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Research Paper

Effect of zinc fertilization on growth and yield of basmati rice (*Oryza sativa*) varieties

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2018 and 2019 at the Crop Research Centre (Campus), Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, to evaluate the effect of zinc fertilization on growth, yield attributes and yield of basmati rice (*Oryza sativa* L.) varieties. Among the varieties 'Pusa Basmati 1121' showed the highest values of growth parameters, yield attributes and yield and was at par with 'Pusa Basmati 1509' during both the years. Variety, 'Pusa Basmati 1121' gave about 8.8% and 9.9%, 2.6% and 2.0% higher yield than 'Pusa Basmati 1401' and 'Pusa Basmati 1509' during both the years. On the other hand, the rice grain yield was increased by 6.6 and 8.0% in 'Pusa Basmati 1509' as compared to 'Pusa Basmati 1401' during 2018 and 2019, respectively. Plant height (103.5 and 102.5 cm), leaf area index (5.12 and 4.93), days taken to maturity (144.5 and 143.9 days), effective tillers/m^2 (422.9 and 414.1), grains weight/panicle (1.90 and 1.81 g) and were found better with 'Pusa Basmati 1121'. 'Pusa Basmati 1401' showed the lowest growth parameters, yield-attributing characters and yield during both the years. Among the zinc-management practices seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage was found to be the best for the growth parameters, yield attributes and yield in 'Pusa Basmati 1121'. 'Pusa Basmati 1509' with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage exhibited significant increase in the growth parameters, yield-attributing characters and finally the yield, leading to enhanced productivity of basmati rice.

Key words: Basmati, Biofortification, Foliar, Zinc and $ZnSO_4$

Rice provides 35–60% of the dietary calories and 50–80% of the energy intake of the people in developing countries (Pooniya *et al.,* 2012). In South-Asia, basmati is a geographical indicator of a distinct type of rice grown for its cooking quality. It is the world's most aromatic and fragrant rice, in terms of its characteristic fragrance attribute by a chemical compound named 2-acetyl-1-pyrroline. Combined with fragrance it has a long, slender, narrow wide grain with "medium" glycemic index, between 56 and 69, therefore making it more appropriate for diabetics (Ashfaq *et al.,* 2014).

About 30% of the world's human population diets are deficient in zinc (Ghasal *et al.,* 2012). Zinc is an imperative micronutrient and has a number of essential functions in the plant system such as the maintenance of structural and functional integrity of biological membranes and facilitation of protein synthesis and gene expression. Zinc deficiency in humans affects physical growth, the functioning of the immune system, reproductive health and neurobehavioural development (Begum *et al.,* 2016). Therefore, the zinc content of staple foods, such as rice and wheat is of major importance. Throughout the world rice is mainly grown in flooded soil condition where zinc is found in reduced condition as it gets bound to sulphur and carbonate in reduced form (Jena *et al.*, 2018).

Timing and rate of zinc application determines the availability of zinc in plant system, more particularly in grains. On an average, 50% of the Indian soils are deficient in zinc, rising to 63% by 2025 (Jena *et al*., 2018), particularly in calcareous soils, due to the formation of insoluble zinc hydroxide and its carbonates. Zinc application in rice is mainly focused as basal application of $ZnSO_4$ along/or with the foliar mean too. Biofortification is the development of nutrient dense staple food crops using the best conventional breeding practices and modern biotechnology, without sacrificing agronomic performance and important

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consumer preferred traits. Biofortification focuses on making plant foods more nutritious as the plants are growing (Jena *et al.*, 2018). Zinc biofortification, which aims to enhance Zn concentration as well as its bioavailability to rice grains, is considered as the more sustainable and economical solution to address human Zn deficiency (Bouis, 2002). Agronomic biofortification, such as Zn fertilization, is an essential and rapid solution for improving Zn concentration in rice grains to address the ongoing human Zn deficiency. Three methods, including soil amendment, seed priming and foliar application used in Zn fertilizations, have been extensively reviewed (Cakmak, 2008). Foliar spray of Zn also increases Zn harvest index, Zn crop recovery efficiency (CRE) and at the same time also raises Zn concentration in grains and thus, it is important from the view point of human and animal nutrition and health (Prasad, 2009).

Use of Zn fertilizers in soil is a general strategy to cope with Zn deficiencies and to increase Zn concentration in grains. Zinc can be applied via the soil, seeds and leaves or by dipping seedlings in a fertilizer solution. Foliar application is more efficient in grains Zn accumulation than the soil application (Jan *et al.,* 2016). Foliar application of Zn has many advantages over soil application owing to its requirement in considerably lower amount of application than the soil application, uniform application and the crop response to applied micronutrient is almost immediate, so that deficiency can be corrected relatively rapidly (Mortvedt, 2000).

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2018 and 2019 at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, (29°042 N and 77°422 E, 227 m above mean sea-level) Uttar Pradesh, on sandy-loam soil having *p*H 8.6. It lies in Western Uttar Pradesh and has sub-tropical climate. The mean annual rainfall of Meerut is 732 mm. The experimental field had an even topography with good drainage system. Soil of the experiment field was low in available N (180 kg/ha), medium in available P (10.6 kg/ha), K (126.7 kg/ha) and organic carbon (0.30%). The available DTPA-extractable Zn in soil was 0.70 mg/kg of the soil. Three basmati rice varieties, viz. V_1, 'Pusa Basmati 1121'; V_2, 'Pusa Basmati 1401'; and V_3, 'Pusa Basmati 1509', were taken in the main plot during both the years. Five treatments of zinc management, viz. Z_1, control (water spray); Z_2, soil application of $ZnSO_4$ @ 15 kg/ha; Z_3, foliar spray of $ZnSO_4$ @ 0.5% at tillering and panicle-initiation stage; Z_4, seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage; and Z_5, seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at panicle-initiation stage, were applied in sub-plots and replicated thrice in split-plot design. Twenty-five days old seedlings were transplanted at the spacing of 20 cm × 15 cm spacing with 2 seedlings/hill. Soil was sampled before transplanting and after harvesting of the crop to know the fertility status of the experiment field.

The experimental field was ploughed twice with disk plough, puddled twice with a heavy puddler in standing water and maintained a level of 5 cm of standing water for transplanting of the seedlings. At final puddling 60 kg phosphorus and 40 kg potash through single superphosphate and muriate of potash, respectively were applied uniformly in all the plots. Nitrogen was applied @ 120 kg/ha as urea in 3 splits–half at the time of transplanting and remaining half at the time of maximum tillering and at panicle initiation stage equally in all the treatments. Among zinc management, $ZnSO_4$ was applied as soil application @ 15 kg/ha, seedlings were dipped in 2% $ZnSO_4$ solution for 15 minutes, and for foliar spray 0.5% $ZnSO_4$, neutralized with lime, was used as per the treatments. Seedlings of basmati rice was transplanted in the field on 18 July 2018 and 21 July 2019. The gross plot size was 4.5 m × 3.6 m for each treatment. Rice crop raised as per standard recommended package of practices and was harvested during October–November during both the years of experimentation.

Plant height was measured from the base of the plant at the ground surface to the tip of the tallest leaf panicle using a standard meter scale. Leaves of 5 hills were plucked and leaf-area index was calculated using leaf-area meter (LA-3100). Five leaves/plot fromdifferent hills were selected and SPAD reading was taken around the mid-point of each leaf blade, 30 mm apart, on one side of the mid-rib using chlorophyll meter (SPAD-502). Effective tillers/m^2 were counted at harvesting. After harvesting, threshing, cleaning and drying, the grain yield of rice was estimated at 14% moisture content. The fertility ratio was calculated as:

$$\text{Fertility ratio} = \frac{\text{Number of filled grains/panicle}}{\text{Total grains/panicle}}$$

Zinc harvest index (ZHI) was calculated as:

$$\text{ZHI} = \frac{\text{Zinc uptake in grains (g/ha)}}{\text{Total zinc uptake in grains (kg/ha)}}$$

The data of 2 years were analyzed statistically using F-test, as per Panse and Sukhatme (1967). CD values at P=0.05 were used to determine the significance of different between treatments means.

RESULTS AND DISCUSSION

Growth parameters

Different basmati rice varieties and zinc-management practices significantly influenced the plant height (cm), leaf-area index (LAI) and days taken to maturity at 60 days after transplanting (DAT) during both the years (Table 1). However, no interaction effect was recorded among them. The maximum plant height, LAI and days taken to maturity were recorded with 'Pusa Basmati 1121' (V_1), which was significantly superior to 'Pusa Basmati 1509' and 'Pusa Basmati-1401', except for plant height which was at par with 'Pusa Basmati 1509' during both the years (Table 1). The lowest height and LAI were recorded with 'Pusa Basmati 1401', while minimum days taken to maturity were recorded in 'Pusa Basamati 1509'. This might be due to the differences in the genetic makeup of variety which might have the variation in growth parameters of the cultivars. Saha *et al.* (2013) and Saravanakumar (2020) also made similar observations. Chlorophyll content did not differ significantly due to different varieties during both the years. The maximum chlorophyll content of 43.8 was recorded with 'Pusa Basmati 1121' at 60 DAT during 2018; while it was highest in 'Pusa Basmati 1401' (40.9) in 2019. The minimum chlorophyll content at 60 DAT was recorded in 'Pusa Basmati 1509' during both the years.

The maximum plant height, LAI and days taken to maturity were recorded with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage, which was significantly superior to rest of the treatments, while for plant height it was at par with soil application of $ZnSO_4$ @ 15 kg/ha during both the years. The minimum plant height, LAI and days taken to maturity were recorded with the control. A reduction of 0.5, 2.3 and 0.6% was recorded in plant height, LAI and days taken to maturity from 2018 to 2019, which might be due to the lesser rainfall received during the crop growth period in 2019. Chlorophyll content did not show any significant effect of different zinc-management practices during 2019, while it differed significantly during 2018. However, the maximum chlorophyll content was recorded at 60 DAT with foliar spray of $ZnSO_4$ @ 0.5% at tillering and panicle-initiation stage, while at 90 DAT, it was noted with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage during 2018 and 2019. The highest values of growth parameters under the treatments receiving the zinc through soil/ foliar and/ or seedling dipping might be owing to favorable effect of zinc on the proliferation of roots which increased the uptake of plant nutrients from the soil, and supplied these to the aerial parts resulting in enhancement of the vegetative growth of the plants. Similar results were also reported by Barua and Saikia (2017). The minimum chlorophyll content was recorded under control during first and second year.

Table 1. Effect of rice varieties and zinc-management practices on plant height, leaf area index (LAI), chlorophyll content and days taken to maturity in rice

Treatment	Plant height (cm)		LAI		Chlorophyll content		Days taken to maturity	
	60 DAT							
	2018	2019	2018	2019	2018	2019	2018	2019
Varieties								
V_1, 'Pusa Basmati 1121'	103.5	102.5	5.12	4.93	43.8	40.7	144.5	143.9
V_2, 'Pusa Basmati 1401'	87.2	86.1	4.52	4.47	43.2	40.9	137.5	136.5
V_3, 'Pusa Basmati 1509'	100.7	99.8	4.65	4.60	41.2	38.6	118.6	118.1
SEm±	1.3	1.6	0.004	1.011	1.1	0.8	0.125	0.122
CD (P=0.05)	5.4	6.6	0.018	0.043	NS	NS	0.503	0.491
Zinc management								
Z_1, Control: water spray	90.9	89.8	4.65	4.58	41.3	39.6	131.1	130.2
Z_2, Soil application of $ZnSO_4$ @ 15 kg/ha	99.8	98.8	4.79	4.70	43.6	39.9	134.8	134.1
Z_3, Foliar spray of $ZnSO_4$ @ 0.5% at T and PI stage	96.5	95.0	4.76	4.65	43.7	40.5	132.6	131.9
Z_4, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at T and PI stage	101.1	100.6	4.84	4.73	43.0	40.2	136.2	135.4
Z_5, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at PI stage	97.3	96.5	4.76	4.67	42.2	39.9	133.0	132.4
SEm±	1.2	1.3	0.007	0.011	0.5	0.6	0.407	0.322
CD (P=0.05)	3.7	3.9	0.021	0.032	1.6	NS	1.196	0.946

DAT, days after transplanting; T, tillering; PI, panicle-initiation

Yield attributes

'Pusa Basmati 1121' rice had the highest number of effective tillers/m^2 and grains weight/panicle (g) followed by 'Pusa Basmati 1509' and 'Pusa Basmati 1401' during both the years (Table 2). Although the difference was significant during both the years, except during 2019 for grains weight/panicle. The filled grains/panicle and panicle density were the highest in 'Pusa Basmati 1401', being significantly higher than rest of the varieties during both the years. The data revealed that, there was significant difference among different rice varieties during 2018; however, fertility ratio did not differ significantly during 2019. The highest fertility ratio was recorded in 'Pusa Basmati 1509' in 2018 and 2019, being superior to the rest of the treatments during 2018. The minimum fertility ratio was recorded in 'Pusa Basmati 1401' during both the years. Chandra *et al*. (2021) reported the similar results.

The application of zinc significantly increased the yield attributes, viz. effective tillers/m^2, filled grains/panicle, fertility ratio, panicle density and grains weight/panicle over the control during both the years. However, the highest values were recorded with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle initiation stage, which were very close to soil application of $ZnSO_4$ @ 15 kg/ha during both the years. The lowest fertility ratio in the control compared with the zinc-applied plots was mainly due to the more number of chaffy grains/panicle and/or the lowest filled grains/panicle. In contrast to this, the more filled grains/panicle were noticed under adequate soil application of $ZnSO_4$ or dual (dipping and foliar mean) application which ultimately improved the growth and yield attributes of rice. Fageria (2001) also observed more number of panicles/unit area with the application of adequate zinc supply in transplanted rice. Similar results were also reported by Baral *et al.* (2020).

Yield, grain: straw ratio, harvest index and zinc harvest index

'Pusa Basmati 1509' had the highest grain: straw ratio, harvest index and zinc harvest index followed by 'Pusa Basmati 1121' and 'Pusa Basmati 1401' during both the years (Table 3). Although the difference was non-significant during 2018 for harvest index and zinc harvest index. Grain yield (t/ha) was highest in 'Pusa Basmati 1121' during both the years and was significantly higher than 'Pusa Basmati 1401' and 'Pusa Basmati 1509' during 2018 and 2019. The lowest grain yield (t/ha), grain: straw ratio, harvest index and zinc harvest index were recorded with 'Pusa Basmati 1401' during both the years. As compared to 'Pusa Basmati 1401', about 6.6 and 8.0% yield increase was observed in 'Pusa Basmati 1509' under same sets of environment during both the years. On the other hand, the rice

Table 2. Effect of rice varieties and zinc-management practices on effective tillers/m^2, filled grains/panicle, fertility ratio, panicle density and grains weight/panicle (g) in rice

Treatment	Effective tillers/m^2		Filled grains/panicle		Fertility ratio		Panicle density		Grains weight/panicle (g)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Varieties										
V_1, 'Pusa Basmati 1121'	422.9	414.1	65.6	68.6	0.72	0.76	2.45	2.57	1.90	1.81
V_2, 'Pusa Basmati 1401'	381.1	371.1	81.0	85.1	0.67	0.73	3.14	3.32	1.57	1.61
V_3, 'Pusa Basmati 1509'	420.3	411.4	68.7	66.1	0.76	0.77	2.53	2.44	1.65	1.64
SEm±	8.0	11.8	0.70	1.28	0.01	0.02	0.05	0.01	0.05	0.05
CD (P=0.05)	32.1	34.6	2.82	5.16	0.02	NS	0.19	0.07	0.21	NS
Zinc management										
Z_1, Control: water spray	310.2	308.9	60.2	58.4	0.66	0.68	2.33	2.26	1.42	1.23
Z_2, Soil application of $ZnSO_4$ @ 15 kg/ha	443.0	428.8	77.2	83.6	0.73	0.78	2.88	3.12	1.75	1.80
Z_3, Foliar spray of $ZnSO_4$ @ 0.5% at T and PI stage	397.1	380.7	69.0	66.0	0.69	0.73	2.62	2.51	1.62	1.50
Z_4, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at T and PI stage	461.5	455.4	82.0	86.8	0.78	0.82	3.02	3.25	2.00	2.15
Z_5, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at PI stage	428.6	420.6	70.7	71.6	0.71	0.75	2.70	2.73	1.72	1.74
SEm±	9.2	11.8	0.77	1.24	0.02	0.02	0.04	0.04	0.08	0.04
CD (P=0.05)	27.0	34.6	2.3	3.65	0.04	0.06	0.12	0.13	0.25	0.12

T, tillering; PI, panicle-initiation

Table 3. Effect of different rice varieties and zinc management practices on grain yield (t/ha), grain straw ratio, harvest index and zinc harvest index of rice

Treatment	Grain yield (t/ha)		Grain straw ratio		Harvest index		Zinc harvest index	
	2018	2019	2018	2019	2018	2019	2018	2019
Varieties								
V_1, 'Pusa Basmati 1121'	5.46	5.38	0.64	0.64	0.389	0.389	0.333	0.331
V_2, 'Pusa Basmati 1401'	4.97	4.85	0.63	0.62	0.384	0.382	0.301	0.298
V_3, 'Pusa Basmati 1509'	5.32	5.27	0.68	0.68	0.405	0.404	0.334	0.333
SEm±	1.0	0.5	0.02	0.01	0.006	0.003	0.007	0.005
CD (P=0.05)	3.9	2.0	NS	0.04	NS	0.014	0.03	0.021
Zinc management								
Z_1, Control: water spray	4.59	4.48	0.59	0.58	0.370	0.366	0.335	0.329
Z_2, Soil application of $ZnSO_4$ @ 15 kg/ha	5.50	5.43	0.67	0.67	0.401	0.400	0.324	0.323
Z_3, Foliar spray of $ZnSO_4$ @ 0.5% at T and PI stage	5.18	5.10	0.65	0.65	0.393	0.392	0.305	0.303
Z_4, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at T and PI stage	5.59	5.52	0.68	0.68	0.403	0.404	0.334	0.335
Z_5, Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at PI stage	5.36	5.29	0.66	0.66	0.398	0.396	0.315	0.313
SEm±	0.1	0.08	0.02	0.02	0.007	0.006	0.007	0.006
CD (P=0.05)	0.28	0.22	0.06	0.05	0.021	0.017	0.029	0.016

T, tillering; PI, panicle-initiation

grain yield was increased by 8.8 and 9.9% in 'Pusa Basmati 1121' as compared to 'Pusa Basmati 1401'. 'However, 'Pusa Basmati 1509' and 'Pusa Basmati 1121' were statistically alike in terms of grain yield, grain: straw ratio, harvest index and zinc harvest index during both the years.

The application of zinc significantly increased the grain yield (t/ha), grain: straw ratio, harvest index and zinc harvest index over the control during both the years. However, the highest values were recorded with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle initiation stage, which was at par with soil application of $ZnSO_4$ @ 15 kg/ha during both the years. This might be due to the positive combined effect of yield-attributing characters like effective tillers/m^2, filled grains/panicle, panicle density and grain weight/panicle. The process of zinc storage in stem and zinc loading in the grains during grain filling have influence on more dry-matter production. Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% Zn at panicle-initiation stage application might have helped in transport process which ultimately resulted in about 17.9 and 18.8% yield increase over the control during both the years. Our results support the finding of Kumar *et al.* (2021). However, the highest zinc harvest index (0.335) was recorded under the control and was significantly superior to foliar spray of $ZnSO_4$ @ 0.5% at tillering and panicle initiation (PI) stage in the first year, while during 2019, it was (0.335) recorded with seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle initiation stage, being at par with rest of the treatments, except Z_3.

Protein yield

Protein yield differed significantly due to different varieties and zinc-management practices during both the years, except during 2018 in varieties. 'Pusa Basmati 1121' gave higher protein yield (418.7 and 410.8 kg/ha) than the other 2 varieties (Fig. 1); however, it was on a par with 'Pusa Basmati 1509' during 2019. The significant differences in protein content might be because of the different capacities of the varieties to absorb and use nitrogen, resulting in

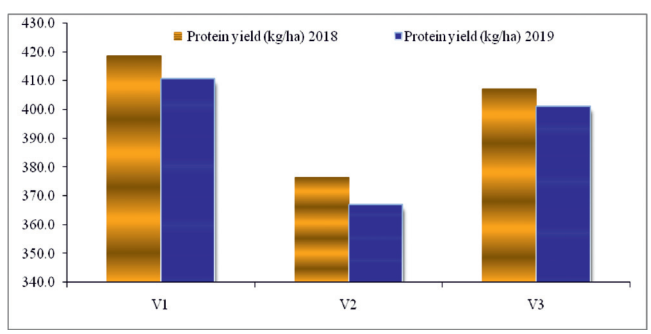

Fig. 1. Protein yield of rice as influenced by rice varieties during 2018 and 2019

different growth and biomass production besides nitrogen uptake. Our results are in close conformity with those of Pooniya and Shivay (2011).

The application of zinc significantly increased the protein yield (kg/ha) during 2018 and 2019. The maximum protein yield (434.9 and 426.8 kg/ha) was recorded with the application of seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle initiation stage which was at par with soil application of $ZnSO_4$ @ 15 kg/ha and seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at PI stage during both the years (Fig. 2). The lowest protein yield was recorded in the control (345.1 and 335.0 kg/ha). Seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle initiation stage resulted in 20.6 and 21.5% higher yield than the control during both the years.

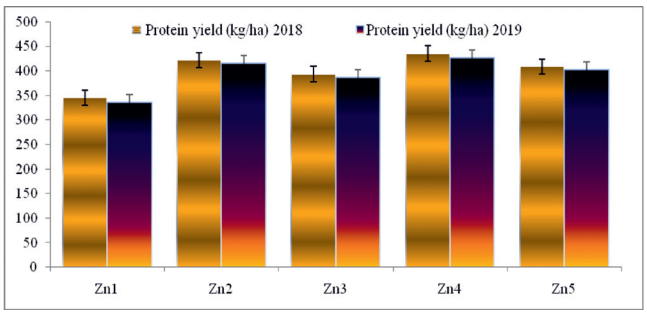

Fig. 2. Protein yield of rice as influenced by different Zn management practices during 2018 and 2019
Details of treatments are given under materials and methods.

The result of 2 year field experiment clearly showed significant effect of different zinc-management practices on basmati rice varieties for increasing crop productivity and profitability. Among the varieties, 'Pusa Basmati 1121' followed by 'Pusa Basmati 1509' were found better for growth parameters, yield attributes and hence the yield. Application of seedling dipping in 2% $ZnSO_4$ + foliar spray @ 0.5% at tillering and panicle-initiation stage proved superior in respect of growth parameters, yield attributes and grain yield.

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