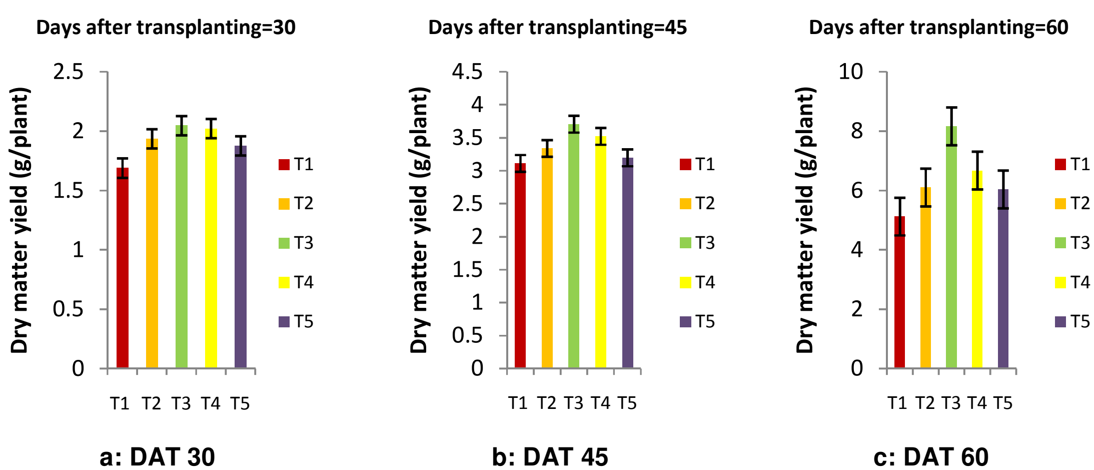


Fig. 3(a,b,c). Dry matter yield of rice (BRRI dhan29) as influenced by different micronutrients

The rates of increase in dry matter yields were higher between 45 and 60 DAT than between 30 and 45 DAT. Our finding is accorded with Nawaz et al. [16] who suggested that dry matter yield of rice was significantly affected by Zn and Cu fertilization.

3.2 Growth Parameters and Yield Components of Rice (BRRI dhan29) at Harvest

At harvest, growth parameters and yield components such as plant height, no. of effective tillers hill^{-1}, panicle length, no. of grains panicle^{-1} and dry matter yield were significantly influenced by the application of different micronutrients (Table 1). The 1000-grain weight remained unaffected by the treatments under study. The tallest plant of 92.13 cm was found in T_3, which was identical with treatment T_4. The shortest plant of 85.67 cm was observed in T_1 (Control NPKS). The highest number of effective tillers hill^{-1} of 18.40 was found in T_3 and the lowest value of 12.10 was observed in T_1. The panicle length varied from 20.60 cm to 25 cm due to different treatments. The highest panicle length (25 cm) was found in T_3 which was identical with T_2, T_4, and T_5 and the lowest panicle length (20.60 cm) was observed in T_1. The number of grains panicle^{-1} varied from 70.30 to 128.50 with the highest value in T_3 which was identical with T_2. The lowest number of grains panicle^{-1} (70.30) was found in control. The highest dry matter yield of 8.45 g plant^{-1} was recorded from T_3 and the lowest value of 5.70 g plant^{-1} was obtained from T_1. Thus among the micronutrients, Zn and Cu as combination with NPK performed the best in increasing growth parameters at harvest and yield components of rice (BRRI dhan29). In contrast heavy metals may have a toxic effects on plant growth. This argument is supported by previous reports by El-Nahhal [17].

The present findings are in agreement with Nawaz et al. [19] who reported that number of panicles m^{-2} and 1000-grain weight of rice were significantly affected by Zn and Cu fertilization and 1000-grain weight was found maximum in the treatments where Zn and Cu were applied @ 10 kg ha^{-1}. Narimani et al. [13] also found higher spike per unit area and increased weight of 1000-kernel in durum wheat due to combined application of Zn and Cu [18].

3.3 Grain and Straw Yields of Rice (BRRI dhan29)

Results in Table 2 show that the grain yield of rice (BRRI dhan29) was significantly influenced due to different treatments. The grain yield ranged from 4.55 to 6.13 t ha^{-1} where the lowest and the highest grain yields were obtained in the T_1 (Control NPKS) and T_3 (NPKS+Zn+Cu) respectively. The highest grain yield as found in T_3 was statistically similar to T_4 (NPKS+Zn+Cu+Mn) and T_2 (NPKS+Zn) treatments. The grain yield due to different treatments may be ranked in the order of $T_3 > T_4 > T_2 > T_5 > T_1$. The percent increase in grain yield of rice (BRRI dhan29) over control due to different treatments ranged from 17.14 to 34.72. Among the treatments, T_3 and T_5 gave the highest (34.72%) and the lowest (17.14%) yield increase over control, respectively.

On the other hand, straw yield of rice (BRRI dhan29) was also influenced significantly by different treatments under study (Table 2). The straw yield ranged from 5.56 to 7.23 t ha^{-1}. It was observed that the treatment T_3 produced the highest straw yield which was statistically identical with T_4 and T_2. The lowest straw yield obtained in T_1 (Control NPKS) was not statistically different from T_5. The straw yield due to different treatments may be ranked in the

Table 1. Growth parameters at harvest and yield components of rice (BRRI dhan29) as influenced by different micronutrients

Treatments	Plant height (cm)	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000 grain wt (g)	Dry matter yield (g plant^{-1})
T_1 (Control NPKS)	85.67±0.72c	12.10±0.82d	20.60±0.52b	70.30±8.55d	20.70±0.12	5.70 ±0.30c
T_2 (NPKS+ Zn)	89.00±1.15b	14.20±1.25c	24.10±0.81a	108.90±11.45b	20.80±0.31	6.94±0.48b
T_3 (NPKS+Zn+Cu)	92.13±0.92a	18.40±0.98a	25.00±0.75a	128.50±13.25a	22.10±0.29	8.45±0.45a
T_4 (NPKS+Zn+Cu+Mn)	89.73±1.24ab	16.50±1.35b	23.10±0.68a	121.30±9.52a	21.40±0.21	7.07±0.52b
T_5(NPKS+Zn+Cu+Mn+B)	87.53±0.85bc	13.50±0.85c	22.70±0.62ab	89.40±8.75c	20.70±0.18	6.66±0.32bc
CV (%)	1.71	3.20	5.08	5.07	5.54	7.96

Figures in a column having common letter(s) do not differ significantly at 5% level of significance. CV = Coefficient of variation;

Table 2. Grain and straw yields of rice (BRRI dhan29) as influenced by different micronutrients

Treatments	Grain yield (t/ha)	% increase over control	Straw yield (t/ha)	% increase over control
T_1 (Control NPKS)	4.55±0.07 c	-	5.560±0.09 c	-
T_2 (NPKS+ Zn)	5.79±0.24 ab	27.25	6.530±0.18 ab	17.45
T_3 (NPKS+Zn+Cu)	6.13±0.17 a	34.72	7.230±0.14 a	30.03
T_4 (NPKS+Zn+Cu+Mn)	5.85±0.21 ab	28.57	6.670±0.15 ab	19.96
T_5 (NPKS+Zn+Cu+Mn+B)	5.33±0.11 b	17.14	6.230±0.06 bc	12.05
CV (%)	4.17	-	5.15	-

Figures in a column having common letter(s) do not differ significantly at 5% level of significance. CV = Coefficient of variation;

order of T_3> T_4> T_2> T_5> T_1. The treatments under study resulted in 12.05% to 30.03% increase in straw yield over control. Thus, in the present study, boro rice (BRRI dhan29) responded significantly to added micronutrients especially Zn, Cu and Mn. In a study, Abedin et al. [20] found very low concentration of the micronutrients in soil solution of Bangladesh Agricultural University farm [10]. Previous studies conducted in the same field also showed a response of Cu and Mn in T-aman and Boro rice.

Imtiaz et al. [21] reported that micronutrients applied alone or together with macronutrients have a significant effect on crop yield. Our results reveal that application of micronutrients including Z, Cu, Mn, and B exerted more or less a significant positive effect on grain and straw yields of rice (BRRI dhan29) when applied with NPKS. Certainly, the combination of Zn and Cu with macronutrients proved its superiority and it gave the highest values for grain yield as well as straw yield of rice (BRRI dhan29). These results were also in agreement with the findings of Qadir et al. [22] Nawaz et al. [19]. In this study, the combined application of Zn with other micronutrients including Cu and Mn on growth and yield performance of rice was better compared to single application of Zn. However, the combination of Zn+Cu+Mn+B was not preferable because of poor growth and yield performance of rice which might be due to some antagonistic effects.

Besides, Zayed et al. [23] suggested that grain and straw yield, harvest index and yield components such as panicle numbers, panicle weight, filled grains panicle^{-1} and 1000-grain weight can be significantly increased in rice by application of micronutrients. Malakouti reported that by supplying plants with micronutrients, increased yield as well as higher quality could be achieved as application of micronutrients can increase grain yield up to 50% in durum wheat (*Triticum durum* L.) [24]. Narimani et al. [13] suggested that micronutrient fertilizers imposed positive effects on economic yield of durum wheat and if only one macronutrient was to be utilized, Zn would obviously be the best choice for improvement of yield and its components. It is also well established that application of Zn increases rice yield [25,26,16]. Application of Cu in rice can also increase dry matter production and yield of rice [27]. Hundal et al. [28] also observed that combined application of micronutrients (Zn, Cu and Mn) can eventually contribute to increase grain yield of rice.

4. CONCLUSION

Micronutrients have immense economic importance since an adequate supply of micronutrients can help to ensure better yields. Application of micronutrients in association with NPKS showed better performance in respect of grain yield and yield contributing characters viz. plant height, number of effective tillers hill^{-1}, number of grains panicle^{-1} and dry matter yield of rice as compared to application of NPKS only. The performance of Zn+Cu with NPKS was the best for improving the growth and yield of rice. Therefore, application of Zn at 1 kg ha^{-1} and Cu at 2 kg ha^{-1} in association with NPKS fertilizers could be the promising combination for maximizing rice yield at BAU farm. This result might be applicable to all over soils under AEZ 9 (Old Brahmaputra Floodplain) of Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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