Effect of Soil Application of Zinc on Growth, Yield and Zinc Concentration in Rice Varieties

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ABSTRACT

Zinc (Zn) deficiency is widespread nutrient disorder in lowland rice growing areas in Asia, especially in Bangladesh. Intensive cropping with modern varieties causes depletion of inherent nutrient reserves in soils. The application of Zn fertilizers results in higher crop productivity and increases Zn concentration in crops. A field experiment was conducted to evaluate the effect of Zn application on growth, yield, and grain-Zn concentration in eight varieties of rice. The experiment was laid out in a split plot design with a distribution of Zn rates (0 kg ha⁻¹ and 3 kg ha⁻¹ from ZnO) to the main plots and rice varieties (BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, Kalizira, Biroin, Gainja and Khirshapath) to the sub-plots. Zinc application improved effective tillers hill⁻¹, grains panicle⁻¹ and 1000-grain weight which impacted the grain yield of rice. Among the eight rice varieties, a significant increase of grain yield was recorded in BRRI dhan49, BRRI dhan52, BRRI dhan56 and BRRI dhan57 due to application of Zn. Zinc concentration of grain significantly increased in all rice varieties except Biroin. The highest grain-Zn concentration (19.1 mg kg⁻¹) was noted in BRRI dhan57 with 3 kg ha⁻¹ Zn and the lowest value (11.3 mg kg⁻¹) was observed in BRRI dhan52 without Zn application. The highest percent increase of grain Zn concentration over control was obtained in high yielding rice variety BRRI dhan49 and the lowest Zn concentration was found in local rice variety Biroin.

Keywords: Grain Yield, Rice Variety, Zinc, Zinc Concentration, Yield Component.

Submitted : November 30, 2021

Published : December 29, 2021

ISSN: 2684-1827

DOI: 10.24018/ejfood.2021.3.6.425

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I. INTRODUCTION

Zinc is an essential trace element for life, responsible for the formation of a large number of enzymes and also plays an essential role, particularly in children, including delays in physical growth, immune system function, DNA transcription etc. [1], [2]. One third of the world populations in the developing countries suffers from Zn deficiency, which is due to inadequate dietary intake [2], [3]. Zinc deficiency reduces immune system, reproductive function, and stunted growth of human [4], [3]. Zinc deficiency in plants inhibits growth and is one of the nutrients influencing rice production in many regions of the world [5], [6]. Among the micronutrients, Zn deficiency one of the most widespread nutrient disorders in lowland rice areas in Asia [7]-[9]. Rice is a major food source consumed by about 50% of the world's population and constitutes 67% of the daily diet and some extent of proteins to humans [10], [11]. Zinc deficiency is an eminent health problem in human populations those consuming rice as their staple food [12], [13]. The average daily rice consumption for adults in Bangladesh of 370 g which is one of the world's highest per capita rice consumptions [14], [15]. Therefore, even a small increase in the nutritive value of rice can be highly significant for human nutrition in Bangladesh [16], [17]. The main reason of Zn deficiency in plant is the precipitation or adsorption of Zn

with various soil components, depending on pH, organic matter, pedogenic oxides and redox potential [18]. The application of Zn may increase grain yield, dry matter content and Zn concentration in rice [19], [20]. Rice varieties showed significant variation in Zn tolerance [20] and in Zn content in rice grains [21]. Rice variety enriched with Zn may be a good source of Zn for those Zn deficient people. For this, biofortification of Zn in rice has emerged as a possible solution to alleviate malnutrition [22], [16], [23]. The practice of intensive cropping with modern crop varieties is a major endeavor of crop production in Bangladesh. This in turn causes a marked depletion of inherent nutrient status in soils. Increasing the Zn concentration of food crops, resulting in higher crop production and improved human health is an important global challenge. Therefore, a field experiment was conducted to study the effect of Zn application on growth, yield, and grain-Zn concentration of four modern and four local varieties of rice.

II. MATERIALS AND METHODS

This study was undertaken at the Soil Science Field Laboratory, Bangladesh Agricultural University, during the T. aman season (August to December) to evaluate the soil application of Zn on growth, yield, and grain Zn concentration of different varieties of rice. The experimental

area comprises the Agro Ecological Zone 9 Old Brahmaputra Flood Plain. Texturally the soil was silt loam having pH 6.3, total N 0.085%, organic matter 1.46%, available P 12.6 mg kg⁻¹, available S 12.8 mg kg⁻¹, exchangeable K 0.105 me% and available Zn 0.70 mg kg⁻¹. There were two rates of Zn viz. 0 and 3 kg Zn ha⁻¹ were applied from ZnO. The experiment was laid out in a split plot design with 3 replications and each treatment having Zn rates in the main plot and rice varieties in the sub plots. The four high yielding rice varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56 and BRRI dhan57, and four local rice varieties viz. Kalizira, Biroin, Gainja and Khirshapath were used in the experiment. There were altogether 16 treatments. The size of each plot was 2×3 m and plots were separated from each other by ails (30 cm). All the plots received 75 kg N, 16 kg P, 42 kg K and 15 kg S ha⁻¹ from urea, triple super phosphate, muriate of potash and gypsum, respectively. The full dose of triple super phosphate, muriate of potash, gypsum and ZnO were applied at the time of final land preparation. The urea was applied in 3 equal splits at 7, 30 and 60 days after transplanting. Thirty-three days old seedlings were transplanted in the experimental plots and each hill consists of 3 seedlings maintaining in an equal distance (20×20 cm) from row to row and from plant to plant. Intercultural operations were employed as and when necessary. The crop was harvested in different dates at maturity. The yield and yield contributing characters (plant height, effective tillers hill⁻¹, filled grains, 1000 grain weight) of all rice varieties were recorded. The grain samples were oven dried at 65°C until constant weight. The grain yields were expressed in t ha⁻¹ at 14% moisture basis while the straw yield on sun dry basis. The grain Zn content was determined by digesting the grain samples with the diacid mixture (HNO₃: HClO₄ in the ratio of 3:1). Zinc was determined from this digest by Atomic Absorption Spectrophotometer (AAS). The analysis of variance for crop parameters and also for nutrient contents in grain was done following the principles of F statistics. The mean results in case of significant F-value were compared by the Duncan's Multiple Range Test (DMRT) [24].

III. RESULTS AND DISCUSSIONS

A. Growth and Yield Parameters

1) Plant height

There was no significant variation of plant height in different rice varieties due to soil application of Zn (Table I). Plant height of 86.33 cm was found rice plants without any Zn application and 90.72 cm with 3 kg Zn ha⁻¹ application. Khirshapath was the tallest (107.90 cm) plant which was statistically similar with Biroin and Gainja. Kalizira had the shortest (73.93 cm) plants which was also statistically similar with BRRI dhan52, BRRI dhan56 and BRRI dhan57. The interaction effect of different rates of Zn and different varieties of rice was statistically significant (TABLE II). The plant height of eight rice varieties over the two Zn rates ranged from 72.03 cm in BRRI dhan49 with 0 kg Zn ha⁻¹ to 108.79 cm in Biroin with 3 kg ha⁻¹ Zn treatment. At two Zn levels, the variety Khirshapath showed the tallest plant and BRRI dhan49 showed the shortest plant. There was no statistically significant variation of plant height with the same

variety due to application of 0 kg ha⁻¹ and 3 kg ha⁻¹ Zn but other varieties.

2) Effective tillers hill⁻¹

Tillering capacity is an important component of grain yield of rice. Increased number of effective tillers per plant can result in higher yield of crop [25]. Zinc application showed insignificant variation in case of effective tillers hill⁻¹ (Table I). The number of effective tillers hill⁻¹ was 7.07 without Zn application and 7.99 with Zn application. The different varieties of rice varied significantly in terms of number of effective tillers hill⁻¹, which ranged from 6.58 to 8.63 (Table II). The highest number of effective tillers hill⁻¹ of 8.63 observed in BRRI dhan57 was statistically identical to those found in BRRI dhan49, BRRI dhan52 and BRRI dhan56. The lowest number (6.58) of effective tillers hill⁻¹ was obtained in Kalizira which was statistically similar with those observed in Biroin, Gainja and Khirshapath. Similar findings have been reported which showed that application of Zn increased number of tillers hill⁻¹ [1]. This result is also consistent with the study showed that application of Zn increased the number of effective tillers hill⁻¹ [26]. The interaction effect of different rates of Zn application and different varieties on number of effective tillers hill⁻¹ was statistically significant (Table II). The formation of effective tillers hill⁻¹ due to application of 3 kg ha⁻¹ of Zn in all varieties was higher than that of Zn control treatments.

3) Filled grains panicle⁻¹

The number of filled grains panicle⁻¹ in rice varieties was found to be insignificant due to soil application of Zn (Table I). The number of filled grains panicle⁻¹ was 65.11 when no Zn was applied, and it was 70.37 with 3 kg ha⁻¹ Zn application. BRRI dhan49 showed the highest number of filled grains panicle⁻¹ (87.54) which was statistically similar to those found in BRRI dhan52, BRRI dhan56 and BRRI dhan57. The interaction of two levels of Zn with different varieties showed significant variation in terms of filled grains panicle⁻¹ of rice (Table II). The highest number of filled grains panicle⁻¹ (92.34) was found in BRRI dhan49 treated with 3 kg ha⁻¹ Zn while the lowest number of filled grains panicle⁻¹ (45.77) was recorded in Kalizira grown without Zn application. The local rice varieties had the lower number of filled grains panicle⁻¹ compared to those of modern rice varieties. The varieties Kalizira, Biroin, Gainja and Khirshapath were statistically similar in both 0 and 3 kg ha⁻¹ Zn applications. Increased rate of Zn significantly increased the number of grains panicle⁻¹ of rice [27] which was similar with the present study. Previous studies confirmed that Zn fertilizer enhanced the number of grains panicle⁻¹ through improving physiological processes of the crop such as photosynthesis and nutrient translocation [28].

4) 1000-grain weight

Result represented in Table I showed that the 1000-grain weight of rice was significantly increased due to application of Zn. The 1000-grain weight was found 17.25 g with 3 kg ha⁻¹ Zn application and 17.12 g without Zn application. Among all the rice varieties, the local rice varieties had lower 1000-grain weight compared to those of the modern rice varieties. The highest 1000-grain weight was observed in BRRI dhan52 (25.07 g) and the lowest weight was observed in Khirshapath (10.88 g). The interaction of Zn and varieties was statistically significant in case of 1000-grain weight (TABLE II). The highest 1000-grain weight (25.07 g) was

observed in BRRI dhan52 with 3 kg ha⁻¹ Zn application and the lowest (10.88 g) was in Khirshapath without Zn application. There was no statistically significant variation of 1000-grain weight due to application of 3 kg ha⁻¹ Zn and without Zn within the same variety, but variations were

observed among the varieties. Proper Zn application rates increased grain weight by allowing Zn to participate more efficiently in the various metabolic processes engaged in good seed production [29].

TABLE I: EFFECTS OF ZINC AND RICE VARIETIES ON THE PLANT HEIGHT, EFFECTIVE TILLERS HILL⁻¹ FILLED GRAINS PANICLE⁻¹ AND 100-GRAIN WEIGHT OF DIFFERENT VARIETIES OF RICE

Factors	Plant height (cm)	Effective tillers hill ⁻¹ (no.)	Filled grains panicle ⁻¹ (cm)	1000-grain wt. (g)
Zn rates (kg ha ⁻¹)				
Zn ₀	86.33	7.07	65.11	17.12
Zn ₃	90.72	7.99	70.37	17.25
CV (%)	5.70	8.28	10.48	6.99
Level of significance	NS	NS	NS	***
Varieties				
BRRI dhan49	74.97b	8.47a	87.54a	18.44c
BRRI dhan52	79.49b	7.78ab	85.79a	25.03a
BRRI dhan56	82.03b	7.77ab	82.32a	22.68b
BRRI dhan57	76.45b	8.63a	83.72a	14.16ef
Kalizira	73.93b	6.58c	46.87b	12.74fg
Biroin	107.23a	7.07bc	56.12b	17.50cd
Gainja	106.17a	6.87bc	47.72b	16.00de
Khirshapath	107.90a	7.07bc	51.84b	10.89g
CV (%)	7.70	8.28	9.48	6.99
Level of significance	**	**	**	**

In a column, the figures having common letter(s) do not differ significantly at 5% level of probability. CV = Coefficient of variation, ** = P<0.001; NS = Not significant.

TABLE II: COMBINED EFFECTS OF ZINC AND RICE VARIETIES ON THE PLANT HEIGHT, EFFECTIVE TILLERS HILL⁻¹ FILLED GRAINS PANICLE⁻¹ AND 100-GRAIN WEIGHT OF DIFFERENT VARIETIES OF RICE

Variety	Zn rates	Plant height (cm)	Effective tillers hill ⁻¹ (no.)	Filled grains panicle ⁻¹ (cm)	1000 grain wt. (g)
BRRI dhan49	Zn ₀	72.03c	7.93bcd	82.73ab	18.42c
	Zn ₃	77.91c	9.00ab	92.34a	18.47c
BRRI dhan52	Zn ₀	74.97c	7.23cdef	81.20ab	25.00a
	Zn ₃	84.01abc	8.33abc	90.37ab	25.07a
BRRI dhan56	Zn ₀	78.00c	7.20cdef	77.80b	22.75b
	Zn ₃	86.06abc	8.33abc	86.84ab	22.60b
BRRI dhan57	Zn ₀	72.87c	8.10abcd	79.53ab	14.13ef
	Zn ₃	80.02bc	9.17a	87.90ab	14.20ef
Kalizira	Zn ₀	73.40c	6.17f	45.77c	12.75fg
	Zn ₃	74.45c	7.00def	47.97c	12.73fg
Biroin	Zn ₀	105.67ab	6.63ef	55.37c	17.50cd
	Zn ₃	108.79a	7.50cde	56.87c	17.50cd
Gainja	Zn ₀	105.67ab	6.63ef	47.30c	16.00de
	Zn ₃	106.67a	7.10def	48.14c	16.00de
Khirshapath	Zn ₀	108.00a	6.63ef	51.17c	10.88h
	Zn ₃	107.81a	7.50cde	52.51c	11.40gh
CV (%)		6.34	8.28	7.48	6.99
Level of significance		**	**	**	**

In a column, the figures having common letter(s) do not differ significantly at 5% level of probability. CV = Coefficient of variation ** = P<0.01.

TABLE III: EFFECTS OF ZINC AND RICE VARIETIES ON THE GRAIN YIELD, STRAW YIELD AND GRAIN ZINC CONCENTRATION OF DIFFERENT VARIETIES OF RICE

Factors	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Zn concentration (mg kg ⁻¹)
Zn rates (kg ha ⁻¹)			
Zn ₀	3.34b	4.53b	13.74b
Zn ₃	3.72a	5.02a	16.62a
CV (%)	6.87	6.59	8.90
Level of significance	*	**	**
Varieties			
BRRI dhan49	4.85a	4.90bc	13.87bcd
BRRI dhan52	4.32b	4.64c	12.66d
BRRI dhan56	4.19b	4.67c	13.69cd
BRRI dhan57	3.29c	3.66d	17.08a
Kalizira	2.60d	4.89bc	16.21ab
Biroin	3.09c	5.61a	15.92abc
Gainja	3.03c	5.28ab	14.78abcd
Khirshapath	2.86cd	4.56c	17.22a
CV (%)	6.87	6.59	8.90
Level of significance	**	**	**

In a column, the figures having common letter(s) do not differ significantly at 5% level of probability. CV = Coefficient of variation, ** = P<0.01.

TABLE IV: COMBINED EFFECTS OF ZINC AND RICE VARIETIES ON THE GRAIN YIELD, STRAW YIELD AND GRAIN ZINC CONCENTRATION OF DIFFERENT VARIETIES OF RICE

Variety	Treatments	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Zn concentration (mg kg ⁻¹)
RRI dhan49	Zn ₀	4.54b	4.67def	12.20gh
	Zn ₃	5.15a	5.13bcd	15.53cdef
BRRi dhan52	Zn ₀	4.02c	4.41ef	11.25h
	Zn ₃	4.62b	4.86cdef	14.07efg
BRRi dhan56	Zn ₀	3.80cd	4.44ef	12.19gh
	Zn ₃	4.60b	4.90cdef	15.19cdef
BRRi dhan57	Zn ₀	3.09efg	3.47h	15.07cdef
	Zn ₃	3.48de	3.85gh	19.09a
Kalizira	Zn ₀	2.53h	4.62def	14.96cdef
	Zn ₃	2.66gh	5.16bcd	17.46abc
Biroin	Zn ₀	2.93fgh	5.31bc	14.79def
	Zn ₃	3.25ef	5.91a	17.04abcd
Gainja	Zn ₀	2.98fgh	5.00cde	13.36fgh
	Zn ₃	3.08efg	5.58ab	16.20bcde
Khirshapath	Zn ₀	2.82fgh	4.32fg	16.06bcde
	Zn ₃	2.90fgh	4.80cdef	18.38ab
CV (%)		6.87	6.59	8.90
Level of significance		*	**	**

In a column, the figures having common letter(s) do not differ significantly at 5% level of probability. CV = Coefficient of variation, ** = P<0.01 * = P<0.1.

B. Grain Yield

Grain yield of rice varieties showed significant variation due to application of Zn to the soil (Table III). The highest grain yield (4.85 t ha⁻¹) was observed in BRRi dhan49 with 3 kg ha⁻¹ Zn application and the lowest (2.53 t ha⁻¹) was in Kalizira without Zn application. The interaction of two levels of Zn with different varieties showed significant variation in grain yield of rice (Table IV). The highest grain yield (5.15 t ha⁻¹) was observed in BRRi dhan49 with 3 kg ha⁻¹ Zn application and the lowest (2.53 t ha⁻¹) was in Kalizira without any Zn application. Among the eight varieties of rice significant increase of grain yield was observed in BRRi dhan49, BRRi dhan52 and BRRi dhan56 due to application of Zn compared to Zn control treatment. In BRRi dhan52 and four local varieties, the yield increase due to Zn application was not significant compared to Zn control treatments. The percent increase in grain yield over control in modern varieties ranged from 12.6-21.1% while in local varieties it ranged from 2.8 to 10.9% (Fig.1). These findings also were in agreement with the other findings [30] [31]. All the research findings indicate a highly significant yield response was obtained from the application of Zn. Zinc fertilization led to a significant increase in rice yield [19]. The increased yield due to Zn fertilization is related to its participation in various metallic enzyme reactions, regulatory functions, and auxin production [32].

Fig. 1. Percent increase of grain yield over control for different varieties of rice

C. Straw Yield

Straw yield of rice showed significant increase due to soil application of Zn (Table III). The highest straw yield was observed in Biroin with 3 kg ha⁻¹ Zn application which was statistically similar with Gainja and the lowest straw yield (3.47 t ha⁻¹) was observed in BRRi dhan57 without any Zn application (Table III). These results have conformity with the evidence of other study [33]. Higher levels of Zn (10 and 15 kg Zn ha⁻¹) increased both straw and grain yields [34]-[37]. The interaction of two levels of Zn with different varieties showed variation in terms of straw yield (TABLE IV). The highest straw yield was observed in Biroin with 3 kg ha⁻¹ Zn application which was statistically similar with Gainja and the lowest straw yield (3.47 t ha⁻¹) was observed in BRRi dhan57 without Zn application.

D. Grain-Zn Concentration

High grain-Zn concentration is considered a desirable quality [38] of food grain. In terms of grain Zn concentration, significant variation was observed with different varieties of rice (Table III & IV). The highest grain Zn concentration (19.09 mg kg⁻¹) was observed in BRRi dhan57 with 3 kg ha⁻¹ Zn application and the lowest Zn concentration (11.25 mg kg⁻¹) was observed in BRRi dhan52 without Zn application. Among the eight varieties of rice, significant increase of Zn concentration in grain was observed in all varieties except Bi-

Fig. 2. Percent increase of grain Zn concentration over control for different varieties of rice

-roin due to Zn fertilization. Application of Zn increased grain Zn contents of rice as reported by various workers [39] [40]. The percent increase in grain Zn concentration over control in modern rice varieties ranged from 24.3-27.3% while in local varieties it ranged from 15.21 to 21.2% (Fig. 2). Based on percent increase in grain Zn concentration over control, the treatments may be ranked in order of BRRI dhan49 > BRRI dhan57 > BRRI dhan52 > BRRI dhan56 > Gainja > Kalizira > Khirshapath > Biroin. That indicates high yielding varieties showed significant Zn enrichment in grain compared to local varieties. Higher levels of Zn increased yield and Zn content in both rice grains and straw [34], supporting the findings of the current study.

IV. CONCLUSION

Zinc application significantly increased the grain yields of BRRI dhan49, BRRI dhan52 and BRRI dhan56. Among the eight rice varieties, significant increase of Zn concentration in grain was observed in all rice varieties except Biroin due to soil application of Zn. Based on percent grain yield increase over control, the varieties may be ranked in order of BRRI dhan56 > BRRI dhan52 > BRRI dhan49 > BRRI dhan57 > Biroin > Kalizira > Gainja > Khirshapath. The highest percent increase of grain Zn concentration over control was obtained in BRRI dhan49 and the lowest one was obtained in Biroin. The application of Zn increased the nutritional quality of rice grain for both local and high yielding varieties.

ACKNOWLEDGMENT

The authors are grateful to the Department of Soil Science, BAU for providing the experiment and analysis facilities.

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