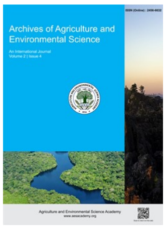
Archives of Agriculture and Environmental Science 8(2): 137-143 (2023)
https://doi.org/10.26832/24566632.2023.080207

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

CrossMark

Maximizing yield of aromatic fine rice through application of zinc and poultry manure

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ARTICLE HISTORY

Received: 08 April 2023
Revised received: 26 May 2023
Accepted: 14 June 2023

Keywords

BRRI dhan34
Grain yield
Manure
Micronutrient

ABSTRACT

Zinc (Zn), one of the most important micronutrients for plants which play vital role in various metabolic functions and deficiency of this nutrient in agricultural soils associated with lower yield of rice in many regions of the world. The integrated use of organic and inorganic fertilizer has been found to be promising for sustainable crop production and poultry manure could be a rich source of organic matter. Considering these factors, a field experiment was conducted to observe the effect of zinc and poultry manure-based fertilization on the yield of aromatic fine rice, BRRI dhan34. Four levels of zinc and three levels of poultry manure (PM) were tested as treatment including control. Application of zinc, PM and their interaction significantly influenced the growth and yield of rice that result the tallest plant (131.33 cm), maximum number of effective tillers/hill (13.89), grains/panicle (128.54), 1000-grain weight (12.09 g) and highest grain yield (3.21 t/ha) where 4 kg Zn/ha were applied. On the other hand, tallest plant (129.92 cm), maximum number of effective tillers/hill (9.13), grains/panicle (128.23), 1000-grain weight (12.05) and grain yield (3.24 t/ha) were obtained where 10 t/ha of PM were applied. The interaction between application of 4 kg Zn/ha and 10 t PM/ha performed best in all yield contributing characters and results maximum grain yield (3.64 t/ha). Therefore, 4 kg Zn/ha along with 10 t PM/ha was found to be suitable combination for cultivation of aromatic fine rice.

Citation of this article: Rasel, M. A., Jha, S., Islam, S. M. M., Hasan, A. K., Rashid, M. H., & Paul, S. K. (2023). Maximizing yield of aromatic fine rice through application of zinc and poultry manure. *Archives of Agriculture and Environmental Science*, *8*(2), 137-143, https://dx.doi.org/10.26832/24566632.2023.080207

INTRODUCTION

Rice (*Oryza sativa* L.) is consumed regularly and is vital for the food security of over half the world's population (Mohidem *et al*., 2022) contributing over 21% of human caloric requirements and up to 76% of the calorific intake of Southeast Asian inhabitants (Zhao *et al*., 2020). The global annual production of rice is about 496.40 million tons from 162.06 million hectares of land in 2019–2020 (FAOSTAT, 2021). The rise in the global population and the effects of climate change in the region influence the need to boost rice production. There is a report that, Asia is expected to account for up to 65% of the projected rise in world rice consumption; however, the growth rate will decrease by 0.15% per annum (FAOSTAT, 2021). Even though crop production of Bangladesh has increased many folds since the last 50-years. Crop yields still need to be increased to meet the food requirements for the increasing population. Along with global agriculture, Bangladesh also faces the challenge of producing crops from its limited land resources to meet the huge demand from its population. The scope is limited to bring new land under cultivation. Moreover, every year, cultivated land is being reduced due to human settlement and rapid urbanization and industrialization. This implies that global rice production will continue to be lower than demand. To combat the changing situation, rice breeders have focused on the development of cultivars having higher yield and yield stability, and increased resistance/ tolerance to biotic and abiotic stresses (Eltaher *et al.*, 2011). At the same time, improved agronomic practices and integrated nutrient management could play vital role in improving yield of rice with minimum cost involvement.

An imbalanced use of inorganic fertilizers and pesticides without organic fertilizers has led to deterioration of soil health and crop yield loss which has become a concern (Urmi *et al.*, 2022). More dependency on chemical fertilizers and imbalanced nutrient management practices has impaired the productivity of soils in many Asian countries including Bangladesh. Increased the cropping intensity and regular cultivation of high-yielding rice varieties has increased the removal of nitrogen (N), phosphorus (P), potassium (K), and other macro and micro-nutrients from the soils in Bangladesh (Saleque *et al.*, 2004). Micronutrient deficiency is being paid more attention in recent times in areas where intensive agriculture is practiced (Fatematuz-Zohora *et al.*, 2023; Islam *et al.*, 2021). Micronutrients depletion in soil have been accelerated by the increase of intensive cultivation with increased dependence on inorganic fertilizer along with high yielding varieties and the decreasing emphasis on the use of organic manures. Among micronutrient deficiencies, Zinc (Zn) deficiency has been identified as a most serious agricultural issue in the world (Meng *et al.*, 2016), which is required for various biochemical and metabolic process in rice such as synthesis of cytochromes and nucleotides, auxin metabolism, production of chlorophyll, activation of several enzymes, membrane integrity, metabolism of carbohydrate, cell wall development, gene expression, respiration and pollen development (Barman *et al.*, 2018; Madhusudanan *et al.*, 2019; Mondal *et al.*, 2020 and He *et al.*, 2021). In some places of the country, yield loss is caused due to the deficiency of Zinc ranged from 10-18% (Rahman *et al.*, 2011). The use of organic manures alone may not be enough to meet the enormous nutrient requirements of present day high yielding cultivars. PM contains high amount of secondary and micronutrients in addition to 1.6%N, 1.5%P and 0.85%K (Aktar *et al.*, 2020). Poultry manure along with other inorganic fertilizer increased yield and quality of rice (Hasan *et al.*, 2004; Roy *et al.*, 2015; Pal *et al.*, 2016, Paul *et al.*, 2020; Paul *et al.*, 2021). Hence, there is a lot of potential for use of PM with the inorganic fertilizer schedule of rice and to reduce total dependence on inorganic fertilizers. The use of poultry manure and its proper management may reduce the need for chemical fertilizer allowing the small farmers to save the part of their cost of crop production. Considering the importance of zinc in wetland rice production as essential plant nutrient and the role of PM in replenishing the soil status, the research was undertaken to evaluate the effect of Zn and PM on yield attributes and yield of aromatic fine rice (cv. BRRI dhan34).

MATERIALS AND METHODS

Experimental site and experimentation

A field experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh (North Latitude and 90°50' Longitude at an elevation of 18 m above the sea level) from June to December, 2021. The soil of experimental site was non-calcareous dark-grey floodplain under the old Brahmaputra Alluvial Tract. BRRI dhan34 was used as plant material which was developed by Bangladesh Rice Research Institute (BRRI) and it is popular for its short duration and high yielding aromatic fine graded quality. Four levels of Zn (0, 2, 4 and 6 kg/ha) and three different doses of PM (0, 5 and 10 t/ha) were tested as treatment and without application of Zn and PM were considered as control.

The experiment was laid out in a randomized complete block design with three replications. Each replication represented a block and each block was divided into 12 unit plots. Total number of plots was 36. The size of unit plot was 2.0m × 2.5m. The distance between two-unit plots was 0.5m and between blocks was 1.0m.

Crop husbandry

Sprouting of seeds was done following standard methods of sprouting and sown in the well prepared land for raising seedling. Thirty-five days aged seedlings were uprooted carefully and transplanted in the main field with three seedlings/hill following 30cm × 20cm spacing. Fertilizers were applied to the plots uniformly at the rate of 90, 60, 75 and 55 kg/ha urea, triple superphosphate (TSP), muriate of potash (MOP) and gypsum, respectively. The whole amount of TSP, MOP and gypsum was applied during final land preparation Urea was applied in three equal splits at 15, 30 and 45 days after Transplanting. Zinc (in the form of Zinc Sulphate) and PM was applied during final land preparation according to the treatment. Different agronomic practices and plant protection was done as and when needed. When 90% of the grains became golden yellow, the crop was considered to be matured. Five hills (excluding border hills and central 1.0m × 1.0m) were selected randomly from each experimental plot to record data on crop characters and yield contributing characters. An area of 1.0 m^2 was selected in the middle portion in each plot and harvested for record the yields of grain and straw. The harvested crop of each plot was separately bundled, properly tagged and then brought to the clean threshing floor. The crop was threshed with a pedal thresher. Grains were then sun dried at 14% moisture level and cleaned. Straws were also sun dried properly. Finally straw and grain yield/plot were recorded and converted to t/ha.

Statistical analysis

The recorded data on various plant characters were statistically analyzed following the analysis of variance (ANOVA) technique and mean difference were adjusted by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using MSTAT.

RESULTS AND DISCUSSION

Plant height

Significant effect was found among different level of Zn application for plant height at the time of harvesting. The tallest plant (131.33 cm) was found where Zn was applied 4 kg/ha and the shortest plant was found where no Zn was applied (Figure 1A). It indicates that plant height was not increases with the increase of Zn doses, as 6 kg Zn dose results lower plant height than 4 kg Zn dose. Similar results were also observed by Genc *et al.* (2006) and; Jain and Dahama (2006) and they found that plant height increased significantly up to application of 6 kg Zn/ha rather than other lower doses of Zn. Similarly, application of PM at different doses also showed significant effect on plant height. The tallest plant (129.92 cm) was observed under treatment where PM was applied 10 t/ha and the shortest plant was observed where PM was not applied (Figure 1B). This finding is in agreement with Sarkar *et al.* (2014) who reported that plant height increases with the increased level of PM dose. In case of interaction between Zn and PM application also showed significant effect on plant height. The highest plant height (133.43 cm) was found from the interaction of 4 kg Zn/ha and 10 t PM/ha application whereas, the lowest plant height (115.57 cm) was observed in the combination between the control treatment (Table 3).

Number effective tillers/hill

Application of Zn exerted a significant influence on the production of effective tillers/hill at 1% level of significance. The maximum number of effective tillers/hill (9.48) was obtained at treatment where Zn was applied at the rate of 4 kg/ha and the lowest one (7.98) was obtained at control treatment (no application of Zn). It is also seen that the higher dose of Zn (6 kg/ha) failed to give maximum number of effective tillers per hill as it gives lower number of tillers compared to 4 kg/ha dose. Similar result was obtained by Islam *et al.* (1999) who concluded that increase in Zn levels caused considerable increase in number of effective tillers/hill of rice. In case of PM treatments also showed significant influence for production of effective tillers/hill. The highest number of effective tillers/hill (9.13) was obtained where PM was applied at the rate of 10 kg/ha and it is statistically significant with 5 t PM/ha whereas, the lowest number of effective tillers (8.19) was obtained at control treatment (no application of PM). Khanam *et al.* (2001) reported that by the application of 10 t PM/ha of gave maximum number of effective tillers per hill than any other lower doses of PM and increased significantly with the increase of doses. The interaction between Zn and PM application showed non significant effects on effective tillers production. The maximum number of effective tillers (9.93) was observed between the interaction of Zn dose of 4 kg/ha and PM at the rate of 10 t/ha. Whereas, the lowest one (7.53) found in the interaction between the control treatments (no Zn and PM application) (Table 3).

Panicle length

The length of panicle was found statistically significant due to different levels of Zn application. The longest panicle (23.01 cm) was obtained when Zn was applied at the rate of 4 kg/ha and the shortest one (21.21 cm) in control treatment (no application of Zn) (Figure 2A). Above findings shown that panicle length was greatly influenced by zinc application and at the same time it is also seen that almost similar panicle length obtained in 2 kg and 6 kg/ha Zn dose and it indicates that higher dose of Zn might not responsible to give longer panicle length. Several researchers reported that by the application of 6 kg Zn/ha than other lower doses, panicle length increased significantly (Khan *et al.*, 2008). Likewise, application PM at different doses showed significant effect on panicle length of BRRI dhan34. The longest panicle (23.67 cm) obtained from the treatment of PM dose 10 t/ha and the shortest panicle length (19.18 cm) observed in control treatment (no application of PM) (Figure 2B). Rashid *et al.* (2011) reported that by the application of PM increased the length of panicle. On the other hand, panicle length was not significantly influenced due to the interaction between different levels of Zn and PM application. Numerically the longest panicle length (24.72 cm) observed between the interaction of Zn application at the rate of 4 t/ha and PM at the rate of 10 t/ha whereas, the shortest panicle length (19.18 cm) was observed in the combination control treatment of Zn and PM (no Zn and PM application) (Table 3).

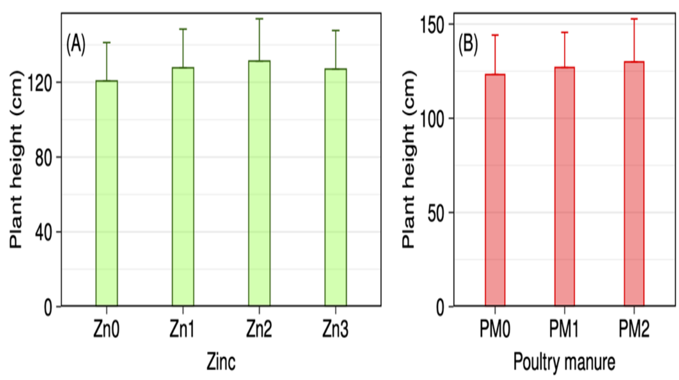

Figure 1. *Effect of zinc and poultry manure on plant height of aromatic rice BRRI dhan34.*

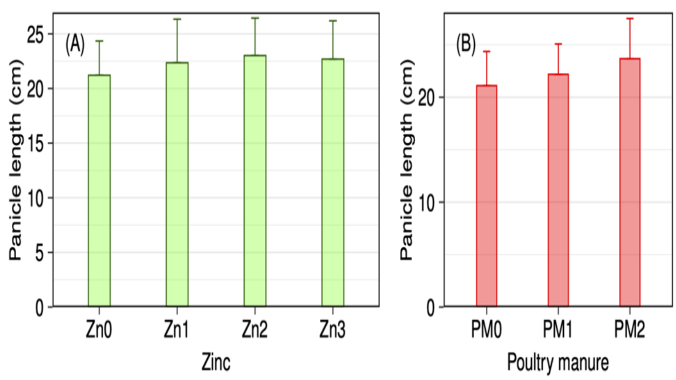

Figure 2. *Effect of zinc and poultry manure on panicle length of aromatic rice BRRI dhan34.*

Table 1. Effect of Zn fertilization on grains/panicle, sterile spikelets/panicle and 1000-grain weight of BRRI dhan34.

Zinc levels (kg per ha)	Effective tillers hill^{-1} (no.)	Grains /panicle (no.)	Sterile spikelets/panicle (no.)	Weight of 1000-grain (g)
Zn_0	7.98 c	109.54c	18.92a	10.79b
Zn_1	8.70 b	118.31b	18.21a	11.24ab
Zn_2	9.48 a	128.54a	15.72b	12.09a
Zn_3	8.57 b	125.22ab	17.10ab	10.94b
Level of Significance	**	**	**	*
CV (%)	5.95	6.31	13.52	8.89

Effect of Zn fertilization on effective tillers/hill, grains/panicle, sterile spikelets/panicle and 1000-grain weight of BRRI dhan34.

Table 2. Effect of PM on grains/panicle, sterile spikelets/panicle and 1000-grain weight of BRRI dhan34.

Poultry manure levels (t/ha)	Effective tillers hill^{-1} (no.)	Grains/ Panicle (no.)	Sterile spikelets/ Panicle (no.)	Weight of 1000-grain (g)
PM_0	8.19 b	112.21c	19.16a	10.40b
PM_1	8.72 ab	120.76b	18.45a	11.35a
PM_2	9.13 a	128.23a	14.86b	12.05a
Level of Significance	**	**	**	**
CV (%)	7.44	6.83	9.90	7.60

Effect of PM on effective tillers/hill, grains/panicle, sterile spikelets/panicle and 1000-grain weight of BRRI dhan34.

Table 3. Interaction of Zn fertilization and PM on crop characters, yield contributing characters and yield of BRRI dhan34.

Treatment	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains / panicle (no.)	Sterile spikelets/ panicle (no.)	Weight of 1000-grain (g)	Grain yield (t/ha)	Harvest index (%)
Zn_0PM_0	115.57	7.53	19.18	100.94h	20.50a	9.52	2.07	21.09f
Zn_0PM_1	119.8	7.97	21.53	111.35g	20.27a	11.13	2.54	26.83d
Zn_0PM_2	126.67	8.43	22.92	116.33ef	16.00de	11.73	2.94	33.51c
Zn_1PM_0	124.13	8.07	21.74	109.11g	18.35c	11.16	2.02	26.37d
Zn_1PM_1	128.77	8.80	21.69	115.53f	19.73ab	10.81	2.77	31.18c
Zn_1PM_2	130.27	9.23	23.6	130.29b	16.54d	11.73	3.2	29.02cd
Zn_2PM_0	129.63	9.03	20.98	119.94d	18.87bc	10.82	2.77	32.2c
Zn_2PM_1	130.93	9.47	23.33	130.35b	15.12e	12.43	3.24	39.26b
Zn_2PM_2	133.43	9.93	24.72	135.33a	13.17f	13.03	3.64	48.17a
Zn_3PM_0	123.43	8.13	22.49	118.87de	18.90bc	10.09	2.26	25.35de
Zn_3PM_1	128.33	8.63	22.15	125.82c	18.67bc	11.02	2.49	24.6e
Zn_3PM_2	129.33	8.93	23.43	130.98b	13.73f	11.71	3.2	29.15cd
Level of sig.	NS	NS	NS	**	**	NS	NS	*
CV%	3.4	3.89	2.87	4.40	4.27	5.74	11.05	11.32

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Non Significant; Here, Zn_0 = 0 kg/ha, Zn_1 = 2.0 kg/ha, Zn_2 = 4.0 kg/ha, Zn_3 = 6.0 kg/ha, PM_0 = 0 t/ha, PM_1 = 5 t/ha, PM_2 = 10 t/ha.

Number of grains/panicle

Statistically significant effect was found for both sole application of Zn and PM at different doses where, maximum grains per panicle was obtained in Zn application of 4 kg/ha (128.54) and in 10 t PM/ha (128.23). Whereas, the lowest grains per panicle was found in control for both Zn and PM application (Tables 1 and 2). Soleimani (2012) reported that the number of grains per panicle of rice increases with the application of Zn and Saha *et al.* (2013) found the same result for PM application as number of grains per panicle increases with the increased dose of PM. The interaction between different levels of Zn and PM application also showed significant effect on number of grains per panicle production. The maximum number of grains/panicle (100.94) was observed in the combination of 4 kg Zn/ha and 10 t PM/ha whereas the lowest number of grains/panicle (100) was observed in the combination of no application of Zn and PM (Table 3).

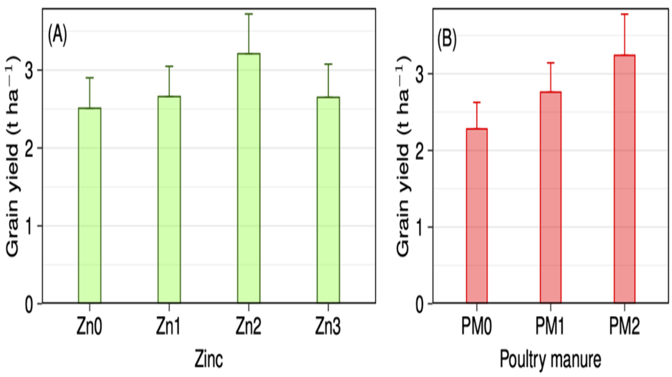

Figure 3. *Effect of zinc and poultry manure on grain yield of aromatic rice BRRI dhan34.*

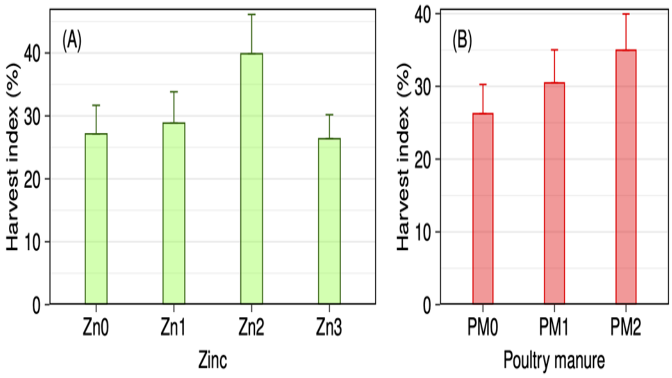

Figure 4. *Effect of zinc and poultry manure on harvest index of aromatic rice BRRI dhan34.*

Number of sterile spikelets/panicle

Significant effect was found for different doses for sole application of Zn and PM; and their interactions. The highest number of sterile spikelets/panicle 18.92 and 19.16 were obtained where no Zn and PM were applied (control) (Tables 1 and 2). These findings are in conformity with that of Sundar *et al.* (2003) who reported that lower dose of Zn increases the sterile spikelets/ panicle compared to higher doses of Zn. Whereas, the lowest number of sterile spikelets/panicle was found in 4 kg Zn/ha with 10 t PM/ha. It is seen that the number of sterile spikelets decreases with the increase of Zn and PM doses. Roy *et al.* (2018) reported that number of sterile spikelets/panicle minimum due to the increased level of PM. The interaction effect was found significant due to treatments of different levels of Zn and PM application and the maximum number of unfilled grains/ panicle (20.50) was found in the interaction between no application of Zn and PM (Control). Whereas, the lowest one (13.17) was found between the interaction of 4 t Zn/ha and 10 t PM/ha. Taznim *et al.* (2020) reported that number of sterile spikelets/ panicle was significantly affected due to combined application of PM and NPKS fertilizers. Yakan *et al.* (2000) reported that Zn application decreased the number of filled grains/panicle and number of sterile spikelets/ panicle and increased the number of panicle/square matter.

Weight of 1000-grain

Statistically significant effect was found due to application of different levels of Zn for 1000 grains weight of rice. Maximum 1000 grains weight (12.09 g) found in 4 kg Zn/ ha and the lowest one (10.79 g) was obtained in control treatment (no application of Zn) (Table 1). These findings are in agreement with that of Ananda and Patil (2007); Kenbaev and Sade (2002) and Hosseini (2006) and they reported that yield components increased with the increase in Zn rate. Similarly, application of PM also showed significant effect for 1000-grain weight (Table 2). Where, the highest (12.05 g) 1000-grain weight was obtained in 10 t PM/ha and control treatment showed the lowest value (10.4 g). Chakraborty *et al.* (2020) reported that the positive effect of PM application on 1000-grain weight. The interaction between application of different level of Zn and PM did not show any significant effect but the maximum weight was obtained in the interaction between 4 kg Zn/ha and 10 t PM/ha dose application (Table 3).

Grain yield

Application of Zn gave a significant influence on the grain yield. The highest grain yield (3.21 t/ha) was obtained from 4 kg Zn/ ha. The lowest grain yield (2.51 t/ ha) was obtained at control treatment (Figure 3A). Here we find that higher doses of Zn application increase the grain yield up to 4 t/ha dose but it found lower for maximum dose of Zn (6 t/ha) compared to lower dose of Zn (2 t/ha). There are some reports showing that higher doses of Zn improve yield components such as number of grains/ panicle and decreased number of sterile spikelets/panicle, which is mostly responsible for higher grain yield. Similar relationship was reported by Torun *et al.* (2001) and Grewal *et al.* (1997), who reported increased grain yield for Zn application. Similarly, application of PM also showed significant influence on the production of grain yields of rice. The highest grain yield (3.24 t/ha) was obtained from the treatment where PM was applied at the rate of 10 t/ha. The lowest grain yield (2.28 t/ha) was obtained in the treatment of control (no application of PM) (Figure 3B). The yield of rice increases with the increasing rate of PM dose compared to control. Biswas *et al.* (2016) reported that due to the increases in the level of PM the grain yield also increased. The interaction between Zn and PM application found statistically non significant. The grain yield ranges from 2.02 to 3.64 t/ha and numerically the highest grain yield (3.64 t/ ha) was obtained between the interaction of 4 kg Zn/ha and 10 t PM/ha treatment interaction and the lowest grain yield (2.02 t/ ha) was obtained from the interaction of 2 kg Zn/ha and 0 t PM/ ha (Table 3).

Harvest index

Harvest index of aromatic fine rice responded significantly due to application of different levels of Zn. The highest harvest index (39.88%) was recorded from the treatment of Zn were applied 4 kg/ha and the lowest harvest index (26.37%) was found in 6 kg Zn/ha treatment (Figure 4A). Khan *et al.* (2008) have reported that Zn application actually decreased harvest index. Similarly, harvest index was significantly affected by the application of different doses of PM. The maximum harvest index (34.97%) was recorded where PM was applied at the rate of 10 kg/ha. The lowest harvest index (26.25%) was found in the control treatment of PM (Figure 4B). Das *et al.* (2018) reported that, harvest index for rice increases with the application of PM. At the same time harvest index was significantly influenced by the application of different level of Zn and PM application. We found the highest harvest index (48.17%) between the interaction of 4 kg Zn/ha and 10 t PM/ha treatment combination and the lowest harvest index (21.09%) was obtained between the control treatment of Zn and PM application (Table 3). Similar findings were also reported by Amanullah *et al.* (2016) and concluded that the growing hybrid rice with application of 120 kg m^{-2} P + 15 kg m^{-2} Zn not only increases total DM accumulation and partitioned greater amounts into the reproductive plant parts (panicles) but also results in higher harvest index. Similarly, Arif *et al.* (2014) reported that harvest index (43.76%) was recorded from the plots receiving poultry manure at the rate of 10 t/ha.

Conclusion

From the present study it can be concluded that Zn and PM showed positive effect on grain yield of BRRI dhan34. The highest grain yield was obtained from the treatment combination of 4 kg Zn/ha and 10 t PM/ha and the lowest grain yield was obtained from the control treatment (0 kg Zn/ha and 0 t PM/ha). So, furthermore research should be done for determining optimum Zn level and PM. Therefore, farmers may be suggested to grow aromatic fine rice cv. BRRI dhan34 with 4 kg Zn/ha and 10 t PM/ha in *Aman* season for obtaining the maximum grain yield.

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