



Effect of Zinc Fertilizer Application on Growth Yield and Yield Contributing Characters in Rice

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Authors' contributions

This work was carried out in collaboration among all authors. Author MIA designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author MAI managed the analyses of the study and literature searches and wrote the first draft of the manuscript. Author QAK wrote the protocol and managed the analyses of the study. Author MAR managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was carried out at the field of Department of Agronomy, BSMRAU campus, Gazipur, of Bangladesh during aman season (July-October) of 2017 to study the effect of zinc fertilizer application on growth, yield and zinc partitioning in three rice varieties: (BRRI dhan 56, BRRI dhan 57 and BRRI dhan 62) at three levels of zinc fertilization, no application of zinc, 10 and 20 kg Zn ha⁻¹. The highest leaf area indices of 3.15 in BRRI dhan 56, and 3.27 in BRRI dhan 57 were recorded with the application of 10 kg Zn ha⁻¹ at 75 DAT and 3.28 in BRRI dhan 62 with 20 kg Zn ha⁻¹. Through the growth period the SPAD value was the maximum at 10 kg Zn ha⁻¹ in BRRI dhan 56 and BRRI dhan 57 and in BRRI dhan 62 at 20 kg Zn ha⁻¹. The highest CGR, RGR, NAR were recorded at 10 kg Zn ha⁻¹ in BRRI dhan 56 and BRRI dhan 57, and at 20 kg ha⁻¹ in BRRI

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dhan 62. Zinc fertilizer at 10 kg Zn ha⁻¹ significantly increased the number of effective tiller m⁻², length of panicle, total number of spikelet's panicle⁻¹, 1000-grain weight, number of filled spikelet's panicle⁻¹, grain yield and straw yield in BRRi dhan 56 and BRRi dhan 57, and at 20 kg Zn ha⁻¹ in BRRi dhan 62. It was revealed that the rice varieties BRRi dhan 56 and BRRi dhan 57 responded to the application of 10 kg Zn ha⁻¹, while BRRi dhan 62 to 20 kg Zn ha⁻¹. Overall results indicates, application of zinc might be necessary to ensure satisfactory yield.

Keywords: Partitioning; agronomic; physiological; apparent recovery and utilization efficiency.

ABBREVIATIONS

BSMRAU : Bangabandhu Sheikh Mujibur
Rahman Agricultural University
BRRi : Bangladesh Rice Research Institute

1. INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family of Graminae is the main staple food of around half of the world's population. Worldwide rice ranks second to wheat in area harvested; but it ranks first as a food crop, providing more calories. Reports showed that 30% soils in the world exhibit zinc deficiency to different extents and more than two billion people can't be supplied with sufficient zinc [1]. Zinc deficiency is prevalent worldwide in temperate and tropical climates [2]. A significant amount of zinc is present in the soil matrix, but only a small fraction of that is available for plant [3]. Several soil factors and conditions may rendered soils deficient in total and available Zn. The problem of Zn deficiency, especially in the developing world, has been furtherly aggravated due to lack of information on Zn sensitivity and by growing cultivars which are highly susceptible to Zn deficiency. Alloway [4] reported widespread deficiency of Zn throughout Bangladesh (~2 m ha of paddy soils). Stagnant yields of major crops have been ascribed to imbalanced use of fertilizers and micronutrient deficiencies, particularly for Zn and B [5]. Today, increasing grain Zn concentration of rice represents an important challenge to be met by using agricultural tools such as breeding and fertilization. In South and Southeast Asia, over half a billion people are estimated to be at risk from inadequate Zn intake [6], and the well-known high incidence and severity of childhood infectious diseases in those regions are commonly associated with Zn deficiency [7]. The optimum dietary intake for human adults is 15 mg Zn day⁻¹ [8]. The critical index of effective Zn in the soil suitable for rice growth is 1.5 mg kg⁻¹ [9]. In a screening study including about 1,000 genotypes, it has been found that there is a four-fold range of rice grain Zn concentration among

the rice varieties [10]. This impressive genotypic variation has led to a suggestion that such substantial genetic potential for Zn concentration in rice should be exploited through plant breeding [11]. Therefore the experiment was conducted to find out the effect of zinc fertilizer on growth, yield and yield contributing characters in rice.

2. MATERIALS AND METHODS

The experiment was carried out at the field of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur of Bangladesh during aman season (July-October) of 2017. The experimental site was located between 24.09° N latitude and 90.26° E longitude having an elevation of 8.4 m from sea level. The soil of the experimental farm belongs to Salna series under the Agro-ecological zone of Madhupur Tract (AEZ 28). The soil represents the Shallow Red Brown Terrace. The texture of the soil is silty clay in surface layer and silty clay loam in subsurface layer (AEZ 28). The experiment was laid out in a factorial Randomized Complete Block Design with three replications. The unit plot size was 3 mx4 m. Row and hill spacing was (20 cmx15 cm). Treatments, three rice varieties: (BRRi dhan 56, BRRi dhan 57 and BRRi dhan 62). To know the response of these varieties to zinc fertilizer application the variety BRRi dhan 62 standard check variety. Three levels of zinc fertilizer: (no application of zinc, 10 and 20 kg Zn ha⁻¹). During final land preparation cow-dung was incorporated into the soil at the rate of 5 t ha⁻¹. A fertilizer dose of 80 kg N ha⁻¹, 36 kg P₂O₅ ha⁻¹, 50 kg K ha⁻¹, 20 kg S ha⁻¹, respectively was applied. Nitrogen, phosphorus, potassium and sulphur were applied in the form of urea, TSP, MoP and gypsum, respectively. The different levels of zinc fertilizer were applied in the form of zinc sulphate after 14 days of transplanting and it was incorporated into the soil. Data were recorded on plant height number of tiller dry matter accumulation on the basis of dry matter accumulation and the leaf area the values for different growth parameters viz. Leaf Area Index (LAI), crop growth rate (CGR) and relative growth rate (RGR) and net

assimilation rate (NAR) were calculated. At maturity, data were recorded on yield contributing characters and analyzed statistically following the procedure described by Gomez and Gomez [12]. The SPAD value (Soil Plant Analysis and Development value) was taken in the experiment using SPAD meter. The statistical analysis was done by using Statistix10.

3. RESULTS AND DISCUSSION

3.1 Leaf Area Index

The data presented in Fig.1 revealed that zinc fertilizer application exerted significant effect on leaf area index (LAI) at 45, 60 and 75 days after transplanting. The maximum LAI of 3.15 in BRRI dhan 56, and 3.27 in BRRI dhan 57 were recorded with application of 10 kg Zn ha⁻¹ at 75 DAT, respectively but in case of BRRI dhan 62 the maximum LAI of 3.28 was found at 20kg Zn

ha⁻¹. In general the application of zinc had boosted up the tissue formation with better plant growth which increased its concentration in leaves and resulted in higher leaf area index. Zinc and other micronutrients help plants in chlorophyll formation and increased the photosynthetic activities [13].

3.2 SPAD Value

The SPAD of rice leaves in three varieties over time as influenced by different levels of zinc fertilizer is shown in (Fig. 2). Through the growth period the SPAD value was the maximum at 10 kg Zn ha⁻¹ in case of BRRI dhan 56 and BRRI dhan 57 but in BRRI dhan 62 it was at 20 kg Zn ha⁻¹. Grewal et al. [14] reported that the application of zinc increased the chlorophyll content. However, this result provided a good similarity with the findings of Arif et al. [15] with application of zinc.

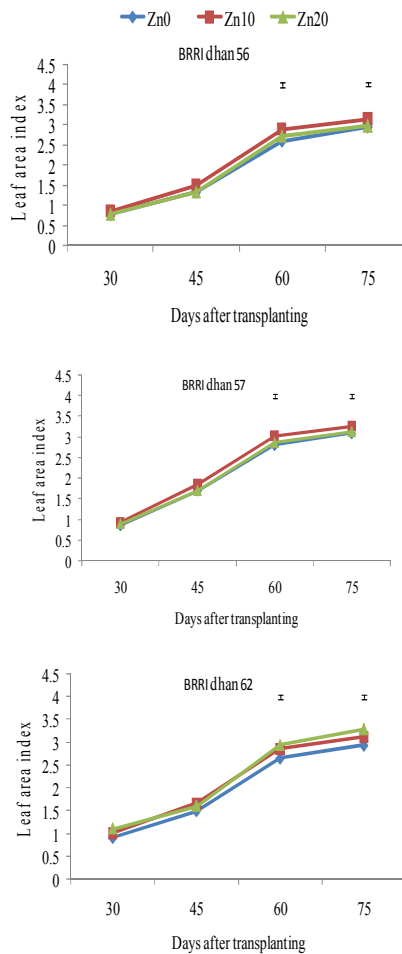


Fig. 1. Leaf area index of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer

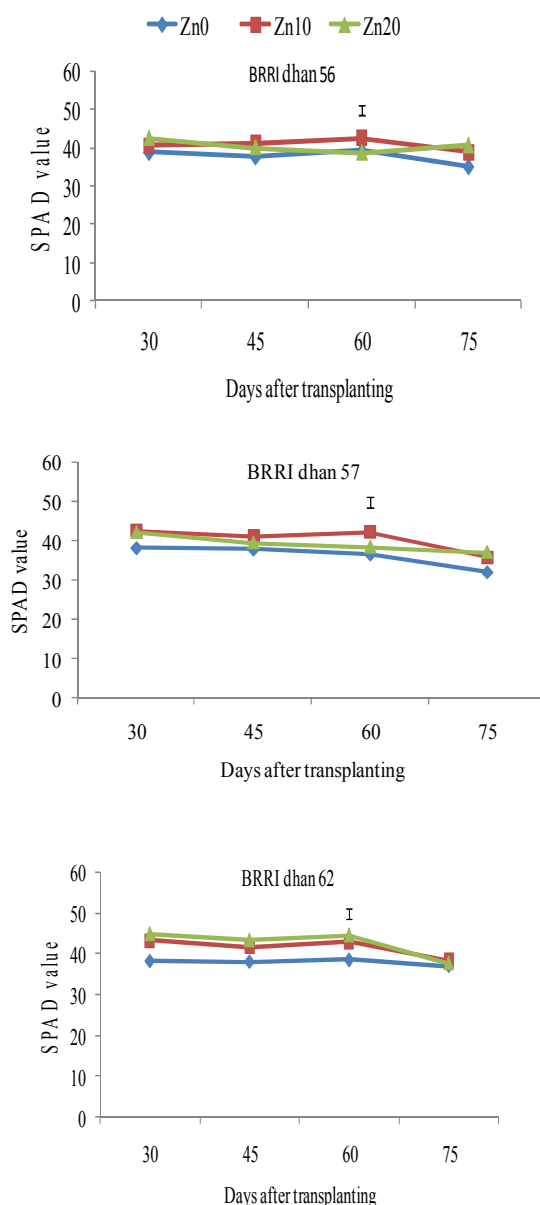


Fig. 2. SPAD value of rice plants leaves in three rice genotypes over time as influenced by different levels of zinc fertilizer

3.3 Crop Growth Rate

Zinc fertilizer application significantly influenced the crop growth rate in the growth stage (45-60 days) of rice in three varieties. Amongst the three levels of zinc, the highest CGR was recorded at 10 kg Zn ha⁻¹ in varieties BRRIdhan 56, BRRIdhan 57, and at 20 kg ha⁻¹ in BRRIdhan 62 (Fig. 3).

3.4 Relative Growth Rate

The RGR increased up to 60 DAT and thereafter, declined gradually up to harvest irrespective of varieties due to leaf senescence or destruction of chlorophyll pigment and less photosynthetic activity. The highest RGR was found in the treatment with 10 kg Zn ha⁻¹ in BRRIdhan 56 and BRRIdhan 57, and with 20 kg Zn ha⁻¹ in BRRIdhan 62 (Fig. 4).

3.5 Net Assimilation Rate

The highest NAR was recorded in the treatment with 10 kg Zn ha⁻¹ in BRRRI dhan 57 at early stages of growth with rapid increase in LAI, and the lowest NAR was found

at 20 kg Zn ha⁻¹ in BRRRI dhan 57 in later growth stage. The higher NAR was found in the treatment with 10 kg Zn ha⁻¹ in the rice varieties BRRRI dhan 56 and BRRRI dhan 57 and with 20 kg Zn ha⁻¹ in BRRRI dhan 62 (Fig. 5).

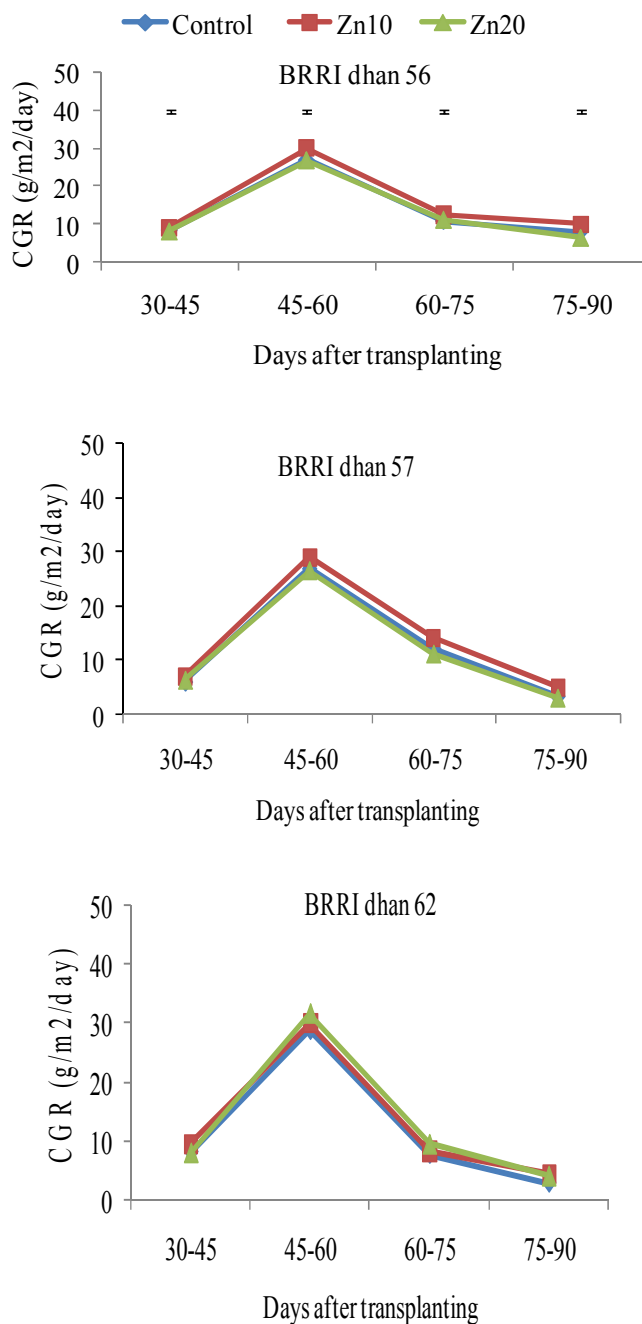


Fig. 3. Crop growth rate in three rice genotypes over time as influenced by different levels of zinc fertilizer

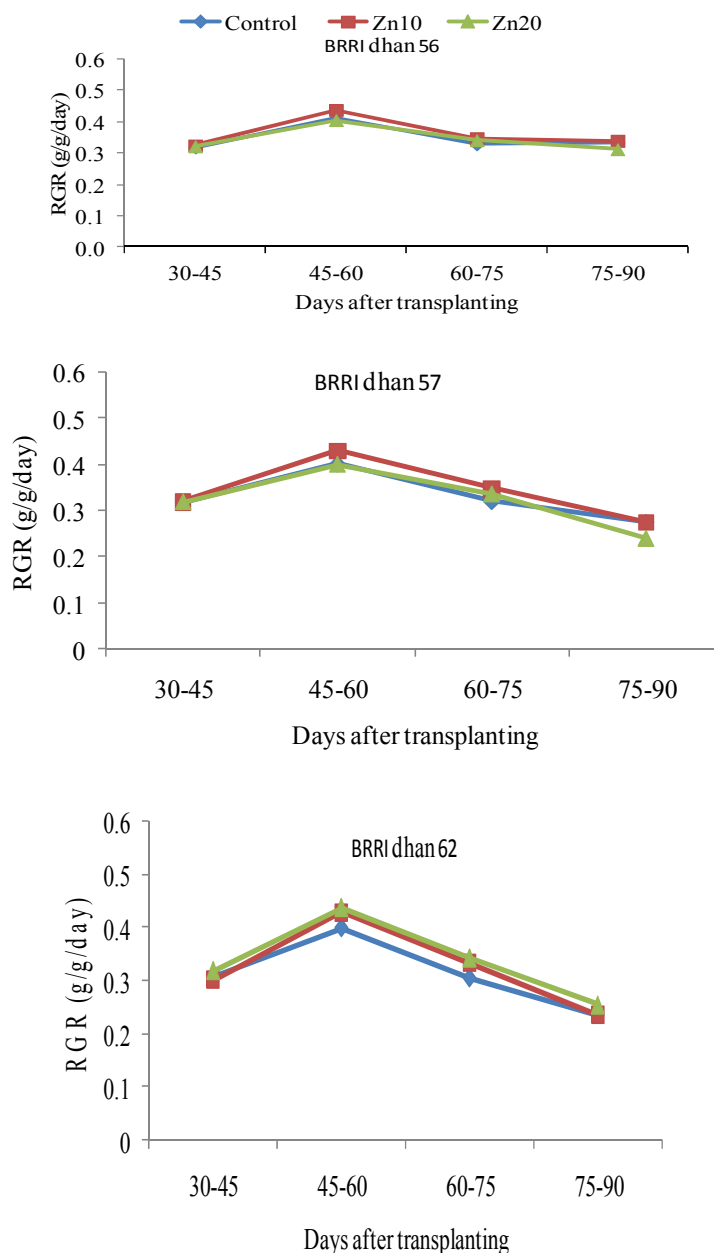


Fig. 4. Relative growth rate of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer

3.6 Yield and Yield Contributing Characters

3.6.1 Number of panicles

The highest number of panicles m⁻² in BRRIdhan 56 was 228 and in BRRIdhan 57 was 239 in the treatment with 10 kg Zn ha⁻¹, and

239 with 20 kg Zn ha⁻¹ in BRRIdhan 62 (Table 1). The increase in panicles m⁻² might be ascribed to adequate supply of zinc that might have increased the availability and uptake of other essential nutrients and thereby resulting in the improvement of crop growth. The results support the findings of Sanzo et al. [16].

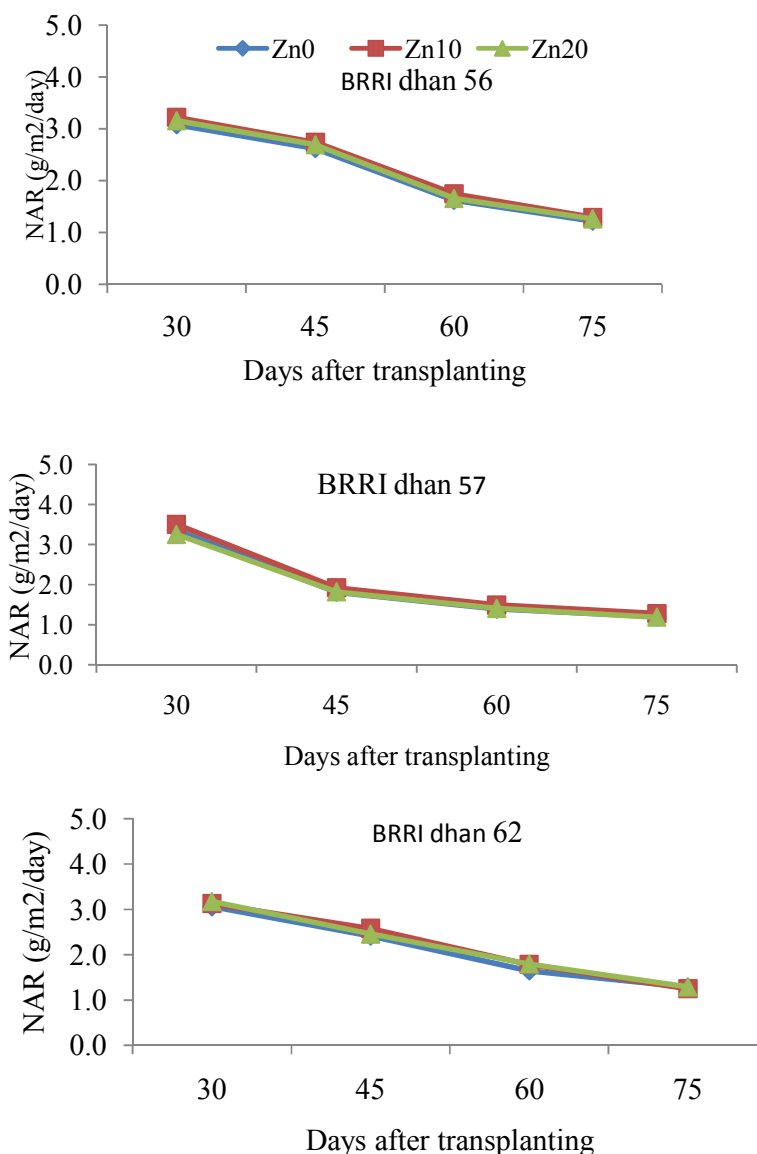


Fig. 5. Net assimilation rate of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer

3.6.2 Panicle length

The highest panicle length was recorded in BRR1 dhan 56 while BRR1 dhan 57 and BRR1 dhan 62 were statistically identical in terms of panicle length (Table 1). Application of zinc fertilizer at 10 kg Zn ha⁻¹ slightly increased the panicles length in the rice varieties BRR1 dhan 56 and BRR1 dhan 57. But the panicle length significantly increased in BRR1 dhan 62 both at 10 kg Zn ha⁻¹ 20 kg Zn ha⁻¹. The highest panicle length (22.88 cm) was recorded in BRR1 dhan 56 at 10 kg Zn ha⁻¹. Plant height response to Zn application was more pronounced, significantly

higher growing efficiency was recorded with Zn and the lowest without Zn application. Ahmed et al. [17] found an increase in plant height of rice with the application of 7.5 kg Zn ha⁻¹.

3.6.3 Number of tillers m⁻²

The number of tillers m⁻² in three varieties over time as influenced by different doses of zinc fertilizer significantly increased at 10kg Zn ha⁻¹ in BRR1 dhan 56 and BRR1 dhan 56 in all the stages of crop growth but in BRR1 dhan 62 the number of tillers m⁻² was the maximum upto maturity stage at 20 kg Zn ha⁻¹. The increase in

tillering might be attributed to improved enzymatic activity and auxin metabolism in plants by zinc. These results are similar to that of Ghani et al. [18], Saravanan and Ramanathan [19].

3.6.4 Total number of spikelets panicle⁻¹

The highest total number of spikelet panicle⁻¹ (150) was recorded with the application of 10 kg Zn ha⁻¹ in BRRIdhan 57 and the lowest (81) with 0 kg Zn ha⁻¹ in BRRIdhan 62 (Table 1). The increase in number of spikelet's panicle⁻¹ due to zinc fertilizer might be due to its effect on enhancing the physiological functions of the crop, like photosynthesis and translocation of plant nutrients which ultimately increased the number of spikelet's panicle⁻¹. Similar results were reported by Ionov and Ionova, [20] who conducted trials on rice and noted that zinc application increased tillering, growth, panicle length, number of spikelet's panicle⁻¹, 1000-grain weight and paddy yield. The results are also supported by the findings of Hung et al. [21].

3.6.5 Filled spikelet percentage

The filled spikelet percentage in rice varieties in BRRIdhan 56 and BRRIdhan 57 significantly

increased upto 10 kg Zn ha⁻¹ and decreased with the increase of zinc level upto 20 kg Zn ha⁻¹. In case of BRRIdhan 62, the filled spikelet percentage significantly increased upto 20 kg Zn ha⁻¹ (Table 1). All the doses of zinc increased the filled spikelet percentage significantly over 0 kg Zn ha⁻¹ which might be due to adequate supply of zinc that increase the availability and uptake of other essential nutrient resulting in increase in metabolic activities.

3.6.6 Thousand grain weight

The thousand grain weight in rice varieties BRRIdhan 56 and BRRIdhan 57 significantly increased upto 10 kg Zn ha⁻¹ and decreased with the further increase in zinc level upto 20 kg Zn ha⁻¹. However, in case of BRRIdhan 62, the 1000-grain weight significantly increased upto 20 kg Zn ha⁻¹. The maximum 1000-grain weight (24.18 g) was recorded in BRRIdhan 62 at 20 kg Zn ha⁻¹ and the lowest 1000-grain weight (17.06 g) with application of 20 kg Zn ha⁻¹ in BRRIdhan 57 (Table 1). The increase of 1000-grain weight with the application of zinc might be due to more efficient participation of Zn in various metabolic processes involved in the production of healthy seeds.

Table 1. Effect of zinc fertilizer and variety on yield and yield contributing characters in rice

Treatment	Panicles/m ²	Panicle length (cm)	Total spikelets/Panicle	%filled Spikelets/panicle	1000 Grain weight	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
Zinc								
0 kg ha ⁻¹	216	21.56	116	82.97	20.49	3.768	4.395	46.0
10 kg ha ⁻¹	232	22.45	121	90.91	21.55	4.024	4.684	46.2
20 kg ha ⁻¹	225	22.08	118	85.83	20.94	3.845	4.432	46.5
LSD _(0.05)	6	Ns	2	1.75	0.45	0.078	ns	ns
Variety								
BRRIdhan56	219	22.56	125	84.79	22.19	4.310	4.409	49.5
BRRIdhan57	225	21.82	145	87.1	17.58	3.695	4.502	45.1
BRRIdhan62	230	21.72	85	87.82	23.21	3.632	4.600	44.1
LSD _(0.05)	5	0.53	2	2.42	0.34	0.100	ns	0.8
Zinc xVariety								
Zn ₀ V ₁	211	22.57	122	81.11	21.70	4.286	4.365	49.6
Zn ₁₀ V ₁	228	22.88	128	89.70	23.28	4.472	4.652	49.0
Zn ₂₀ V ₁	220	22.22	125	83.57	21.58	4.171	4.210	49.8
Zn ₀ V ₂	219	21.51	145	85.29	17.51	3.652	4.495	44.8
Zn ₁₀ V ₂	239	22.47	150	92.94	18.18	3.953	4.830	45.0
Zn ₂₀ V ₂	217	21.48	141	83.06	17.06	3.480	4.179	45.4
Zn ₀ V ₃	219	20.60	81	82.51	22.27	3.365	4.326	43.8
Zn ₁₀ V ₃	230	22.00	85	90.11	23.18	3.647	4.568	44.4
Zn ₂₀ V ₃	239	22.55	87	90.87	24.18	3.884	4.906	44.2
LSD _(0.05)	9	0.92	4	4.19	0.60	0.173	0.266	ns
CV (%)	2.35	2.42	3.53	2.80	1.64	2.58	3.42	1.67

3.6.7 Grain yield

The grain yield in the rice varieties BRR1 dhan 56 and BRR1 dhan 57 significantly increased with the application of zinc fertilizer at 10 kg Zn ha⁻¹ and decreased with the increase in zinc fertilizer upto 20 kg Zn ha⁻¹. However, in BRR1 dhan 62 the grain yield significantly increased both at 10 kg Zn ha⁻¹ and 20 kg Zn ha⁻¹. The highest grain yield 4.472 t ha⁻¹ was obtained from BRR1 dhan 56 at 10 kg Zn ha⁻¹ and the lowest (3.365 t ha⁻¹) from BRR1 dhan 62 without zinc application (Table 1). Kausar et al. [5] also reported similar results. Higher yield due to zinc fertilization is attributed to its involvement in many metallic enzyme systems, regulatory functions and auxin production enhanced synthesis of carbohydrates and their transport to the site of grain production [22]. Singh et al. [23] and Srivastava et al. [24] reported that zinc application to zinc deficient soil increased the total biomass and grain yield in rice.

3.6.8 Straw yield

The straw yield in the rice varieties BRR1 dhan 56 significantly increased with the application of 10 kg Zn ha⁻¹ and decreased thereafter with further increase in zinc fertilizer level upto 20 kg Zn ha⁻¹. But in case of BRR1 dhan 62 the straw yield significantly increased upto 20 kg Zn ha⁻¹ (Table 1). Increase in the straw yield in rice with the application of zinc fertilizer might be due to favorable effect of zinc on the proliferation of roots and thereby increasing the uptake of plant nutrients from the soil, supplying it to the aerial parts of the plant and ultimately enhancing the vegetative growth of plants. Gurmani et al. [25], Ghani et al. [18] and Srivastava et al. [24] also obtained similar results.

3.6.9 Harvest index

The application of zinc fertilizer did not exerted any significant effect on harvest index of three rice varieties studied. However, the varieties BRR1 dhan 56 gave the highest harvest index. The highest harvest index (49.8%) was recorded at 20 kg Zn ha⁻¹ in BRR1 dhan 56 and the lowest with 0 kg Zn ha⁻¹ in BRR1 dhan 62 (Table 1).

4. CONCLUSION

The plant height, LAI, SPAD value, CGR, RGR, NAR and yield were the highest at 10 kg Zn ha⁻¹ in BRR1 dhan 56 and BRR1 dhan 57 but in BRR1 dhan 62 at 20 kg Zn ha⁻¹. The highest number of

tillers m⁻², panicle length, total filled spikelets panicle⁻¹, total spikelets panicle⁻¹, 1000-grain weight, grain yield and straw yield of rice significantly increased at 10 kg Zn ha⁻¹ in BRR1 dhan 56 and BRR1 dhan 56 and at 20 kg Zn ha⁻¹ in BRR1 dhan 62. Application of 10 kg Zn ha⁻¹ produced the highest grain yield (4.024 kg ha⁻¹) over 0 kg Zn ha⁻¹ (3.768 kg ha⁻¹).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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