Effect of zinc fertilizer application on growth yield and yield contributing characters in rice

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, 10and 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 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.

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 (Cakmak et al., 2008). Zinc deficiency is prevalent worldwide in temperate and tropical climates (Slaton, 2005). A significant amount of zinc is present in the soil matrix, but only a small fraction of that is available for plant (Ahmad *et al*., 2012). Several soil factors ad 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 (2008) 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 (Kauser et al*.,* 2001).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 (Hotz and Brown, 2004), and the well-known high incidence and severity of childhood infectious diseases in those regions are commonly associated with Zn deficiency (Black *et al.,* 2008). The optimum dietary intake for human adults is 15 mg Zn day^{-1} (Hafeez et Al., 2013).The critical index of effective Zn in the soil suitable for rice growth is 1.5 mg kg^{-1} (Xu, 2003). 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 (Graham *et al*., 1999). 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 (Bouis and Welch, 2010). 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^{0} N latitude and 90.26^{0} 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 3mx4m. Row and hill spacing was (20cmx15 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 P_2O_5 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 (1984). 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. Result and Discussion

3.1 Leaf area index

The data presented inFig.1revealed 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 10kg 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 (Ziaeian and Malakouti, 2001).

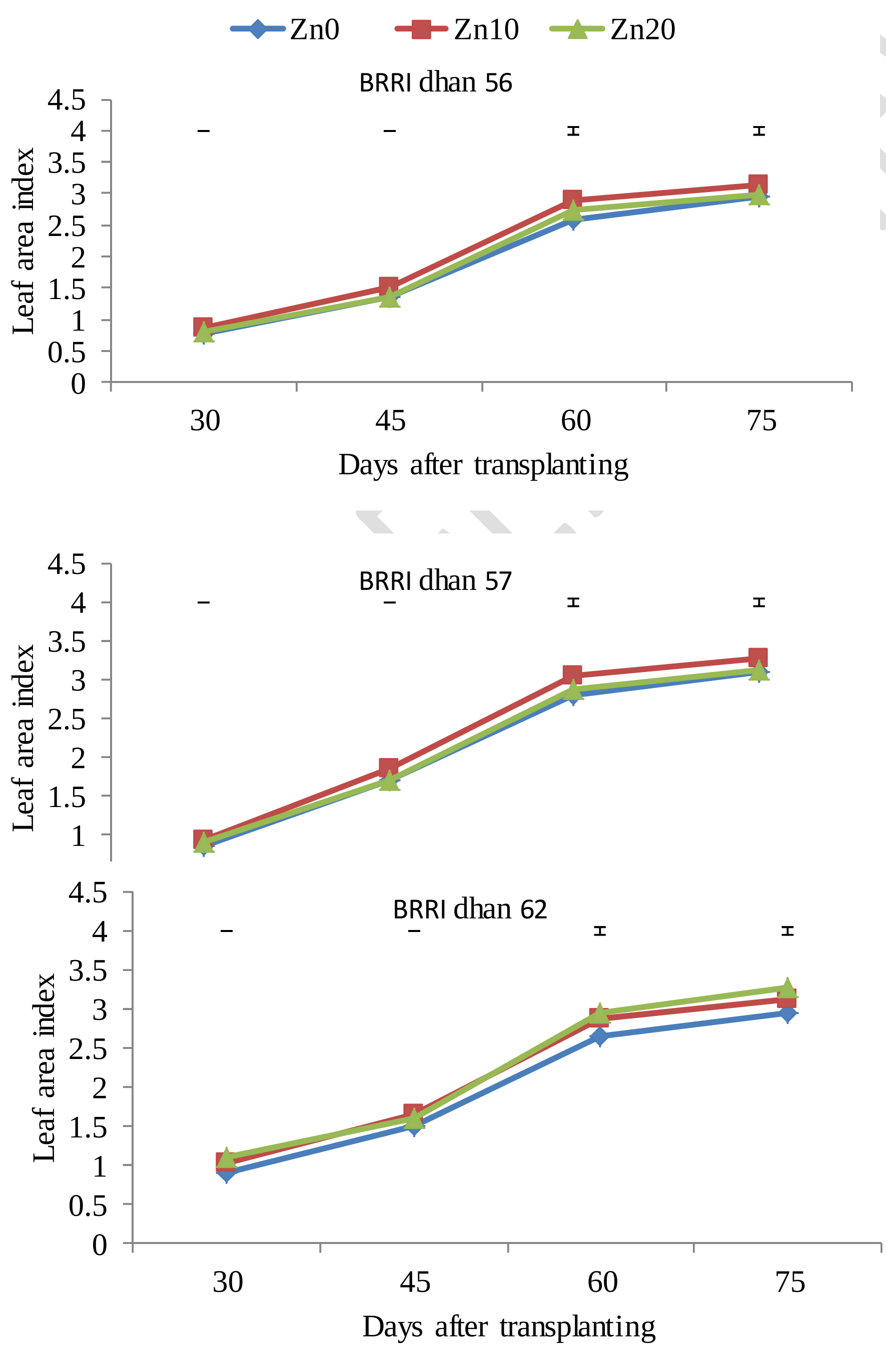
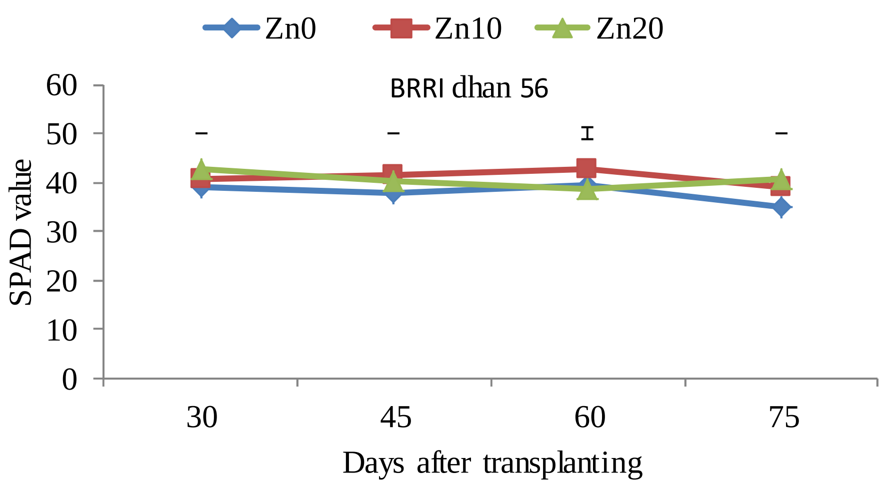
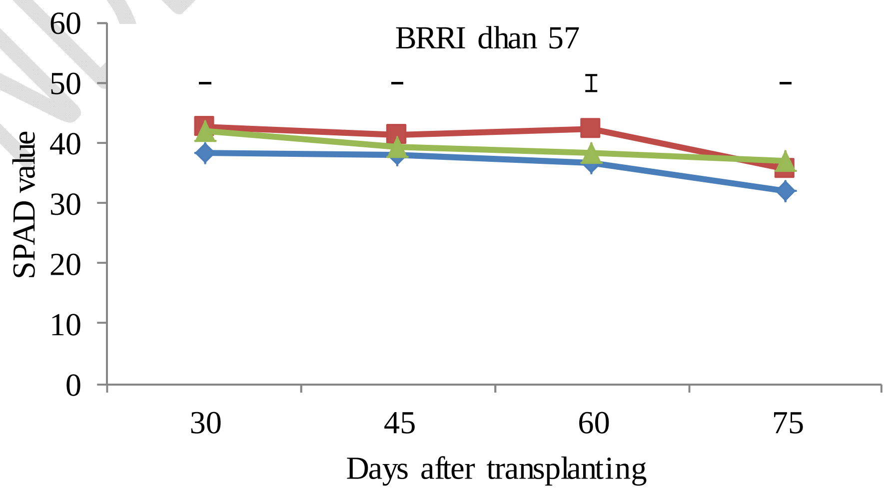


Fig. 1: Leaf area index of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer.

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 10kg 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.,* (1997) reported that the application of zinc increased the chlorophyll content. However, this result provided a good similarity with the findings of Arif *et al.,* (2012) with application of zinc.





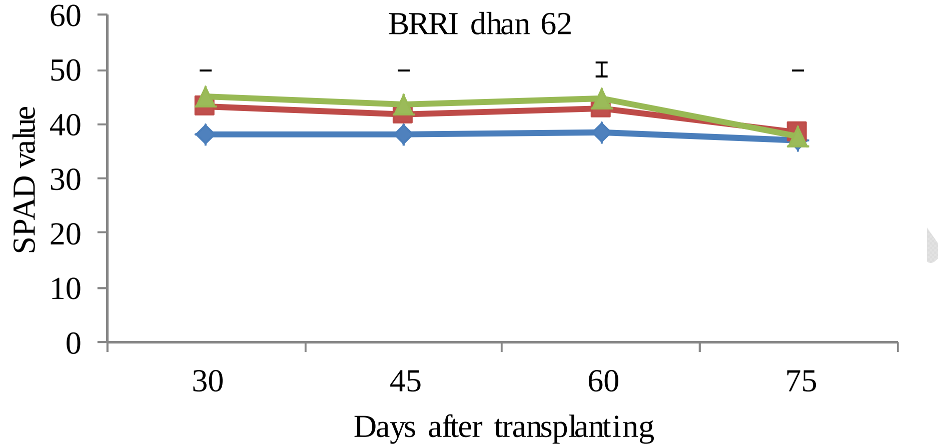
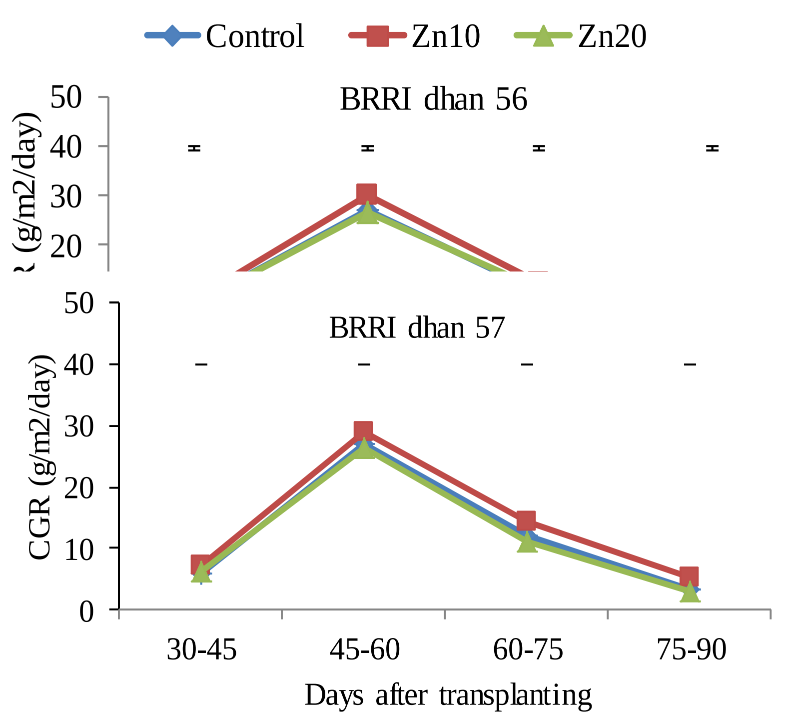


Fig. 2: SPAD value of rice plants leaves in three rice genotypes over time as influenced by different levels of zinc fertilizer.

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 BRRI dhan 56, BRRI dhan 57, and at 20 kg ha^{-1} in BRRI dhan 62 (Fig. 3).



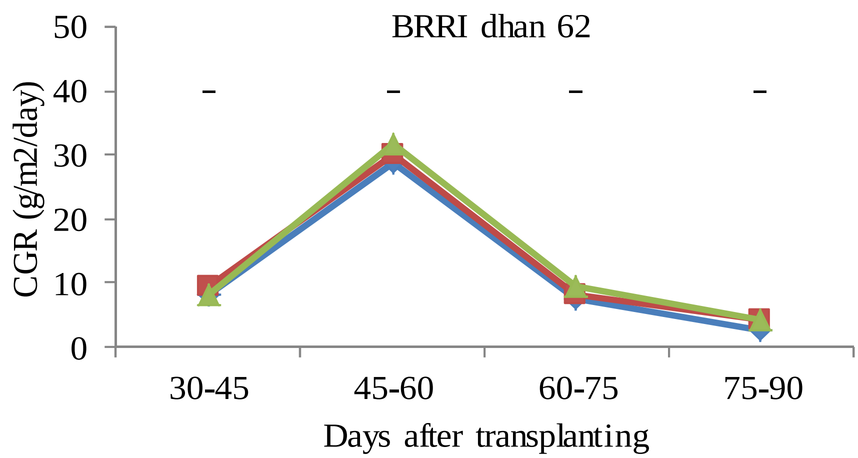
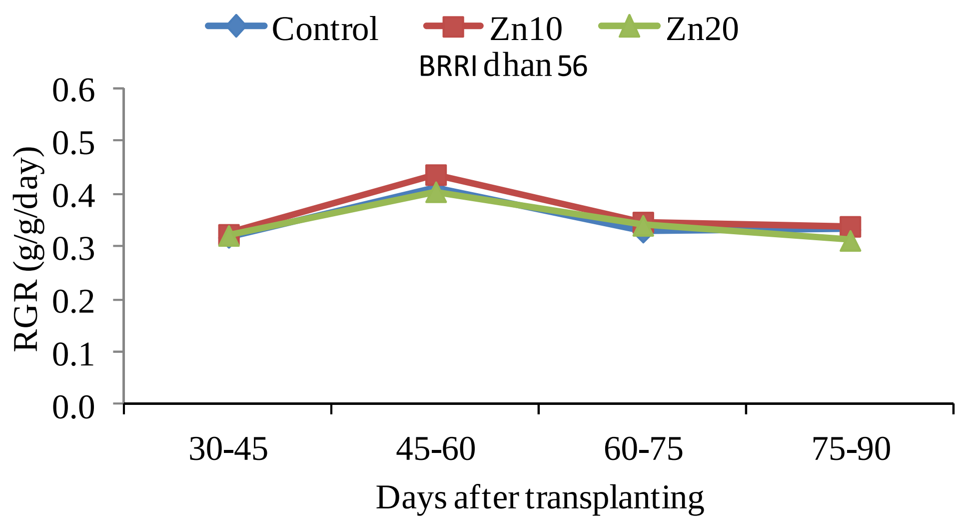
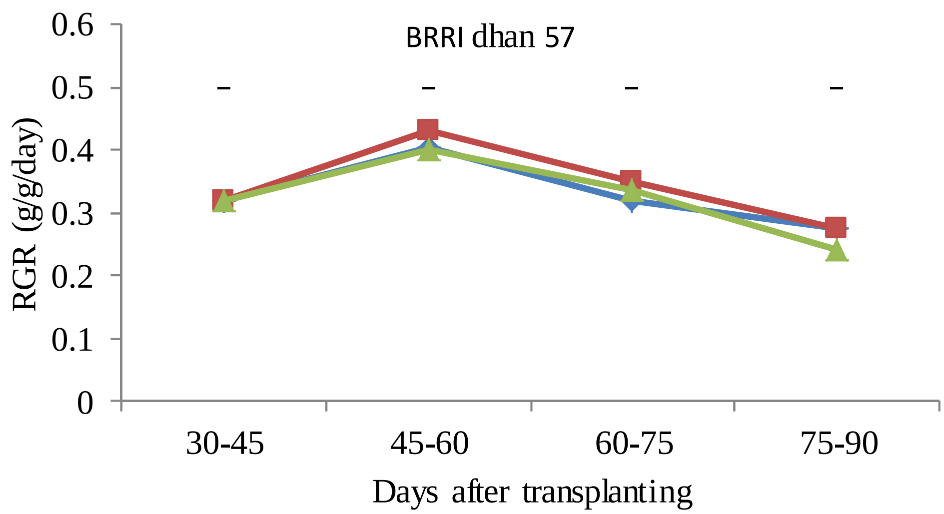


Fig. 3: Crop growth rate in three rice genotypes over time as influenced by different levels of zinc fertilizer.

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 BRRI dhan 56 and BRRI dhan 57,and with 20 kg Zn ha^{-1} in BRRI dhan 62 (Fig. 4).



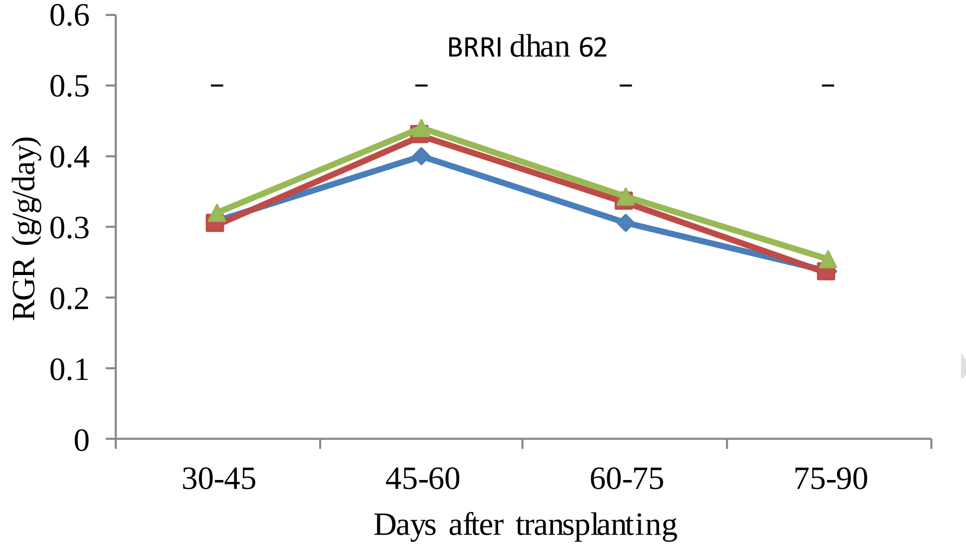
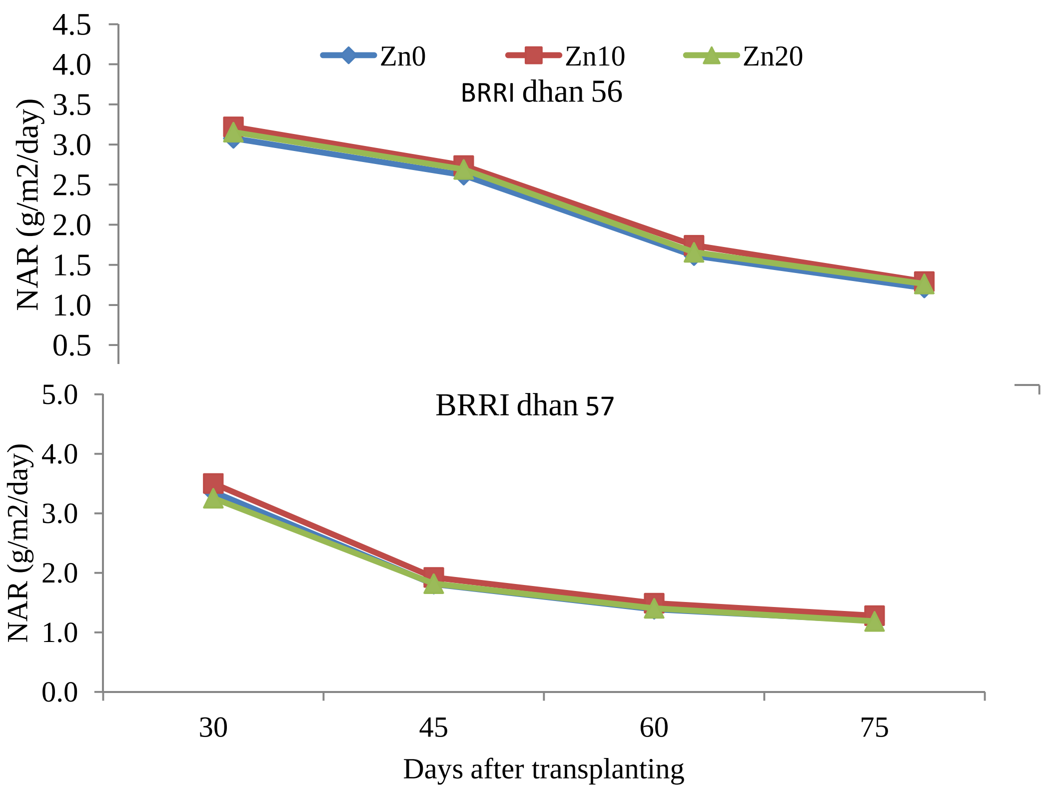


Fig. 4: Relative growth rate of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer.

3.5 Net assimilation rate

The highest NAR was recorded in the treatment with 10 kg Zn ha^{-1} in BRRI 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 BRRI dhan 57 in later growth stage. The higher NAR was found in the treatment with 10kg Zn ha^{-1} in the rice varieties BRRI dhan 56 and BRRI dhan 57 and with 20 kg Zn ha^{-1} in BRRI dhan 62 (Fig. 5).



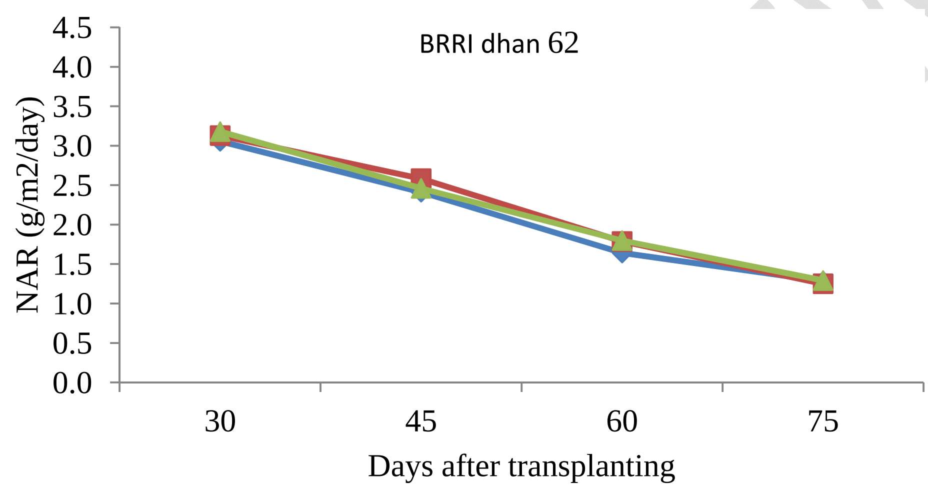


Fig. 5: Net assimilation rate of rice plants in three rice genotypes over time as influenced by different levels of zinc fertilizer.

3.6 Yield and yield contributing characters

3.6.1 Number of panicles

The highest number of panicles m^{-2} in BRRI dhan 56 was 228 and in BRRI dhan 57 was 239 in the treatment with 10 kg Zn ha^{-1}, and 239 with 20kg Zn ha^{-1} in BRRI dhan 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.,* (1989).

3.6.2 Panicle length

The highest panicle length was recorded in BRRI dhan 56 while BRRI dhan 57 and BRRI dhan 62 were statistically identical in terms of panicle length (Table 1). Application of zinc fertilizer at 10kg Zn ha^{-1} slightly increased the panicles lengthin the rice varieties BRRI dhan 56 and BRRI dhan 57. But the panicle length significantly increased in BRRI dhan 62 both at 10kg Zn ha^{-1} 20 kg Zn ha^{-1}. The highest panicle length (22.88 cm) was recorded in BRRI 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.,* (1983) found an increase in plant height of rice with the application of 7.5kg 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 BRRI dhan 56 and BRRI dhan 56 in all the stages of crop growth but in BRRI 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.,* (1990), Saravanan and Ramanathan (1986).

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 BRRI dhan 57 and the lowest (81) with 0 kg Zn ha^{-1} in BRRI dhan 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, (1977) 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.,* (1990).

3.6.5 Filled spikelet percentage

The filled spikelet percentage in rice varieties in BRRI dhan 56 and BRRI dhan 57 significantly increased upto10kg Zn ha^{-1} and decreased with the increase of zinc level upto20kg Zn ha^{-1}. In case of BRRI dhan 62, the filled spikelet percentage significantly increased upto20 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 BRRI dhan 56 and BRRI dhan 57 significantly increased upto10kg Zn ha^{-1} and decreased with the further increase in zinc level upto20 kg Zn ha^{-1}. However, in case of BRRI dhan 62, the 1000-grain weight significantly increased upto20 kg Zn ha^{-1}. The maximum 1000-grain weight (24.18 g) was recorded in BRRI dhan 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 BRRI dhan 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.

3.6.7 Grain yield

The grain yield in the rice varieties BRRI dhan 56 and BRRI dhan 57 significantly increased with the application of zinc fertilizer at 10kg Zn ha^{-1} and decreased with the increase in zinc fertilizer upto 20 kg Zn ha^{-1}. However, in BRRI 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 BRRI dhan 56 at 10kg Zn ha^{-1} and the lowest (3.365 t ha^{-1}) from BRRI dhan 62 without zinc application (Table 1). Kausar*et al.,* (2001) 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 (Sachdev *et al.,* 1991). Singh *et al.,* (1996) and Srivastava *et al.,* (1999) 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 BRRI dhan 56 significantly increased with the application of10 kg Zn ha^{-1} and decreased thereafter with further increase in zinc fertilizer level upto 20 kg Zn ha^{-1}. But in case of BRRI 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.,* (1988), Ghani *et al.,* (1990), and Srivastava *et al.,* (1999) 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 BRRI dhan 56 gave the highest harvest index.The highest harvest index (49.8%) was recorded at 20 kg Zn ha^{-1} in BRRI dhan 56 and the lowest with 0 kg Zn ha^{-1} in BRRI dhan 62 (Table 1).

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 ×Variety								
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

4. Conclusion

The plant height, LAI, SPAD value, CGR, RGR, NARand yield were the highest at 10 kg Zn ha^{-1} in BRRI dhan 56 and BRRI dhan 57 but in BRRI 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 BRRI dhan 56 and BRRI dhan 56 and at 20 kg Zn ha^{-1} in BRRI dhan 62. Application of 10kg 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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DEFINITIONS, ACRONYMS, ABBREVIATIONS

BSMRAU = Bangabandhu Sheikh Mujibur Rahman Agricultural University

BRRI=Bangladesh Rice Research Institute