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Effect of Biofortified and Non-Biofortified Varieties and Zinc Fertilization Strategies on Growth, Productivity and Profitability of Rice

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ABSTRACT

The field experiment was conducted in the rainy (*Kharif*, June to October) seasons of 2019 and 2020 at ICAR-Indian Agricultural Research Institute, New Delhi, India with the objective to appraise the effect of biofortified and non-biofortified varieties and zinc fertilization strategies on the growth, productivity and profitability of rice. The biofortified variety DRR Dhan 45 recorded a higher value of dry matter accumulation, leaf area index, and crop growth rate, and the non-biofortified variety Pusa 44 recorded higher effective tillers, panicle weight, filled grain weight per panicle, number of filled grains and total grains per panicle, fertility percentage and grain yield (5.2 t ha^{-1}), though the performance of both varieties was statistically similar. But, the higher straw yield was recorded with the non-biofortified variety, Pusa *Basmati* 1121 (10.8 t ha^{-1}). Pusa *Basmati* 1509 recorded higher cost of cultivation, gross returns, net returns and B:C. Among zinc fertilization strategies, soil application of 2.5 kg Zn ha^{-1} along with the foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages recorded higher growth parameters, yield, and yield attributes and better economics. On average, the soil+foliar Zn application increased grain yield by 14% and straw yield by 10.5%, and gross returns and net returns by 15.6% and 26.7%, respectively, than the control. Cultivation of rice varieties, Pusa 44 or DRR Dhan 45, along with soil+foliar Zn fertilization enhanced growth and productivity, while the aromatic variety, Pusa *Basmati* 1509 enhanced the profitability.

KEYWORDS: Biofortified variety, economics, growth parameters, yield, zinc fertilization

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1. INTRODUCTION

More than half of the world's population depends on rice as their staple food and rice contributes significantly to human nutrition by supplying 15% and 21% of the protein and energy needs of the global population, respectively (Rehman et al., 2012, Prasad et al., 2017). India is the second-largest producer of rice and is responsible for 20% of total global rice production (Kumar et al., 2021). Further, India is expected to produce about 130 million tonnes of rice by 2030 to ensure food security of the ever-growing population (Kumar et al., 2021). However, the rice production is currently facing myriads of challenges like inadequate irrigation, deteriorating soil health, macro- and micronutrient deficiency (Rehman et al., 2012, Bhatt et al., 2016, Kumar et al., 2021).

Among micronutrient deficiency, Zn deficiency is the most common problem faced by rice cultivation in the rice-wheat cropping systems of the Indo-Gangetic plains of India owing to prolonged submergence led low redox potential and problem of high soil pH (Rehman et al., 2012, Meng et al., 2014, Prasad et al., 2014). Zn deficiency in plants causes chlorosis of leaves, stunted growth, smaller leaves, and spikelet sterility (Cakmak, 2008, Hefferon, 2019). Soil application of Zn fertilizer is a general strategy to overcome Zn deficiency and the recommended dose for the rice-wheat system in India is 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$, but this approach is not always effective to increase the growth, yield, and nutritional quality of rice. The efficiency of applied Zn fertilizer is reduced under continuous flooding due to the formation of insoluble Zn compound (Rehman et al., 2012, Prasad et al., 2014, Wang et al., 2014) and this leads to Zn deficiency at the flowering stage. Recently, the foliar application of Zn is gaining more attraction due to higher use efficiency, quicker action, grain Zn enrichment, and cost-effectiveness (Shivay et al., 2010, Cakmak and Kutman, 2018, Zhang et al., 2020). Foliar application of $ZnSO_4$ is effective in correcting Zn deficiency at later stage of crop growth (Boonchuay et al., 2013).Though the yield advantage with the foliar application of Zn is comparable with the soil application (Shivay et al., 2010, Prasad et al., 2014), the effectiveness of foliar applied Zn depends on the type of fertilizer, nutrient requirement, and crop characteristics, especially, leaf characteristics (Fernández et al., 2013, Zaman et al., 2018). Soil plus the foliar application of zinc to rice may enhance the growth, productivity, and profitability to a greater extent. Hence, we have evaluated the response of different varieties of rice to combinations of Zn fertilization strategies.

Generally, the Zn-deficient soils produce Zn-deficient rice grains which ultimately cause Zn malnutrition in the human population that depends on rice as their staple food (Nayak et al., 2022). Breeding the Zn-biofortified variety is considered as the most sustainable and economic way to alleviate this malnutrition problem (Cakmak, 2008, Koc and Karayigit, 2022). However, the performance of such Zn-efficient varieties in the field is limited by adverse soil and agronomic condition (Mabesa et al., 2013, Prasad et al., 2014, Rao et al., 2020). This necessitates a better Zn fertilization strategy in conjunction with a Zn-efficient genotype for better growth, productivity, and Zn biofortification. However, very few experiments have been conducted to assess the effect of Zn fertilization on growth performance as well as the economics of biofortified varieties. It's important to study the behaviour of biofortified varieties comparatively along with other non-biofortified varieties. Hence, the present experiment was planned to study the effect of biofortified and non-biofortified varieties and Zn fertilization strategies on the growth, productivity, and profitability of rice.

2. MATERIALS AND METHODS

A field experiment on rice varieties and zinc fertilization was conducted at the research farm of the ICAR-Indian Agricultural Research Institute, New Delhi, India, for two successive years (June to October of 2019 and 2020). The institute farm falls under the 'Trans-Indo-Gangetic plains' agro-climatic zone of India and is located at 28°38'N latitude and 77°10' E longitude with an elevation of 228.6 m above mean sea level. The climate is of sub-tropical and semi-arid type with hot and dry summer and cold winter. The mean annual rainfall and pan evaporation are 650 mm and 850 mm, respectively. The total amount of rainfall received was 608.1 mm and 685.9 mm during the first (2019) and second (2020) years, respectively. The experimental soil was clay in texture comprising of 11.8% sand, 36.0% silt, and 52.2% clay and the *p*H of the soil was 7.8 (1:2.5 soil: water ratio) (Prasad et al., 2006). The soil of the experimental field had 225.0 kg ha^{-1} alkaline permanganate oxidizable nitrogen (N), 12.2 kg ha^{-1} available phosphorus (P), 226.0 kg ha^{-1} 1 N ammonium acetate exchangeable potassium (K), and 0.51% organic carbon (OC) (Prasad et al., 2006).The diethylenetriaminepentaacetic acid (DTPA)-extractable Zn (Lindsay and Norvell, 1978) in soil was 0.61 mg kg^{-1} soil, which falls within the range of critical limits (0.38–0.90 mg kg^{-1} soil) of DTPA extractable Zn for rice cultivated in the rice-wheat belt of North India (Shivay et al., 2015). Hence, the response of rice to Zn fertilization was expected.

The experiment was carried out under a split-plot design and replicated thrice. In main plots, four rice varieties, one biofortified (DRR Dhan 45) and three non-biofortified (Pusa *Basmati* 1121, Pusa *Basmati* 1509, and Pusa 44) were allotted, and in subplots, four Zn fertilization methods i.e. (i) no Zn application (control); (ii) soil application of Zn at

5 kg ha^{-1} through $ZnSO_4.7H_2O$; (iii) soil application of Zn at 2.5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$+foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages; (iv) foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering stage, anthesis, and initiation of grain filling stage, were allotted. The non-biofortified aromatic variety, Pusa *Basmati* 1121 and Pusa *Basmati* 1509 and high yielding variety, Pusa 44 were released from ICAR-IARI, New Delhi, while the biofortified variety, DRR Dhan 45 was released from ICAR-Indian Institute of Rice Research (IIRR), Hyderabad. The main plot size was 21.2×2.6 m^2, while the size of the sub-plot was 5.3×2.6 m^2. During both the years of the experiment, the field was ploughed twice and then puddled and levelled to prepare the field for transplanting. Before transplanting, 26.2 kg ha^{-1} P through single superphosphate and 41.7 kg ha^{-1} K through muriate of potash fertilizer were uniformly broadcasted over puddled soil. Nitrogen at 120 kg ha^{-1} was applied through urea in three splits: one-third at eight days after transplanting and the remaining two-thirds at maximum tillering and panicle initiation stages. In main plots, the twenty-five-days-old seedlings of different rice varieties were transplanted at 20×10 cm^2 spacing in the first fortnight of July in both years. Soil and foliar application of Zn were done as per treatment details. Zn fertilizer ($ZnSO_4.7H_2O$) was broadcasted in the subplots after 4 to 5 days of transplanting. An aqueous solution of 0.5% $ZnSO_4.7H_2O$ (500 l ha^{-1}) was sprayed over the crop canopy at various growth stages of rice (maximum tillering, anthesis, and initiation of grain filling stage) using a Knapsack sprayer with flat fan nozzle. All the other standard recommended cultural practices were followed for the cultivation of rice, and harvesting was done in between the last weeks of October to the first week of November during both years.

At harvesting stage plant height of rice was measured from the base of the plant at ground surface to the tip of the tallest leaf panicle using a standard meter scale. Tillers' number was counted from the labelled hill at the harvesting stage. Five hills of rice were sampled at 60, 90 days and at harvesting stage of the crop and air-dried followed by hot-air oven drying at 60±2°C till a constant weight. Then the total dry-matter accumulation by rice was estimated and expressed in g hill^{-1}. The plants sampled for measurement of the dry matter accumulation were used for leaf area measurement. The leaves were detached from the stem and cleaned with tap water, followed by soaking with tissue paper. Leaf area (cm^2) was measured using LI–COR leaf area meter (Model L1-3000, Lambda Instrument Corporation, Nebraska, USA) and leaf area index (LAI) was calculated at 60 days after transplanting (Evans, 1972).

Crop growth rate (CGR), which indicates the increase in dry weight over a given time interval in relation to land area was calculated using the following formula (Evans, 1972):

CGR (g m^{-2} day^{-1})=$(W_2-W_1)/(T_2-T_1\times$land area) ....(1)

Where, W_1 and W_2 are the dry weight (g) values at time T_1 and T_2, respectively. T_1 and T_2 are time in days after transplanting.

Net assimilation rate (NAR) represent the photosynthetic efficiency of leaves and indicate the net gain of assimilate per unit leaf area over a period of time. It was determined using following formula (Evans, 1972):

NAR (g m^{-2} day^{-1}) = (W_2-W_1)(lnLA2-lnLA1)/(T_2-T_1) (LA2-LA1) ....(2)

Where, W_1 and W_2 are dry weights and LA1 and LA2 are leaf area values recorded at times T_1 and T_2, respectively.

Panicle-bearing (effective) tillers of the marked 5 hills were counted at harvesting. Ten samples of panicle were obtained randomly from the five marked hills and the length of the panicle was measured and average panicle length was calculated. The selected panicles were also used to record the mean panicle weight and total number of grains panicle^{-1} was counted. The selected panicles were cleaned to separate the unfilled (chaffy) grains and to note the filled grain weight and numbers. The 1,000-filled grains, taken from sampled panicles, were first counted by a seed counter and then weighed to compute the 1,000-grain weight. The fertility percentage was calculated using following equation as:

Fertility percentage (%)=(Number of filled grains/panicle)/(Total grains/panicle)×100 ....(3)

Harvesting was done followed by threshing, winnowing, and cleaning. The grains were dried to 14% moisture content and grain yield of rice was estimated. Similarly, the straw yield was recorded by subtracting grain yield from the total biomass yield. Grain and straw yield were expressed in t ha^{-1}. The cost of cultivation for different rice varieties and Zn fertilization strategies were estimated based on the market price of various inputs. Gross returns were calculated based on the grain and straw yield and the prevailing market prices of grain and straw in respective seasons and net returns were calculated by deducting the cost of cultivation from gross returns. The benefit-cost ratio was calculated by dividing the cost of cultivation from net returns (net returns/cost of cultivation). The statistical analysis of all the data obtained from this two year-experiment were done using the *F*-test, as per the procedure given by Gomez and Gomez (1984). CD values at p=0.05 were used to determine the significance of difference between treatment means. Further, the data recorded over two years were subjected to the pooled analysis and the mean values were reported. The figures were constructed using the data analysis tool pack of Microsoft Excel (2013).

3. RESULTS AND DISCUSSION

3.1. Growth parameters

The varieties and zinc fertilization strategies significantly affected the various growth parameters of rice during the experiment (Table 1). The varietal difference was observed with respect to plant height, tiller numbers, dry matter accumulation, leaf area index, CGR, and NAR. The non-biofortified variety Pusa *Basmati* 1121 recorded significantly higher plant height at the harvesting stage, while the non-biofortified variety Pusa 44 recorded a higher number of tillers per hill at the harvesting stage. The biofortified variety DRR Dhan 45 recorded a higher value of dry matter accumulation at harvest and leaf area index at 60 DAT and it was statistically on par with the non-biofortified variety, Pusa 44. The higher value of CGR and NAR was observed with the variety DRR Dhan 45 and Pusa *Basmati* 1509, respectively, during the trial. Significant variation among different varieties regarding growth parameters might be due to differences in genetic makeup (Ghasal et al., 2015) and differences in their responses to Zn fertilization (Fageria and Baligar, 2005).

Table 1: Effect of varieties and Zn fertilization strategies on various growth parameters of rice (pooled data of two years)

Treatment	Plant height at harvest (cm)	Tillers hill^{-1} at harvest (Nos.)	Dry matter accumulation at harvest (g hill^{-1})	Leaf area index at 60 DAT	CGR at 60–90 DAT (g m^{-2} day^{-1})	NAR at 60–90 DAT (g m^{-2} day^{-1})
Varieties						
Pusa *Basmati* 1121	126.7	11.7	42.6	4.4	19.5	4.9
Pusa *Basmati* 1509	111.8	11.0	38.8	3.4	17.0	5.8
Pusa 44	104.2	12.8	42.7	6.3	23.6	4.3
DRR Dhan 45	119.0	12.5	44.1	6.4	26.4	4.7
SEm±	2.32	0.17	0.67	0.09	0.53	0.11
CD (p=0.05)	8.02	0.59	2.33	0.30	1.84	0.39
Zinc fertilization						
Control (no Zn)	113.0	11.7	39.1	5.0	19.1	4.5
5 kg Zn ha^{-1} SA	114.7	12.0	42.0	5.2	21.5	4.9
2.5 kg Zn ha^{-1} SA+0.5% ZnSHH FS at MT & Anth	118.4	12.3	44.2	5.3	23.3	5.1
0.5% ZnSHH FS at MT, Anth & GF	115.8	12.1	43.0	5.2	22.5	5.1
SEm±	1.86	0.18	0.74	0.09	0.5	0.11
CD (p=0.05)	NS	NS	2.16	NS	1.46	0.31
Interaction effect	NS	NS	NS	NS	NS	NS

DAT: Days after transplanting; CGR: Crop growth rate; NAR: Net assimilation ratio; SA: Soil application; ZnSHH: $ZnSO_4.7H_2O$; FS: Foliar spray; MT: Maximum tillering; Anth: Anthesis; GF: Grain filling; NS: Non-significant

Though the Zn fertilization strategies had not significantly affected the plant height, tiller numbers per hill, and leaf area index, the treatment soil application of 2.5 kg Zn ha^{-1} +foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages recorded comparatively higher values during the experiment (Table 1). The higher dry matter accumulation at harvest, CGR and NAR at 60–90 DAT was recorded with soil application of 2.5 kg Zn ha^{-1} along with the foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages and it was statistically similar with foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering, anthesis and grain filling stages. On average, the soil+foliar application of Zn increased the dry matter accumulation by 13% more than the control. However, the interaction effect between rice varieties and Zn fertilization was non-significant during both years. Zinc application augmented the growth and development of the rice plant, as it had an active role in the vital physiological and metabolic processes like photosynthesis, chlorophyll formation, carbohydrate metabolism, and biotic and abiotic stress tolerance (Marschner, 1995, Cakmak, 2008). Furthermore, the involvement of Zn in auxin synthesis might have led to higher hormonal activity and growth performance at critical crop growth stages (Chattha et al., 2017). However, 2–3 foliar applications of Zn in addition to soil application performed better, as it ensured increased availability of zinc in plants at reproductive stages.

3.2. Yield attributes and yields

The yield attributes and yields of rice were significantly influenced by different varieties and zinc fertilization strategies during the experiment (Table 2; Figure 1). The higher effective tillers, panicle weight, filled grain weight per panicle, the number of filled grains and total grains per panicle, and fertility percentage were observed with the non-biofortified variety Pusa 44 and it was closely followed by the biofortified variety DRR Dhan 45. The high-yielding variety, Pusa 44, and the biofortified variety, DRR Dhan 45 recorded higher dry matter accumulation, leaf area index, and crop growth rate. That might have helped to achieve better yield attributes. However, the non-biofortified variety Pusa *Basmati* 1121 and Pusa *Basmati* 1509 recorded higher panicle length and 1000-grain weight, respectively.

Table 2: Effect of varieties and Zn fertilization strategies on yield attributes of rice (pooled data of two years)

Treatment	Effective tillers hill^{-1} (Nos.)	Panicle weight (g)	Panicle length (cm)	Total grains panicle^{-1} (Nos.)	Filled grains panicle^{-1} (Nos.)	Filled grains weight panicle^{-1} (g)	Fertility percentage (%)	1,000-grain weight (g)
Varieties								
Pusa *Basmati* 1121	10.9	2.68	28.9	85.6	59.3	1.64	68.7	27.0
Pusa *Basmati* 1509	10.0	2.82	28.1	88.5	68.0	1.84	76.7	27.5
Pusa 44	12.3	5.00	26.5	214.5	190.5	4.17	88.9	21.9
DRR Dhan 45	11.9	4.40	25.1	167.5	143.5	3.35	85.8	23.3
SEm±	0.17	0.05	0.37	2.74	1.13	0.03	2.08	0.33
CD (p=0.05)	0.59	0.16	1.27	9.47	3.93	0.09	7.19	1.13
Zinc fertilization								
Control (no Zn)	10.9	3.23	26.9	127.2	98.4	2.30	73.4	24.6
5 kg Zn ha^{-1} SA	11.3	3.65	27.1	137.5	112.8	2.68	79.5	24.8
2.5 kg Zn ha^{-1} SA+0.5% ZnSHH FS at MT & Anth	11.5	4.21	27.4	150.5	131.9	3.22	85.8	25.6
0.5% ZnSHH FS at MT, Anth & GF	11.3	3.82	27.2	141.0	118.2	2.80	81.4	24.7
SEm±	0.18	0.05	0.35	1.65	1.75	0.03	1.29	0.45
CD (p=0.05)	NS	0.14	NS	4.82	5.11	0.10	3.77	NS
Interaction effect	NS	NS	NS	NS	NS	1.84	NS	NS

SA: Soil application; ZnSHH: $ZnSO_4.7H_2O$; FS: Foliar spray; MT: Maximum tillering; Anth: Anthesis; GF: Grain filling; NS: Non-significant

Significantly higher grain yield was noted with the non-biofortified variety, Pusa 44 (5.3 t ha^{-1}), which was statistically similar to the biofortified variety, DRR Dhan 45 (Figure 1). But, the higher straw yield was recorded with the non-biofortified variety, Pusa *Basmati* 1121 (10.8 t ha^{-1}) (Figure 1). Improved yield attributes of rice varieties ensued in the higher grain yield, which was corroborated by the positive correlation (R^2=0.71 to 0.79) between grain yield and yield attributes such as panicle weight (g), filled grains panicle^{-1} (Nos.), filled grains weight panicle^{-1} (g) and total grains panicle^{-1} (Nos.) (Figure 2). Moreover, the varietal difference in responses to Zn fertilization was reflected in variation in yield and yield attributes. Zn fertilization maintained better source-sink balance as it has a positive influence on the translocation of assimilates and photosynthates from the source toward the sink (Ozturk et al., 2006, Alloway, 2008).

Zinc, irrespective of its method and time of application, significantly improved yield attributes and grain and straw yields of rice over the control (no Zn). Soil application of 2.5 kg Zn ha^{-1}+foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages recorded higher panicle weight, filled grain weight panicle^{-1}, number of filled grains and total grains panicle^{-1}, fertility percentage, and

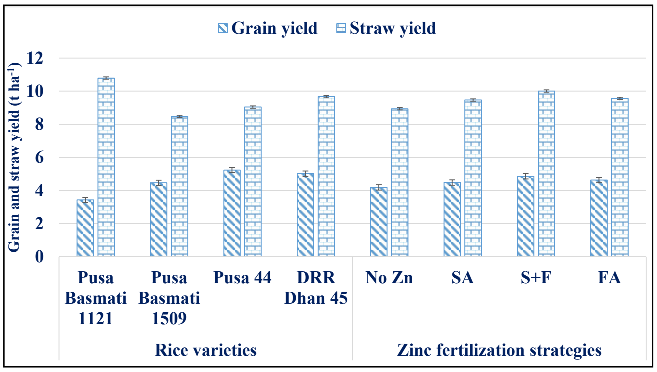

Figure 1: Grain and straw yields of rice as influenced by varieties and Zn fertilization strategies (pooled data of two years)

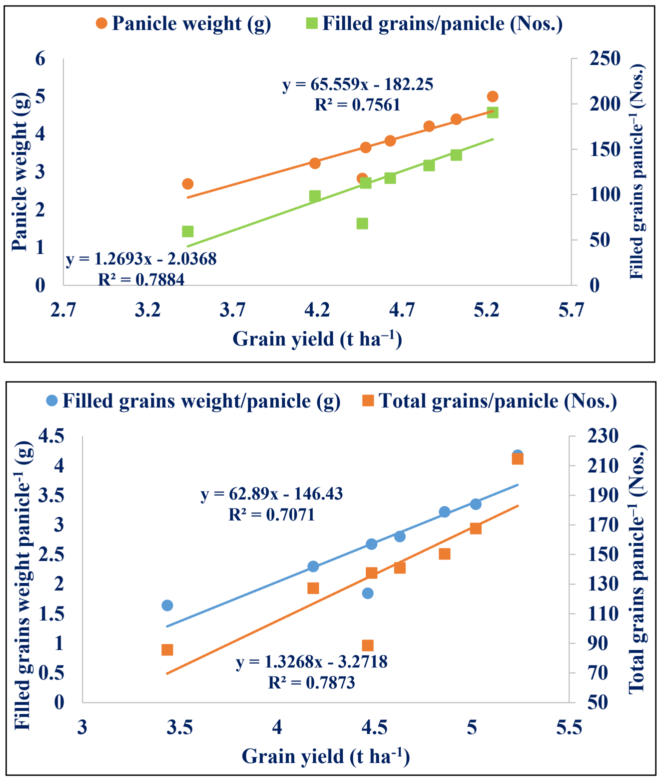

Figure 2: Correlation between grain yield (t ha^{-1}) and yield attributes, viz. panicle weight (g), filled grains $panicle^{-1}$ (Nos.), filled grains weight $panicle^{-1}$ (g), total grains $panicle^{-1}$ (Nos.), etc

grain and straw yield (Table 2; Figure 1), and it was followed by 0.5% $ZnSO_4.7H_2O$ foliar applications, 5 kg Zn ha^{-1} soil application and control. On average, the soil+foliar Zn application increased grain yield by 14% and straw yield by 10.5% more than the control. Nevertheless, the interaction effect between rice varieties and Zn fertilization strategies was not significant.

Improvement in yield attributes and yield of rice with Zn fertilization might be due to higher Zn availability to plants in treated plots than control (no Zn) plots, which ultimately led to higher Zn uptake and utilization (Shivay et al., 2008b, Shivay and Prasad, 2012). Though soil application of Zn increased available Zn in the soil during seed germination and seedling development stage, Zn availability decreased with time due to fixation to soil matrix (Rehman et al., 2012, Prasad et al., 2014). Furthermore, the root activity was also lowered at the grain filling stage due to a lower allocation of photo-assimilates (Stomph et al., 2011, Impa and Johnson-Beebout, 2012). Hence, foliar applications of Zn at maximum tillering, anthesis stages, and grain filling stages maintained a high concentration of zinc in plant tissues, which contributed considerably to various metabolic processes of vigorous grain production. Additionally, adequate Zn supply at the anthesis stage might have stimulated improved pollen germination and fertilization resulting in higher fertility percentage (Pandey et al., 2006, Liu et al., 2020). Hence, foliar application of $ZnSO_4.7H_2O$ at a later stage along with adequate soil Zn application is the best approach to improve the growth and yield attributes of rice (Shivay et al., 2015).

3.3. *Economics*

The biofortified and non-biofortified varieties markedly impacted the economics of rice cultivation (Table 3). A higher cost of cultivation was incurred with non-biofortified varieties Pusa *Basmati* 1121 and Pusa *Basmati* 1509 due to the comparatively higher seed price of the *Basmati* variety. However, Pusa *Basmati* 1509 recorded higher gross returns, net returns and B:C during the trial and it was statistically on par with Pusa *Basmati* 1121. The better economic with the cultivation of Pusa *Basmati* 1509 might be due to the higher yield and premium selling price of *Basmati* (aromatic) rice in the market, which is generally higher than the non-aromatic rice variety. The biofortified variety, DRR Dhan 45 recorded lower gross returns, net returns and B:C. The cultivation of biofortified variety will be more profitable if a premium price would be also offered for the Zn-biofortified grain.

The Zn fertilization strategies also significantly influenced the economics of rice cultivation (Table 3). Among Zn fertilization strategies, soil application of 2.5 kg Zn ha^{-1} +foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering and anthesis stages recorded significantly the higher cost of cultivation, gross returns, net returns and B:C and it was followed by foliar application of 0.5% $ZnSO_4.7H_2O$ at maximum tillering, anthesis and grain filling stages, 5 kg Zn ha^{-1} soil application and control. On an average, the soil+foliar application of Zn was ₹ 1,700 costlier than no Zn application (control), but it increased the gross returns and net returns by ₹ 20,100 (15.6%) and ₹ 18,350 (26.7%), respectively. The soil+foliar Zn fertilization cost (fertilizer+application cost) is small compared with the economic returns, thus, could be a remunerative choice to farmers in Zn deficient land (Nayak et al., 2022). However, economics apart, Zn fertilization has greater public health benefits as it increases the micro-nutrient density in the grains (Shivay et al., 2008a, Cakmak and Kutman, 2018, Karmakar et al., 2021).

Table 3: Economics of rice as influenced by varieties and Zn fertilization strategies (pooled data of two years)

Treatment	Cost of cultivation (₹ ×10^3 ha^{-1})	Gross returns (₹×10^3 ha^{-1})	Net returns (₹×10^3 ha^{-1})	B:C ratio
Varieties				
Pusa *Basmati* 1121	61.8	153.3	91.5	1.48
Pusa *Basmati* 1509	61.8	160.5	98.7	1.59
Pusa 44	61.6	123.5	61.9	1.00
DRR Dhan 45	61.7	121.4	59.7	0.97
SEm±	–	1.79	1.18	0.02
CD (p=0.05)	–	6.21	4.08	0.07
Zinc fertilization				
Control (no Zn)	60.6	129.2	68.6	1.13
5 kg Zn ha^{-1} SA	61.9	137.8	75.9	1.22
2.5 kg Zn ha^{-1} SA+0.5% ZnSHH FS at MT & Anth	62.3	149.3	87.0	1.40
0.5% ZnSHH FS at MT, Anth & GF	62.1	142.3	80.3	1.29
SEm±	–	1.66	1.20	0.02
CD (p=0.05)	–	4.85	3.50	0.06
Interaction effect	–	NS	NS	NS

1 US $=INR 71.02 and INR 73.57 (average value of October' 2019 and 2020, respectively); SA: Soil application; ZnSHH: $ZnSO_4.7H_2O$; FS: Foliar spray; MT: Maximum tillering; Anth: Anthesis; GF: Grain filling; NS: Non-significant

4. CONCLUSION

Better crop growth and yields were observed with biofortified variety DRR Dhan 45 and non-biofortified variety Pusa 44, while higher gross and net returns were obtained from Pusa *Basmati* 1509. Among zinc fertilization strategies, soil plus foliar application of Zn recorded higher growth parameters, yield, and yield attributes and better economics. Hence, basal application of 2.5 kg Zn ha^{-1} plus two 0.5% $ZnSO_4.7H_2O$ foliar spray at maximum tillering and anthesis stages should be recommended for higher productivity and profitability of rice in Zn-stress soil conditions.

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