EFFECT OF ZINC AND COWDUNG ON GROWTH, YIELD AND NUTRIENT CONTENT OF TRANSPLANTED AMAN RICE (BRRI dhan33)

BY

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This is to certify that the thesis entitled **"Effect of Zinc and Cowdung on Growth, Yield and Nutrient Content of Transplanted Aman Rice (BRRI dhan33)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **Agricultural Chemistry**. The result of a piece of bonafide research work carried out by **Md. Oahiduzzaman**, Registration number: **06-01955** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

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DEDICATED
TO
MY BELOVED PARENTS

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EFFECT OF ZINC AND COWDUNG ON GROWTH, YIELD AND NUTRIENT CONTENT OF TRANSPLANTED AMAN RICE (BRRI dhan33)

ABSTARCT

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November 2012 to study the effect of zinc and cowdung on growth, yield and nutrient content of transplanted aman rice. BRRI dhan33 was used as the test crop in this experiment. The experiment consisted of two factors. Factor A: 4 levels of zinc (Zn_0: 0 kg Zn ha^{-1} (control), Zn_1: 2.0 kg Zn ha^{-1}, Zn_2: 3.0 kg Zn ha^{-1}, Zn_3: 4.0 kg Zn ha^{-1}) and Factor B: 4 levels of cowdung (C_0: 0 ton cowdung ha^{-1} (control), C_1: 4.5 ton cowdung ha^{-1}, C_2: 5.0 ton cowdung ha^{-1} and C_3: 5.5 ton cowdung ha^{-1}). Recommended doses of N, P, K, and S were applied. The experiment was laid out in a randomized complete block design (RCBD) with three replications. For 4.0 kg Zn ha^{-1} (Zn_3), the tallest plant (25.12, 41.09, 58.90, 75.03 and 88.34 cm) were recorded at 30, 50, 70, 90 days after transplanting (DAT) and harvest, respectively. On the other hand, the shortest plant (19.95, 33.52, 51.08, 65.25 and 80.50 cm) were found from control treatment (Zn_0) at 30, 50, 70, 90 DAT and harvest, respectively. The maximum number of effective tillers $hill^{-1}$ (13.30) was observed from Zn_3 and the minimum number (10.18) from Zn_0. The highest grain yield ha^{-1} (5.11 ton) was found from Zn_3 and the lowest grain yield ha^{-1} (3.28 ton) from Zn_0. The highest Zn content in grain (0.0276%) was found from Zn_3 and the lowest (0.0175%) from Zn_0. In case of cowdung, at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.29, 40.91, 58.20, 74.47 and 88.57 cm) were observed from C_3 and the shortest plant (20.00, 34.07, 52.61, 66.13 and 79.65 cm) were observed from C_0, respectively. The maximum number of effective tillers $hill^{-1}$ (13.38) was observed from C_3, while the minimum number (10.23) was found from C_0. The highest grain yield ha^{-1} (5.18 ton) was observed from C_3, while the lowest grain yield ha^{-1} (3.29 ton) was observed from C_0. The highest Zn content in grain (0.0259%) was observed from C_3, again the lowest (0.0204%) was observed from C_0. Due to the interaction effect of different levels of zinc and cowdung, at 30, 50, 70, 90 DAT and harvest, the tallest plant (27.27, 43.50, 61.00, 78.70 and 92.11 cm) was observed from Zn_3C_3, while the shortest (16.23, 28.13, 46.97, 57.67 and 70.43 cm) was recorded from Zn_0C_0. The maximum number of effective tillers $hill^{-1}$ (14.60) was recorded from Zn_3C_3, whereas the minimum number (8.93) was found from Zn_0C_0. The highest grain yield ha^{-1} (6.13 ton) was attained from Zn_2C_2, whereas the lowest grain yield ha^{-1} (2.14 ton) from Zn_0C_0. The highest Zn content in grain (0.0295%) was observed from Zn_3C_3 and the lowest (0.0126%) from Zn_0C_0.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh and it is the staple food for more than two billion people in Asia (Hien *et al.*, 2006) and it provides 21% and 15% per capita of dietary energy and protein, respectively (Maclean *et al.*, 2002). In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. However, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low compared to those of other rice growing countries, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (FAO, 2009). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. As it is not possible to have horizontal expansion of rice area. So, rice yield $unit^{-1}$ area should be increased to meet this ever-increasing demand of food in the country.

Agriculture in Bangladesh is dominated by intensive rice cultivation covering 80% of arable land and the most dominant cropping pattern is rice. Bangladesh Rice Research Institute (BRRI) has developed BRRI dhan33 which is a short duration and anti-Monga paddy. BRRI dhan33 now grows excellent everywhere and its harvesting will begin from the first week of October (Anon., 2006). The short duration paddy is being cultivated at larger scales under the government-non government organization collaboration during T-Aman season in greater Rangpur to create job opportunities for the farm laboures during the lean period of Ashwin and Kartik months.

Among the production factors affecting crop yield, essential nutrient is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers today hold the key to success of production systems of Bangladesh agriculture being responsible for about 50% of the total crop production (BARC, 1997). Nutrient imbalance can be minimized by judicious application of different fertilizers. There is a need to develop appropriate management technique to assess the nutrient requirement for rice cultivation in the country.

Depleted soil fertility is a major constrain to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrient in soils. The farmers of this country use on an average 102 kg nutrients ha^{-1} annually (70 kg N + 24 kg P + 6 kg K + 2 kg S and Zn) while the crop removal is about 200 kg ha^{-1} (Islam *et al.*, 1994). In Bangladesh, most of the cultivated soils have less then 1.5% organic matter while a good agricultural soil should contain at least 2% organic matter (Ali, 1994). Moreover, this important component of soil is declining with time due to intensive cropping and use of higher dose of chemical fertilizers with little or no addition of organic manure in the farmer's field. In addition, rapid mineralization of soil organic matter occurs due to humid tropic climatic conditions of Bangladesh. Cowdung can supply a good amount of plant nutrients which can contribute to crop yields. Mineralization and immobilization are biochemical in nature and are mediated through the activities of microorganisms. The rate and extent of mineralization determines crop availability of nutrients. The transformation of N, P and S in soil depends on the quality and quantity of organic matter and cowdung is well known organic manure in our country. The long-term research of Bangladesh Rice Research Institute (BRRI) revealed that the application of cowdung @ 5 t ha^{-1} $year^{-1}$ improved rice productivity as well as prevented the soil resources from degradation. Soil organic matter improves the physicochemical properties of the soil and ultimately promotes crop production. Evidences from different Agro-Ecological Zone (AEZ) of the country have shown a decrease in the content of organic matter by the range of 15 to 30% over the last 20 years (Miah, 1994). Therefore, it would not be wise to depend only on inherent potentials of soils for higher crop production. More recently, attention is focused on the global environmental problems; utilization of organic manures as the most effective measure for the purpose.

Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. The length of roots, shoots and spikelets of BRRI dhan33 increased with increasing zinc levels. Zinc deficiency is prevalent worldwide in temperate and tropical climates (Fageria *et al.*, 2003; Slaton *et al.*, 2005). Zinc is a major component and activator of several enzymes involved in metabolic activities. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country (Chaudhary *et al.*, 2007). Zinc deficiency in rice has been reported in lowland rice (Mandal *et al.*, 2000 and Fageria *et al.*, 2011). Zinc deficiency is noticed when the supply of zinc to the rice plant is inadequate. Among the many factors which influence zinc supply to the plants, pH, concentration of zinc, iron, manganese and phosphorus in soil solution are very important. Zinc deficiency and response of rice to zinc under flooded condition have been studied by many workers (Kausar *et al.*, 2004; Naik and Das, 2007; Mollah *et al.*, 2009; Fageria *et al.*, 2011).

Application of both zinc and cowdung needs to be applied for the improvement of soil physical properties and supply of essential plant nutrients for higher yield. A Suitable combination of zinc and cowdung source of nutrients is necessary for BRRI dhan33 (Reganold *et al.*, 1990). Nambiar (1991) stated that integrated use of zinc and cowdung would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. Under this circumstance the present research work has been taken with the following objectives:

a. To find out the effects of zinc and cowdung on growth and yield of BRRI dhan33.

b. To observe the N, P, K, S and Zn content in grain.

CHAPTER II

REVIEW OF LITERATURE

Among the essential nutrient elements zinc is the important micronutrients and primary elements for the growth and development and better yield of crops. Zinc is play crucial role at yield and yield attributes of rice. On the other way, use of organic manure also the essential factor for sustainable soil fertility and crop productivity. The cowdung is the common and well known organic manure in our country. Organic fertilizer increase plant growth, yield contributing characters and yield because is the store house of plant nutrients. The available relevant reviews that are related to the effect of level of zinc and cowdung application on the yield and yield attributes of rice are reviewed below under the following headings-

2.1 Effect of zinc on rice yield attributes and yield

The effect of single and multiple applications of S and Zn in a continuous rice cropping system on loam soil were investigated by Hoque and Jahiruddin (1994) at Mymensingh, Bangladesh. The treatments were S alone, Zn alone and S + Zn, each added to the 1st crop, 1st and 2nd crops or all 3 crops. The rate of S was 20 kg ha^{-1} (gypsum form) and that of Zn was 10 kg ha^{-1}. Crop yields were increased by S but not by generally by Zn.

A field experiment was conducted by Ullah *et al.* (2001) in Mymensingh, Bangladesh, to study the effect of zinc sulfate (0, 10, and 20 kg ha^{-1}) on rice cv. BR30. Zinc sulfate, along with 60 kg P_2O_5 and 40 kg K_2O ha^{-1}, was incorporated during land preparation. 80 kg N ha^{-1} was applied by 3 equal installments during land preparation, and at 25 and 60 days after transplanting. Plant height; tiller number; 1000-grain weight; grain and straw yields; and grain, straw, and soil Zn contents increased with zinc sulfate application. The tallest plants (75.667 cm) and the highest number of tillers (10.60 hill^{-1}), 1000-grain weight (28.700 g), and the concentration of Zn in straw (101.93 ppm) and grain (73.33 ppm) were obtained with 20 kg zinc sulfate ha^{-1}.

A study was carried out by Cheema *et al.* (2006) to evaluate the effect of four zinc levels on the growth and yield of coarse rice cv. IR-6 at Faisalabad, Pakistan. Four zinc levels viz., 2.5, 5.0, 7.5 and 10.kg $ZnSO_4$ ha^{-1} caused increase in yield and yield component as compared with control. Final plant height, number of tillers $hill^{-1}$, panicle bearing tillers, number of primary and secondary spikelets, panicle size, 1000 grain weight, paddy and straw yield and harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

A pot experiment was conducted by Khan *et al.* (2007) at Faculty of Agriculture Gomal University, Pakistan to evaluate the effect of different levels of zinc application on the yield and growth components of rice at eight different soil series. Zn as $ZnSO_4.7H_2O$ (21%) was applied @ 0, 5, 10 and 15kg ha^{-1} along with the basal doses of 120 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}. Thirty days old four seedlings of rice cv. IRRI-6 were grown. The increasing levels of Zn in these soil series significantly influenced yield and yield components of rice. Application of 10 kg Zn ha^{-1} appeared to be an optimum dose for rice crop in these soil series.

Naik and Das (2007) reported that rice is mostly transplanted under puddled low land soil conditions in India, where Zinc (Zn) deficiency is a common problem. The objective of this study was to find out the efficacy of split application of Zn on growth and yield of rice in an inceptisol. The split application of Zn as $ZnSO_4.7H_2O$ performed better than its single basal application, while the split application of Zn-EDTA did not show any significant difference on yield and yield components of rice over its single basal application. Zn-EDTA was found to be better for growth and yield of rice among the two sources of Zn. The soil application of Zn at 1.0 kg ha^{-1} as Zn-EDTA (T_7) recorded highest grain yield of 5.42 t ha^{-1}, filled grain percentage of 90.2%, 1000-grain weight of 25.41 g and number of panicles m^{-2} of 452. The Zn content of grain and straw were also found to be maximum in the treatment T_7 i.e. 38.19 and 18.27 mg Zn kg^{-1}, respectively. Linear regression studies indicated that grain yield of rice is significantly influenced by Zn content of grain, Zn content of straw and DTPA extractable Zn content of soil at the level of 95.96, 96.74 and 95.57%, respectively.

Muthukumararaja and Sriramachandrasekhara (2012) reported that Zinc deficiency in flooded soil is impediment to obtain higher rice yield. Zinc deficiency is corrected by application of suitable zinc fertilizer. The results revealed that rice responded significantly to graded dose of zinc applied. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 100% and 86% greater than control (no zinc) respectively. The highest zinc concentration and uptake in grain and straw and DTPA-Zn at all stages was noticed at 7.5 mg Zn kg^{-1}. The linear regression analysis showed grain zinc concentration and grain Zn uptake caused 89.64 and 89.01% variation in rice yield. Similarly, the linear regression analysis of DTPA-Zn caused 98.31, 96.34 and 93.12% variation in yield of rice at tillering, panicle initiation and harvest stages respectively. The agronomic, physiological and agrophysiological apparent recovery and utilization efficiencies was highest at lower level of zinc application and decreased with Zn doses.

An experiment was carried out by Yadi *et al.* (2012) at Sari, Mazandaran, Iran in 2012. This experiment was done as split plot in randomized complete blocks design based three replications. Zinc fertilizer application was chosen as main plots (0, 20 and 40 kg ha^{-1}) and genotypes as sub plots. The results showed that the most panicle number m^{-2} and harvest index had observed in 40 kg Zn ha^{-1} and the least of those was obtained in control treatment. The highest zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed in 40 kg Zn ha^{-1}, as the most zinc content in straw, nitrogen, potassium, phosphorus and sulphur content in grain and straw, and nitrogen uptake in straw were observed highest with application of 40 and 20 kg Zn ha^{-1}.

2.2 Effect of cowdung on rice yield attributes and yield

Rajput and Warsi (1991) conducted a field experiment and reported that rice yield was increased to 34.44 kg ha^{-1} with the application at FYM of 10 t ha^{-1}. Sharma and Mitra (1991) reported a significant increase in N, P and K content and also the nutritional status of soil with 5 t ha^{-1} of FYM of rice based cropping system.

Gurung and Sherchan (1993) reported that the application of cowdung with chemical fertilizers produced significantly higher grain yield than that of chemical fertilizers alone.

Miah (1994) stated that only the first crop following the application recovered one-fifth to one-half of the nutrient supplied by animal manure, reminder was held as humus to very slow decomposition, 2.4% element being released per annum.

Islam *et al.* (1994) found a significant yield increase with fertilizers with cowdung compared to fertilizer-N alone in T. Aman rice. In the following rice, the yields with fertilizer-N + residual of cowdung were higher than fertilizer-N alone.

Kant and Kumar (1994) reported that the increasing rates of amendments with FYM increased the number of effective tillers $hill^{-1}$ significantly, number of grain $panicle^{-1}$, weight of 1000-grain also increased over the control. At the maximum level of FYM (30 t ha^{-1}) the increase of 48% tillers $hill^{-1}$, 14% number of grain $panicle^{-1}$ and 4.5% weight of 1000-grain over the control were recorded. They also reported that higher rate of FYM (30 t ha^{-1}) resulted 22.00% increase in grain yield over the untreated plots.

Thakur and Patel (1998) conducted field experiments during *kharif* season to study the effect of split application of 60 or 80 kg N ha^{-1} on growth, yield and nitrogen uptake by rice with and without 5 t FYM ha^{-1} and proposed that both N rates increased yields attributes, yield, plant N content and N uptakes of rice compared with N or application of FYM alone. N rates and use of split doses had no effect. The highest grain yield (3.84 t ha^{-1}) was recorded with the application of 80 kg N ha^{-1} in three split doses with 5 t ha^{-1} FYM during both the years, 60 kg N in three split doses with 5 t ha^{-1} FYM gave seed grain 3.85 t ha^{-1}.

A field experiment was conducted by Gupta *et al.* (1999) on clay loam soil in 1993 in Jummu and Kasmir using rice cv. PC-19 as test crop with 0-100 kg P_2O_5 ha^{-1} and 0 or 10 t FYM. The crop also received a basal dressing of N, K and Zn. Grain yield was highest with 100 kg P_2O_5 + FYM (5.20 t ha^{-1}).

A field experiment was conducted by Mannan *et al.* (2000) at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, during August to December 1995 to study the effect of manuring and fertilizer application on growth, yield and quality of transplanted aman rice. Four varieties, namely, BR10, BR11, BR22, and BR23, and five fertilizer application treatments, namely, F_1 = inorganic fertilizers (IF), F_2 = IF + cowdung 5 t ha^{-1}, F_3 = IF + cowdung 10 t ha^{-1}, F_4=IF with late N application + cowdung 5 t ha^{-1}, and F_5 = IF with late N application + cow dung 10 t ha^{-1}. The doses of inorganic fertilizers were 150 kg urea, 90 kg triple superphosphate, 40 kg muriate of potash, 60 kg gypsum and 10 kg zinc sulfate $hectare^{-1}$. In F_4 and F_5 treatments, urea top dressing was delayed at second and third applications by one and two weeks, respectively. Among the fertilizer application treatments, F_5 and F_3 produced the highest and F_1 the lowest grain and straw yields. Grain protein content was higher in F_5, F_4 and F_3 treatments receiving 5 or 10 t ha^{-1} cowdung and late N application. Manuring with cowdung up to 10 t ha^{-1} in addition to recommended inorganic fertilizers with late N application improved grain and straw yields and quality of transplant aman rice over inorganic fertilizers alone.

Saitoh *et al.* (2001) conducted an experiment to evaluate the effect of organic fertilizers (cowdung and poultry manure) and pesticides on the growth and yield of rice and revealed that the yield of organic manure treated and pesticide free plots were 10% lower than that of chemical fertilizer and pesticide treated plot due to a decreased in the number of panicle. Yearly application of manure increased the total carbon and nitrogen content in soil.

Rahman (2001) reported that in rice-rice cropping pattern, the highest grain yield of Boro rice was recorded in the soil test basis (STB) N P K S Zn fertilizers treatment while in T. Aman rice the 75% or 100% of N P K S Zn (STB) fertilizers plus green manure (GM) with or without cow dung gave the highest or a comparable yield. The mean yearly N, P, K, S and Zn uptake by rice (Boro + T. Aman) increased with increasing supply of nutrients. Application of cow dung along with N P K S Zn (STB) resulted in markedly higher uptake of nutrients in Boro rice. In T. Aman rice, application of NPKS (STB) with GM and/or cowdung (CD) showed higher N, P, K, S, Zn uptake than that of NPKS and NPK treatments. The total N content and the available N, P, K, S, and Zn status in soils increased slightly due to manuring. The whole results suggested that the integrated use of fertilizers with manure (viz. cowdung) could be an efficient practice for ensuring higher crop yields without degradation of soil fertility.

An experiment was conducted by Ali *et al.* (2003) at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the aman season to study the combined effect of cowdung with urea super granule (USG) on the yield and nutrient uptake by BRRI Dhan30. The experiment was laid out in a randomized complete block design with three replications. There were six treatments such as T_1= Control (no fertilizer), T_2= USG at 29 kg N ha^{-1}, T_3= cowdung @ 1.3 t ha^{-1} plus USG at 29 kg N ha^{-1}, T_4=USG at 58 kg N ha^{-1}, T_5= cowdung @ 1.3 t ha^{-1} plus USG at 58 kg N ha^{-1} and T_6 = USG at 87 kg N ha^{-1}. Phosphorus @ 15 kg ha^{-1}, potassium @ 50 kg ha^{-1} and sulphur @ 15 kg ha^{-1} were applied as basal dose to all the experimental plots. Cowdung @ 1.3 t ha^{-1} was applied before 6 days of transplanting. The highest grain yield was recorded with the incorporation of cowdung @ 1.3 t ha^{-1} combined with USG at 58 kg N ha^{-1} (T_5) which was statistically different from all other treatments. The NPKS contents of grain and straw as well as total NPKS uptake by the crop increased due to application of cowdung in combination with urea super granule. The study clearly indicated a great prospect of cowdung combined with USG at 58 kg N ha^{-1} application of rice cultivation.

A 7 year long field trial was conducted by Saha *et al.* (2007) on integrated nutrient management for dry season rice (Boro) green manure wet season rice (T. Aman) cropping system at the Bangladesh Rice Research Institute Farm, Gazipur. Five packages of inorganic fertilizers, cowdung, and green manure dhaincha (*Sesbania aculeata*) were evaluated for immediate and residual effect on crop productivity, nutrient uptake, soil-nutrient balance sheet, and soil-fertility status. Plant height, active tiller production, and grain and straw yields were significantly increased as a result of the application of inorganic fertilizer and organic manure. Application of cowdung at the rate of 5 t ha^{-1} once a year at the time of Boro transplanting supplemented 50% of the fertilizer nutrients other than nitrogen (N) in the subsequent crop of the cropping pattern. A positive effect of green manure on the yield of T. Aman rice was observed. Following green manure, the application of reduced doses of phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) to the second crop (T. Aman) did not reduce yield, indicating the beneficial residual effect of fertilizer applied to the first crop (Boro rice) of the cropping pattern. The comparable yield of T. Aman was also observed with reduced fertilizer dose in cowdung treated plots. The total P, K, and S uptake (k $ha^{-1}yr^{-1}$) in the unfertilized plot under an irrigated rice system gradually decreased over the years. This study showed that the addition of organic manure cowdung gave more positive balances.

The literature review discussed above indicates that cowdung manure can supply a good amount of plant nutrients and thus can contribute to crop yields. The properties of soils are also influenced by the inclusion of organic manure and crop residues in the soil fertility management system either directly or through residual action.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November 2012 to study the effect of zinc and cowdung on growth, yield and nutrient content of transplanted (T.) aman rice BRRI dhan33. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings -

3.1 Experimental site and soil

The experiment was conducted in typical rice growing silty clay soil at the Sher-e-Bangla Agricultural University Farm, Dhaka. The morphological, physical and chemical characteristics of the soil are shown in Appendix I.

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-February). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season June to November 2012 have been presented in Appendix II.

3.3 Planting material

BRRI dhan33 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 850-2 and BG388/BG367-4 in 1997. It is recommended for early *Aman* season. Average plant height of the variety is 100 cm at the ripening stage. The grains are small, fine and white. It requires about 118 days completing its life cycle with an average grain yield is 4.5 t ha^{-1} (BRRI, 2011).

3.4 Land preparation

The land was first opened on 20 June, 2012 by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling for transplanting seedlings.

3.5 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 16 unit plots as treatments with raised bunds around. Thus the total numbers of plots were 48. The unit plot size was 3 m × 2.0 m and was separated from each other by 0.5 m ails. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m respectively. The layout of the experiment is shown in Appendix III.

3.6 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (10 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis.

3.7 Raising of seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 25 kg ha^{-1} were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

3.8 Treatments

The experiment was designed to study the effect of zinc and cowdung on growth, yield and nutrient content of transplanted aman rice (BRRI dhan33). The experiment consisted of two factors. Details were presented below:

Factor A: Level of zinc (4 levels)

i. Zn_0: 0 kg Zn ha^{-1} (Control)

ii. Zn_1: 2.0 kg Zn ha^{-1}

iii. Zn_2: 3.0 kg Zn ha^{-1}

iv. Zn_3: 4.0 kg Zn ha^{-1}

Factor B: Level of cowdung (4 levels)

i. C_0: 0 ton cowdung ha^{-1} (Control)

ii. C_1: 4.5 ton cowdung ha^{-1}

iii. C_2: 5.0 ton cowdung ha^{-1}

iv. C_3: 5.5 ton cowdung ha^{-1}

There were a total of 16 (4 × 4) treatment combinations such as Zn_0C_0, Zn_0C_1, Zn_0C_2, Zn_0C_3, Zn_1C_0, Zn_1C_1, Zn_1C_2, Zn_1C_3, Zn_2C_0, Zn_2C_1, Zn_2C_2, Zn_2C_3, Zn_3C_0, Zn_3C_1, Zn_3C_2 and Zn_3C_3.

3.9 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MOP, Gypsum, zinc sulphate and borax, respectively were applied. The one third amount of urea and entire amount of TSP, MOP, gypsum, zinc sulphate and borax were applied during the final preparation of land. Rest urea was applied in two equal installments at tillering and panicle initiation stages. The dose and method of application of fertilizers are presented below-

Dose and method of application of fertilizers in rice field

Fertilizers	Dose (kg ha^{-1})	Application (%)		
		Basal	1st installment	2nd installment
Cowdung	As per treatment			
Urea	150	33.33	33.33	33.33
TSP	120	100	--	--
MP	120	100	--	--
Gypsum	100	100	--	--
Zinc sulphate	As per treatment			
Borax	10	100	--	--

Source: BRRI, 2011 (Adunik Dhaner Chash)

3.10 Cowdung incorporation

Cowdung as organic manure were used and it was applied before four days of final land preparation. Chemical compositions of cowdung have been presented below-

Chemical compositions of cowdung (dry basis)

Sources of organic manure	Nutrient content					
	C (%)	N (%)	P (%)	K (%)	S (%)	C:N
Cowdung	3.6	1.48	0.45	0.53	0.21	2.4

3.11 Transplanting

Thirty days old seedlings of BRRI dhan33 were carefully uprooted from the seedling nursery and transplanted on 03 July, 2012 in well puddled plot. Three seedlings $hill^{-1}$ were used following a spacing of 20 cm × 20 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.12 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.12.1 Irrigation

Necessary irrigations were provided to the plots as and when required during the growing period of rice crop.

3.12.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the period of the cropping season.

3.12.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was observed in the field and used Malathion @ 1.12 L ha^{-1}.

3.13 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor.

3.14 Data collection on yield components and yield

3.14.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 50, 70, 90 days after transplanting and at harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle/flag leaf.

3.14.2 Effective tillers $hill^{-1}$

The total number of effective tillers $hill^{-1}$ was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers $hill^{-1}$ were counted from 10 selected hills and average value was recorded.

3.14.3 Non-effective tillers hill^{-1}

The total number of non-effective tiller hill^{-1} was counted as the number of non-panicle bearing tiller during harvesting. Data on non effective tiller hill^{-1} were counted from 10 selected hills and average value was recorded.

3.14.4 Total tillers hill^{-1}

The total number of tiller hill^{-1} was counted as the number of effective tillers hill^{-1} and non-effective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 10 selected hills and average value was recorded.

3.14.5 Length of panicle

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.14.6 Filled grains panicle^{-1}

The total numbers of filled grain was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.14.7 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.14.8 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 10 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.14.9 Weight of 1000-grain

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.14.10 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final grain yield $plot^{-1}$ and finally converted to ton $hectare^{-1}$ ($t\ ha^{-1}$).

3.14.11 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final straw yield $plot^{-1}$ and finally converted to ton $hectare^{-1}$ ($t\ ha^{-1}$).

3.14.12 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

3.14.13 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$HI = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

3.15 Chemical analysis of grain samples

3.15.1 Digestion of grain samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 5 ml conc. H_2SO_4 were added. The flasks were heating at 120^0C and added 2.5 ml 30% H_2O_2 then heated was continued at 180^0C until the digests became clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 with indicator solution and titrated with 0.01N H_2SO_4.

3.15.2 Digestion of grain samples with nitric-perchloric acid for P, K, S and Zn

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K, S and Zn were determined from this digest.

3.15.3 Determination of P, K, S and Zn from grain samples

3.15.3.1 Phosphorus

Phosphorus in the digest was determined by using 1 ml for grain sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex using ascorbic acid and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.15.3.2 Potassium

Five ml of digest sample for the grain were taken and diluted 50 ml volume to make desired concentration so that the emission of K of sample were measured within the range of standard solutions. The K was determined by flame photometer.

3.15.3.3 Sulphur

Sulphur content was determined from the digest of the grain samples (with $BaCl_2$ solution as described by Page *et al.*, 1982. The digested S was determined by developing turbidity by adding $BaCl_2$ seed solution. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.15.3.4 Zinc

Zinc content was determined from the digest of the grain samples (with $BaCl_2$ solution as described by Page *et al.*, 1982. The digested Zn was determined by developing turbidity by adding $BaCl_2$ seed solution. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.16 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on growth, yield and nutrient content of transplanted aman rice BRRI dhan33. The mean values of all the characters were calculated and analysis of variance were performed by the 'F' (variance ratio) test. The significance of the differences among the treatment means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

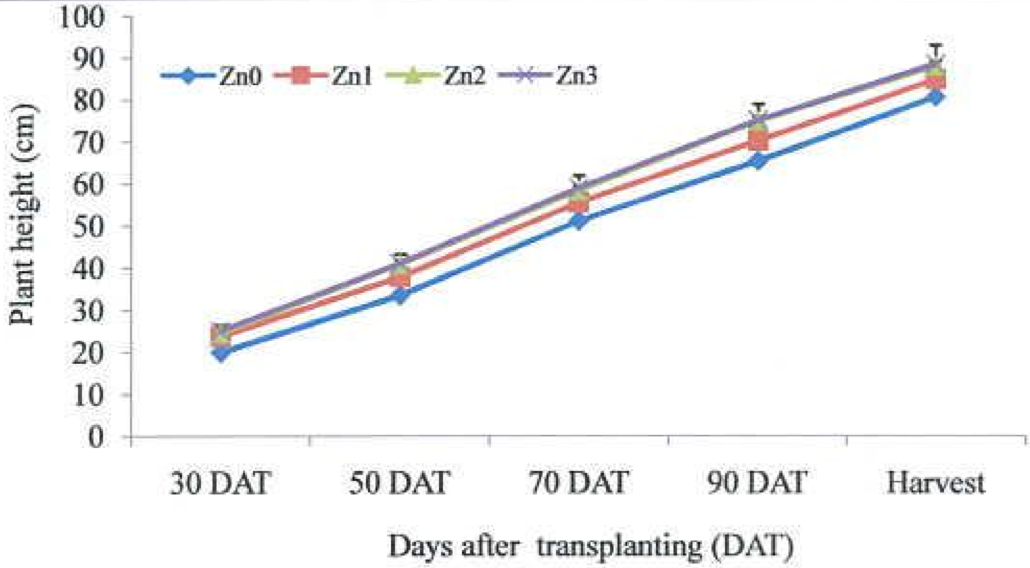
RESULTS AND DISCUSSION

The experiment was conducted to study the effect of zinc and cowdung on growth, yield and nutrient content of transplanted aman rice (BRRI dhan33). The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-IX. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Yield contributing characters and yield of rice

4.1.1 Plant height

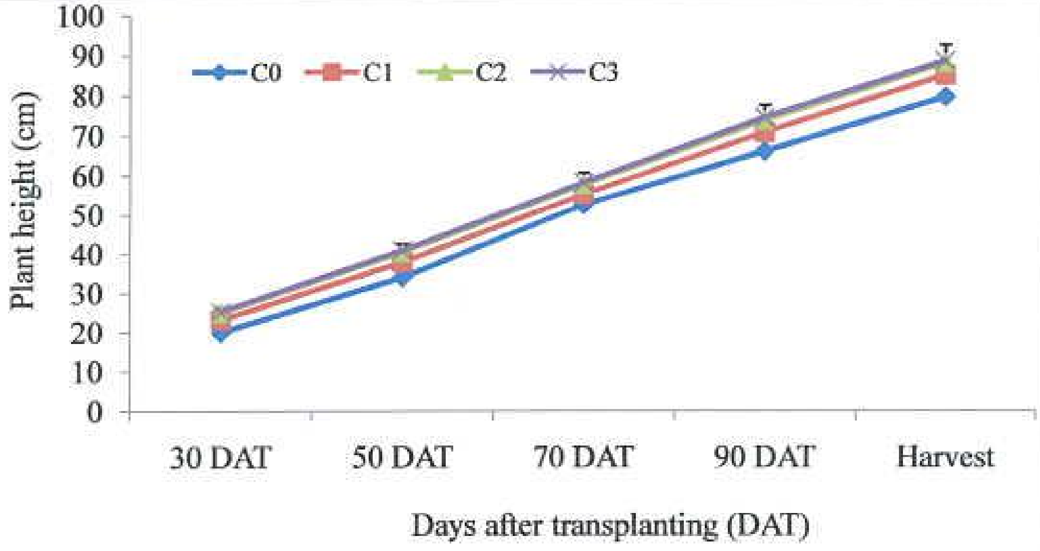
Statistically significant variation was recorded for plant height of BRRI dhan33 due to different levels of zinc at 30, 50, 70, 90 days after transplanting (DAT) and harvest (Figure 1). Data revealed that at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.12, 41.09, 58.90, 75.03 and 88.34 cm, respectively) were recorded from 4.0 kg Zn ha^{-1} (Zn_3) which were statistically similar (24.65, 40.88, 58.38, 74.83 and 87.93 cm, respectively) with 3.0 kg Zn ha^{-1} (Zn_2) and closely followed (23.80, 37.90, 55.48, 70.12 and 84.65 cm, respectively) by 2.0 kg Zn ha^{-1} (Zn_1), whereas the shortest plant (19.95, 33.52, 51.08, 65.25 and 80.50 cm, respectively) from 0 kg Zn ha^{-1} i.e. control condition (Zn_0) (Appendix IX). It was revealed that with the increase of zinc fertilizer, plant height increased upto the highest of Zn. Zinc ensured the availability of other macro and micro nutrients that created a favorable condition for the growth of BRRI dhan33 with optimum vegetative growth and the ultimate results was the tallest plant under the present trial. Ullah *et al.* (2001) obtained the tallest plants (75.667 cm) with 20 kg zinc sulfate ha^{-1}. Cheema *et al.* (2006) reported that plant height, showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1} Zn_3: 4.0 kg Zn ha^{-1}

Figure 1. Effect of different levels of zinc on plant height of BRRI dhan33



C_0: 0 ton cowdung ha^{-1} (control) C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1} C_3: 5.5 ton cowdung ha^{-1}

Figure 2. Effect of different levels of cowdung on plant height of BRRI dhan33

The plant height of BRRI dhan33 varied significantly for different levels of cowdung at 30, 50, 70, 90 DAT and harvest (Figure 2). At 30, 50, 70, 90 DAT and harvest, the tallest plant (25.29, 40.91, 58.20, 74.47 and 88.57 cm, respectively) were observed from C_3 (5.5 ton cowdung ha^{-1}), which were statistically identical (25.02, 40.44, 57.74, 73.80 and 88.13 cm, respectively) with C_2 (5.0 ton cowdung ha^{-1}) and closely followed (23.23, 37.96, 55.29, 70.83 and 84.91 cm, respectively) by C_1 (4.5 ton cowdung ha^{-1}), again the shortest plant (20.00, 34.07, 52.61, 66.13 and 79.65 cm, respectively) were observed from C_0 (0 ton cowdung ha^{-1} i.e. control condition) (Appendix X). It revealed that with the increase of application of cowdung plant height showed increasing trend. It was found that cowdung manure can supply a good amount of plant nutrients and thus can contribute to plant growth. Saha *et al.* (2007) reported that plant height.

Interaction effect of different levels of zinc and cowdung showed significant variation on plant height of BRRI dhan33 at 30, 50, 70, 90 DAT and harvest (Table 1). At 30, 50, 70, 90 DAT and harvest, the tallest plant (27.27, 43.50, 61.00, 78.70 and 92.11 cm, respectively) were observed from Zn_3C_3 (4.0 kg Zn ha^{-1} and 5.5 ton cowdung ha^{-1}) which were statistically identical with Zn_2C_3, Zn_1C_3, Zn_3C_2, Zn_2C_2, Zn_1C_2. On the other hand, the shortest plant (16.23, 28.13, 46.97, 57.67 and 70.43 cm) were recorded at 30, 50, 70, 90 DAT and harvesting, respectively from Zn_0C_0 i.e. control condition.

4.1.2 Number of effective tillers hill^{-1}

Different levels of zinc showed statistically significant variation for number of effective tillers hill^{-1} of BRRI dhan33 (Table 2). The maximum number of effective tillers hill^{-1} (13.30) was attained from 4.0 kg Zn ha^{-1} which was statistically similar (12.98) with 3.0 kg Zn ha^{-1} and closely followed (12.12) by 2.0 kg Zn ha^{-1}, while the minimum number (10.18) from control condition. Cheema *et al.* (2006) reported that panicle bearing tillers showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

Table 1. Interaction effect of different levels of zinc and cowdung on plant height at different stages of transplanted aman rice BRRI dhan33

Zinc and Cowdung		Plant height (cm) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Zn_0	C_0	16.23 d	28.13 e	46.97 e	57.67 h	70.43 e
	C_1	20.77 c	35.80 cd	52.33 d	69.47 d-g	86.07 a-d
	C_2	21.70 c	34.67 cd	52.03 d	65.80 fg	80.10 cd
	C_3	21.10 c	35.47 cd	52.97 cd	68.07 e-g	85.40 a-d
Zn_1	C_0	20.69 c	34.09 cd	52.19 d	66.52 fg	79.44 d
	C_1	21.68 c	33.49 d	50.90 d	63.00 gh	77.86 d
	C_2	26.73 a	42.76 a	60.02 a	76.84 a-c	90.13 ab
	C_3	26.12 a	41.28 ab	58.80 ab	74.13 a-d	89.21 ab
Zn_2	C_0	20.27 c	36.13 cd	54.70 b-d	70.00 c-g	83.17 b-d
	C_1	24.73 ab	41.20 ab	59.30 a	74.73 a-e	88.07 a-c
	C_2	26.33 a	42.67 a	59.50 a	77.60 ab	90.93 ab
	C_3	26.67 a	43.40 a	60.03 a	77.00 a-c	89.53 ab
Zn_3	C_0	22.80 bc	37.93 bc	56.57 a-c	70.33 b-f	85.57 a-d
	C_1	25.76 a	41.35 ab	58.63 ab	76.11 a-d	88.28 a-c
	C_2	25.30 a	41.67 ab	59.40 a	74.97 a-e	89.37 ab
	C_3	27.27 a	43.50 a	61.00 a	78.70 a	92.11 a
$LSD_{(0.05)}$		2.264	3.859	3.865	6.313	7.246
Level of significance		*	*	*	*	*
CV(%)		5.81	6.04	4.14	5.31	5.09

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

* → Significant at 0.05 level of probability

Table 2. Effect of different levels of zinc and cowdung on yield contributing characters of transplanted aman rice BRRI dhan33

Zinc level	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$	Number of total tillers $hill^{-1}$	Length of panicle (cm)	Weight of 1000 grains (g)
Zn_0	10.18 c	3.25 a	13.43 c	19.12 c	19.74 c
Zn_1	12.12 b	3.02 b	15.13 b	21.14 b	20.87 b
Zn_2	12.98 a	2.93 b	15.91 a	22.05 ab	22.08 a
Zn_3	13.30 a	2.63 c	15.93 a	22.72 a	22.21 a
$LSD_{(0.05)}$	0.574	0.213	0.617	1.053	0.628
Level of significance	**	**	**	**	**
CV(%)	5.67	8.62	4.90	5.94	3.55
Cowdung level					
C_0	10.23 c	3.77 a	14.00 b	20.12 b	20.17 c
C_1	11.87 b	3.24 b	15.11 a	21.04 ab	21.21 b
C_2	13.10 a	2.44 c	15.54 a	21.75 a	21.63 ab
C_3	13.38 a	2.37 c	15.76 a	22.12 a	21.88 a
$LSD_{(0.05)}$	0.574	0.213	0.617	1.053	0.628
Level of significance	**	**	**	**	**
CV(%)	5.67	8.62	4.90	5.94	3.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

** ➤ Significant at 0.01 level of probability

Statistically significant variation was recorded in terms of number of effective tillers hill^{-1} of BRRI dhan33 for different levels of cowdung (Table 2). The maximum number of effective tillers hill^{-1} (13.38) was observed from C_3, which was statistically identical (13.10) with C_2 and closely followed (11.87) by C_1, while the minimum number (10.23) was found from C_0. Saha *et al.* (2007) reported that active tiller production were significantly increased as a result of the application cowdung at the rate of 5 t ha^{-1}.

Number of effective tillers hill^{-1} showed significant variation of BRRI dhan33 due to the interaction effect of different levels of zinc and cowdung (Table 3). The maximum number of effective tillers hill^{-1} (14.60) was recorded from Zn_3C_3, which was statistically similar with Zn_2C_3, Zn_3C_2, Zn_2C_2, Zn_1C_2, Zn_1C_3, Zn_3C_1, Zn_2C_1 and Zn_1C_1, whereas the minimum number (8.93) was found from Zn_0C_0.

4.1.3 Number of non-effective tillers hill^{-1}

Statistically significant variation was recorded for number of non-effective tillers hill^{-1} of BRRI dhan33 due to different levels of zinc (Table 2). The maximum number of non-effective tillers hill^{-1} (3.25) was attained from Zn_0 which was closely followed (3.02 and 2.93) with Zn_1 and Zn_2 they were statistically similar and the minimum number (2.63) from Zn_3. Khan *et al.* (2007) reported that Zn significantly influenced non-effective tillers.

Number of non-effective tillers hill^{-1} of BRRI dhan33 varied significantly for different levels of cowdung (Table 2). The maximum number of non-effective tillers hill^{-1} (3.77) was recorded from C_0, which was closely followed (3.24) by C_1, again the minimum number (2.37) from C_3 which was statistically similar (2.44) with C_2. Similar results also reported by Ali *et al.* (2003).

Interaction effect of different levels of zinc and cowdung showed significant variation on number of non-effective tillers hill^{-1} of BRRI dhan33 (Table 3). The maximum number of non-effective tillers hill^{-1} (4.33) was found from Zn_0C_0, whereas the minimum number (2.20) was recorded from Zn_3C_3.

Table 3. Interaction effect of different levels of zinc and cowdung on yield contributing characters of transplanted aman rice BRRI dhan33

Zinc and Cowdung		Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Number of total tillers hill^{-1}	Length of panicle (cm)	Weight of 1000 grains (g)
Zn_0	C_0	8.93 d	4.33 a	13.26 b	17.47 e	18.37 d
	C_1	10.60 bc	3.30 b-d	13.90 b	19.60 de	20.25 c
	C_2	10.47 bc	2.87 de	13.34 b	18.87 de	19.70 c
	C_3	10.77 bc	2.50 ef	13.27 b	20.55 b-d	20.63 bc
Zn_1	C_0	10.07 cd	4.07 a	14.14 b	20.10 cd	20.08 c
	C_1	10.20 bc	3.20 b-d	13.40 b	19.37 de	19.51 cd
	C_2	14.33 a	2.27 f	16.60 a	22.62 ab	22.24 a
	C_3	13.87 a	2.53 ef	16.40 a	22.46 ab	21.66 ab
Zn_2	C_0	10.47 bc	3.60 b	14.07 b	19.79 de	20.53 bc
	C_1	13.33 a	3.43 bc	16.77 a	22.19 a-c	22.60 a
	C_2	13.80 a	2.44 ef	16.24 a	23.40 a	22.67 a
	C_3	14.33 a	2.23 f	16.57 a	22.83 ab	22.50 a
Zn_3	C_0	11.47 b	3.07 cd	14.53 b	22.13 a-c	21.70 ab
	C_1	13.33 a	3.04 cd	16.37 a	22.63 ab	22.48 a
	C_2	13.80 a	2.23 f	16.03 a	23.00 a	21.90 ab
	C_3	14.60 a	2.20 f	16.80 a	23.13 a	22.74 a
$LSD_{(0.05)}$		1.148	0.425	1.233	2.106	1.256
Level of significance		**	**	**	**	**
CV(%)		5.67	8.62	4.90	5.94	3.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 2.0 kg Zn ha^{-1}
Zn_2: 3.0 kg Zn ha^{-1}
Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)
C_1: 4.5 ton cowdung ha^{-1}
C_2: 5.0 ton cowdung ha^{-1}
C_3: 5.5 ton cowdung ha^{-1}

** ➤ Significant at 0.01 level of probability

4.1.4 Number of total tillers hill^{-1}

Variation was observed for number of total tillers hill^{-1} of BRRI dhan33 due to different levels of zinc (Table 2). The maximum number of total tillers hill^{-1} (15.93) was recorded from Zn_3 which was statistically similar (15.91) with Zn_2 and closely followed (15.13) by Zn_1, while the minimum number (13.43) from Zn_0. Ullah *et al.* (2001) obtained the highest number of tillers (10.600 hill^{-1}) with 20 kg zinc sulfate ha^{-1}.

Different levels of cowdung varied significantly for number of total tillers hill^{-1} of BRRI dhan33 (Table 2). The maximum number of total tillers hill^{-1} (15.76) was found from C_3, which was statistically identical with C_2 and C_1, whereas the minimum number (14.00) from C_0. Kant and Kumar (1994) reported that the maximum level of FYM (30 t ha^{-1}) the increase of 48% tillers hill^{-1}.

Interaction effect of different levels of zinc and cowdung varied significantly on number of total tillers hill^{-1} of BRRI dhan33 (Table 3). The maximum number of total tillers hill^{-1} (16.80) was recorded from Zn_3C_3 which was statistically similar with Zn_3C_2, Zn_2C_2, Zn_1C_2, Zn_1C_3, Zn_3C_1, Zn_2C_1 and Zn_1C_1 and the minimum number (13.26) was recorded from Zn_0C_0. Similar results reported earlier by Saha *et al.* (2007).

4.1.5 Length of panicle

Length of panicle of BRRI dhan33 showed statistically significant differences due to different levels of zinc (Table 2). The longest panicle (22.72 cm) was recorded from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, whereas the shortest panicle (19.12 cm) from Zn_0. Cheema *et al.* (2006) reported that panicle size showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

Statistically significant variation was recorded in terms of length of panicle of BRRI dhan33 for different levels of cowdung (Table 2). The longest panicle

(22.12 cm) was observed from C_3, which was statistically identical with C_2 and C_1 and the shortest panicle (20.12 cm) was found from C_0.

Interaction effect of different levels of zinc and cowdung showed significant variation on length of panicle of BRRI dhan33 (Table 3). The longest panicle (23.40 cm) was recorded from Zn_2C_2 which was statistically similar with Zn_2C_3, Zn_3C_2, Zn_2C_2, Zn_1C_2, Zn_1C_3, Zn_3C_1, Zn_2C_1 and Zn_1C_1, while the shortest panicle (17.47 cm) was recorded from Zn_0C_0.

4.1.6 Weight of 1000-grain

Statistically significant variation was recorded for weight of 1000-grain of BRRI dhan33 due to different levels of zinc (Table 2). The highest weight of 1000-grain (22.21 g) was attained from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, while the lowest weight (19.74 g) from Zn_0. Ullah *et al.* (2001) reported that the highest 1000-grain weight (28.700 g), from 20 kg zinc sulfate ha^{-1}.

Weight of 1000-grain of BRRI dhan33 varied significantly for different levels of cowdung (Table 2). The highest weight of 1000-grain (21.88 g) was found from C_3, which was statistically similar with C_2 and closely followed (21.21 g) by C_1, whereas the lowest weight (20.17 g) was observed from C_0. Kant and Kumar (1994) reported that the maximum level of FYM (30 t ha^{-1}) the 4.5% weight of 1000 grains over the control were recorded.

Interaction effect of different levels of zinc and cowdung showed significant variation on weight of 1000-grain of BRRI dhan33 (Table 3). The highest weight of 1000-grain (22.74 g) was attained from Zn_3C_3, which was statistically similar with Zn_2C_3, Zn_3C_2, Zn_2C_2, Zn_1C_2, Zn_1C_3, Zn_3C_1, Zn_2C_1 and Zn_1C_1, while the lowest weight (18.37 g) was found from Zn_0C_0.

4.1.7 Number of filled grains panicle^{-1}

Different levels of zinc showed statistically significant variation for number of filled grains panicle^{-1} of BRRI dhan33 (Table 4). The maximum number of filled grains panicle^{-1} (84.27) was recorded from Zn_3 which was statistically similar (83.00) with Zn_2 and closely followed (78.82) by Zn_1, while the minimum filled grains (72.27) from Zn_0. Khan *et al.* (2007) reported that increasing levels of Zn significantly influenced yield components of rice.

Variation was recorded for number of filled grains panicle^{-1} of BRRI dhan33 due to different levels of cowdung (Table 4). The maximum number of filled grains panicle^{-1} (83.73) was found from C_3, which was statistically identical (83.28) with C_2 and closely followed (78.45) by C_1, while the minimum filled grains (72.88) was recorded from C_0. Kant and Kumar reported that the maximum level of FYM (30 t ha^{-1}) increase of 14% number of grain panicle^{-1} over the control.

Number of filled grains panicle^{-1} of BRRI dhan33 showed significant variation for the interaction effect of different levels of zinc and cowdung (Table 5). The maximum number of filled grains panicle^{-1} (91.80) was found from Zn_1C_2. On the other hand, the minimum filled grains (60.47) from Zn_0C_0.

4.1.8 Number of unfilled grains panicle^{-1}

Statistically significant variation was recorded for number of unfilled grains panicle^{-1} of BRRI dhan33 due to different levels of zinc (Table 4). The maximum number of unfilled grains panicle^{-1} (10.63) was observed from Zn_0 which was followed (9.52) with Zn_1, whereas the minimum unfilled grains (7.90) from Zn_3 which was statistically similar (8.12) with Zn_1.

Number of unfilled grains panicle^{-1} of BRRI dhan33 varied significantly for different levels of cowdung (Table 4). The maximum number of unfilled grains panicle^{-1} (10.15) was observed from C_0, which was statistically identical (9.57) with C_1, again the minimum unfilled grains (8.02) was found from C_3 which was statistically similar (8.43) with C_2.

Table 4. Effect of different levels of zinc and cowdung on yield contributing characters and yield of transplanted aman rice BRRI dhan33

Zinc level	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Zn_0	72.27 c	10.63 a	3.28 c	4.93 c	39.32 b
Zn_1	78.82 b	9.52 b	4.35 b	5.79 b	41.70 ab
Zn_2	83.00 a	8.12 c	4.87 a	6.48 a	42.59 a
Zn_3	84.27 a	7.90 c	5.11 a	6.64 a	43.59 a
$LSD_{(0.05)}$	3.670	0.622	0.308	0.387	2.561
Level of significance	**	**	**	**	**
CV(%)	5.53	8.25	8.36	7.77	7.35
Cowdung level					
C_0	72.88 c	10.15 a	3.29 c	4.84 c	39.81 b
C_1	78.45 b	9.57 a	4.15 b	5.81 b	41.30 ab
C_2	83.28 a	8.43 b	5.00 a	6.47 a	42.64 a
C_3	83.73 a	8.02 b	5.18 a	6.72 a	43.44 a
$LSD_{(0.05)}$	3.670	0.622	0.308	0.387	2.561
Level of significance	**	**	**	**	*
CV(%)	5.53	8.25	8.36	7.77	7.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

* ➔ Significant at 0.05 level of probability

** ➔ Significant at 0.01 level of probability

Table 5. Interaction effect of different levels of zinc and cowdung on yield contributing characters and yield of transplanted aman rice BRRI dhan33

Zinc and Cowdung		Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Zn_0	C_0	60.47 g	13.80 a	2.14 h	3.59 g	37.39 de
	C_1	82.80 bc	9.73 cd	4.54 d	5.88 cd	43.54 a-c
	C_2	70.27 ef	10.07 cd	2.56 gh	4.68 f	35.30 e
	C_3	75.53 c-e	8.93 c-f	3.89 e	5.59 de	41.04 b-e
Zn_1	C_0	72.87 e	10.13 c	3.02 fg	4.75 f	38.30 c-e
	C_1	64.87 fg	12.33 b	2.70 gh	4.77 f	36.12 e
	C_2	91.80 a	7.27 h	5.71 ab	6.90 ab	47.08 a
	C_3	85.73 ab	8.33 e-h	5.55 ab	6.73 a-c	45.29 ab
Zn_2	C_0	74.80 de	9.23 c-e	3.36 ef	5.03 ef	40.03 b-e
	C_1	84.73 ab	7.90 e-h	4.54 d	6.63 bc	40.62 b-e
	C_2	85.60 ab	7.70 f-h	6.13 a	7.19 ab	46.05 ab
	C_3	86.87 ab	7.63 f-h	5.87 ab	7.06 ab	45.39 ab
Zn_3	C_0	81.40 b-d	8.70 d-g	4.62 d	5.99 cd	43.52 abc
	C_1	83.40 a-c	8.30 e-h	4.83 cd	5.94 cd	44.90 ab
	C_2	85.47 ab	7.43 gh	5.42 bc	7.12 ab	43.22 a-d
	C_3	86.80 ab	7.17 h	5.59 ab	7.52 a	42.69 a-d
$LSD_{(0.05)}$		7.339	1.245	0.615	0.773	5.122
Level of significance		**	**	**	**	**
CV(%)		5.53	8.25	8.36	7.77	7.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

** ➤ Significant at 0.01 level of probability

Interaction effect of different levels of zinc and cowdung showed significant variation on number of unfilled grains panicle^{-1} of BRRI dhan33 (Table 5). The maximum number of unfilled grains panicle^{-1} (13.80) was observed from Zn_0C_0, while the minimum unfilled grains (7.17) was attained from Zn_3C_3 which was statistically similar with Zn_1C_2.

4.1.9 Number of total grains panicle^{-1}

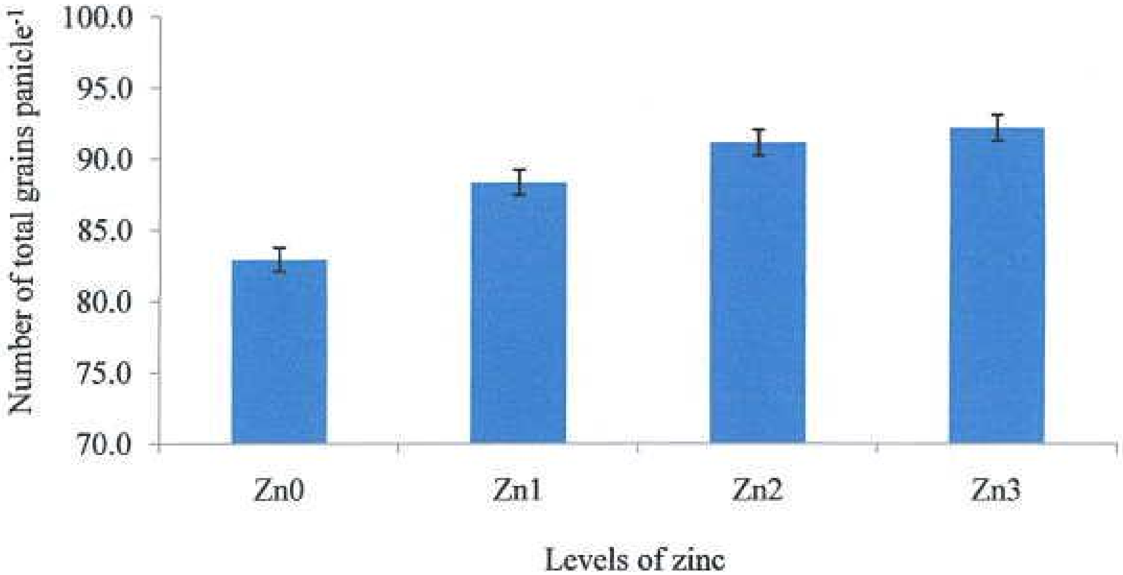
Significant variation was observed for number of total grains panicle^{-1} of BRRI dhan33 due to different levels of zinc (Figure 3). The maximum number of total grains panicle^{-1} (92.17) was observed from Zn_3 which was statistically similar (91.12) with Zn_2 and closely followed (88.33) by Zn_1, again the minimum total grains (82.90) from Zn_0.

Number of total grains panicle^{-1} of BRRI dhan33 varied significantly for different levels of cowdung (Figure 4). The maximum number of total grains panicle^{-1} (91.75) was attained from C_3, which was statistically identical (91.72) with C_2 and closely followed (88.02) by C_1, while the minimum total grains (83.03) from C_0.

Number of total grains panicle^{-1} of BRRI dhan33 showed significant variation due to the interaction effect of different levels of zinc and cowdung (Figure 5). The maximum number of total grains panicle^{-1} (99.07) was obtained from Zn_1C_2 and the minimum total grains (74.27) was found from Zn_0C_0. Similar results reported earlier by Saha *et al.* (2007)

4.1.10 Grain yield ha^{-1}

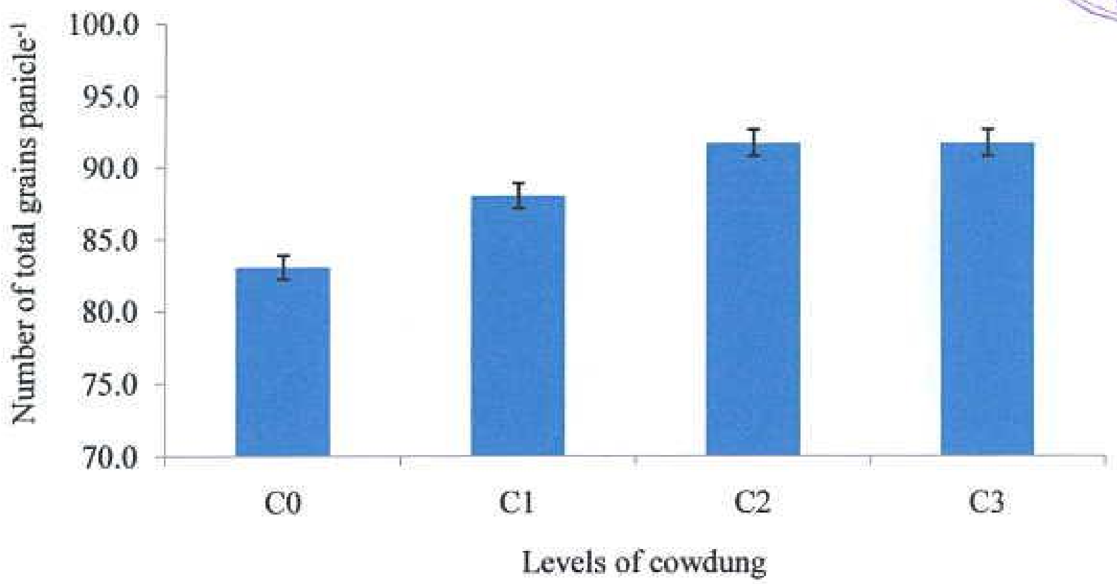
Grain yield ha^{-1} of BRRI dhan33 varied significantly due to different levels of zinc (Table 4). The highest grain yield ha^{-1} (5.11 ton) was found from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, and the lowest grain yield ha^{-1} (3.28 ton) from Zn_0. Cheema *et al.* (2006) reported that paddy yield showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Khan *et al.* (2007) reported that the increasing levels of Zn significantly influenced yield and yield components of rice.



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1} Zn_3: 4.0 kg Zn ha^{-1}

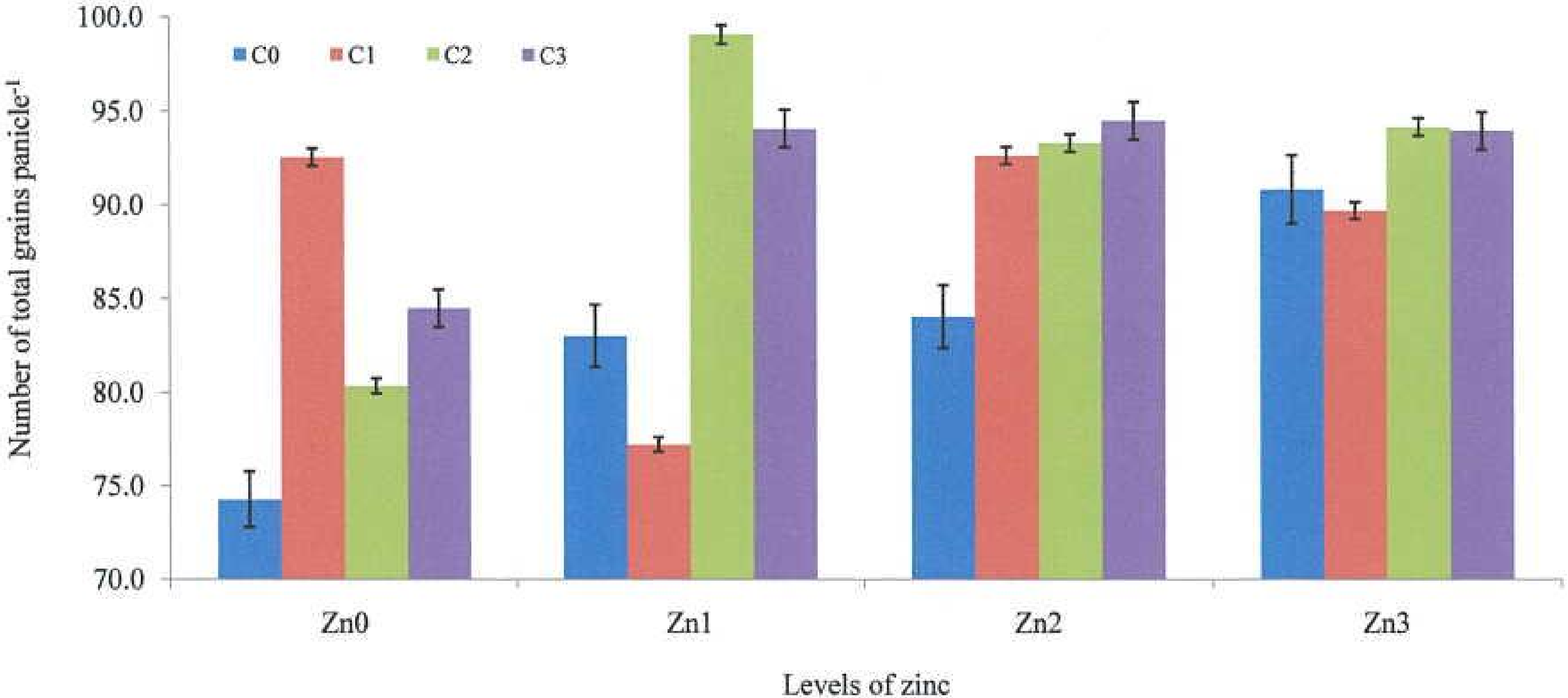
Figure 3. Effect of different levels of zinc on number of total grains panicle^{-1} of BRRI Dhan33



C_0: 0 ton cowdung ha^{-1} (control) C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1} C_3: 5.5 ton cowdung ha^{-1}

Figure 4. Effect of different levels of cowdung on number of total grains panicle^{-1} of BRRI dhan33



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 2.0 kg Zn ha^{-1} C_0: 0 ton cowdung ha^{-1} (control) C_1: 4.5 ton cowdung ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1} Zn_3: 4.0 kg Zn ha^{-1} C_2: 5.0 ton cowdung ha^{-1} C_3: 5.5 ton cowdung ha^{-1}

Figure 5. Interaction effect of different levels of zinc and cowdung on number of total grains panicle^{-1} of BRRI dhan33

Statistically significant variation was recorded for grain yield ha^{-1} of BRRI dhan33 for different levels of cowdung (Table 4). The highest grain yield ha^{-1} (5.18 ton) was observed from C_3, which was statistically identical with C_2 and closely followed by C_1, while the lowest grain yield ha^{-1} (3.29 ton) was observed from C_0. It was found that cowdung manure can supply a good amount of plant nutrients and thus can contribute to crop yields. Saha *et al.* (2007) reported that grain yields were significantly increased as a result of the application cowdung at the rate of 5 t ha^{-1}.

Interaction effect different levels of zinc and cowdung showed significant variation on grain yield $hectare^{-1}$ of BRRI dhan33 (Table 5). The highest grain yield ha^{-1} (6.13 ton) was obtained from Zn_2C_2, whereas the lowest grain yield ha^{-1} (2.14 ton) from Zn_0C_0.

4.1.11 Straw yield ha^{-1}

Significant differences were observed for straw yield ha^{-1} of BRRI dhan33 due to different levels of zinc (Table 4). The highest straw yield ha^{-1} (6.64 ton) was recorded from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, and the lowest straw yield ha^{-1} (4.93 ton) from Zn_0.

Data revealed that straw yield ha^{-1} of BRRI dhan33 varied significantly for different levels of cowdung (Table 4). The highest straw yield ha^{-1} (6.72 ton) was observed from C_3, which was statistically identical (6.47 ton) with C_2, while the lowest straw yield ha^{-1} (4.84 ton) was observed from C_0. Saha *et al.* (2007) reported that straw yields were significantly increased as a result of the application cowdung at the rate of 5 t ha^{-1}.

Interaction effect of different levels of zinc and cowdung showed significant variation on straw yield ha^{-1} of BRRI dhan33 (Table 5). The highest straw yield ha^{-1} (7.52 ton) was observed from Zn_3C_3. On the other hand, the lowest straw yield ha^{-1} (3.59 ton) was recorded from Zn_0C_0.

4.1.12 Biological yield ha^{-1}

Biological yield ha^{-1} of BRRI dhan33 varied significantly due to different levels of zinc (Figure 6). It was observed that the highest biological yield ha^{-1} (11.76 ton) was recorded from Zn_3 which was statistically similar (11.35 ton) with Zn_2, while the lowest biological yield ha^{-1} (8.22 ton) from Zn_0.

Biological yield ha^{-1} of BRRI dhan33 varied significantly for different levels of cowdung (Figure 7). The highest biological yield ha^{-1} (11.91 ton) was found from C_3, which was statistically identical (11.47 ton) with C_2 and the lowest biological yield ha^{-1} (8.13 ton) was observed from C_0.

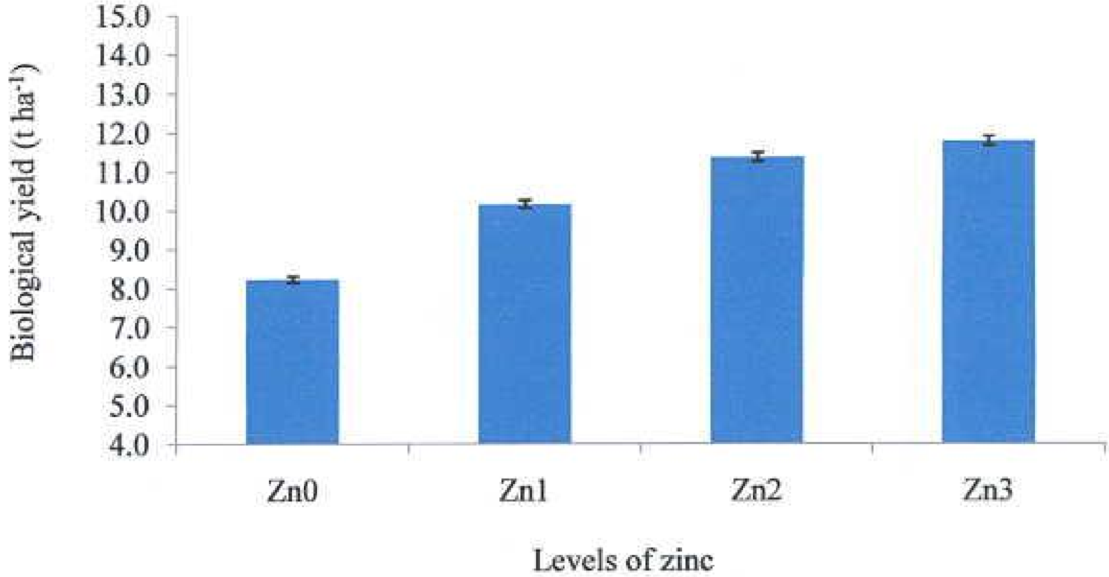
Interaction effect of different levels of zinc and cowdung showed significant variation on biological yield ha^{-1} of BRRI dhan33 (Figure 8). The highest biological yield ha^{-1} (13.32 ton) was observed from Zn_2C_2, whereas the lowest biological yield ha^{-1} (5.73 ton) was recorded from Zn_0C_0.

4.1.13 Harvest index

Different levels of zinc showed statistically significant variation for harvest index of BRRI dhan33 (Table 4). The highest harvest index (43.59 %) was recorded from Zn_3 which was statistically similar with Zn_2 and Zn_1, whereas the lowest harvest index (39.32%) from Zn_0. Cheema *et al.* (2006) reported that harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

Harvest index of BRRI dhan33 varied significantly for different levels of cowdung (Table 4). The highest harvest index (43.44%) was observed from C_3, which was statistically identical with C_2 and C_1, again the lowest harvest index (39.81%) from C_0.

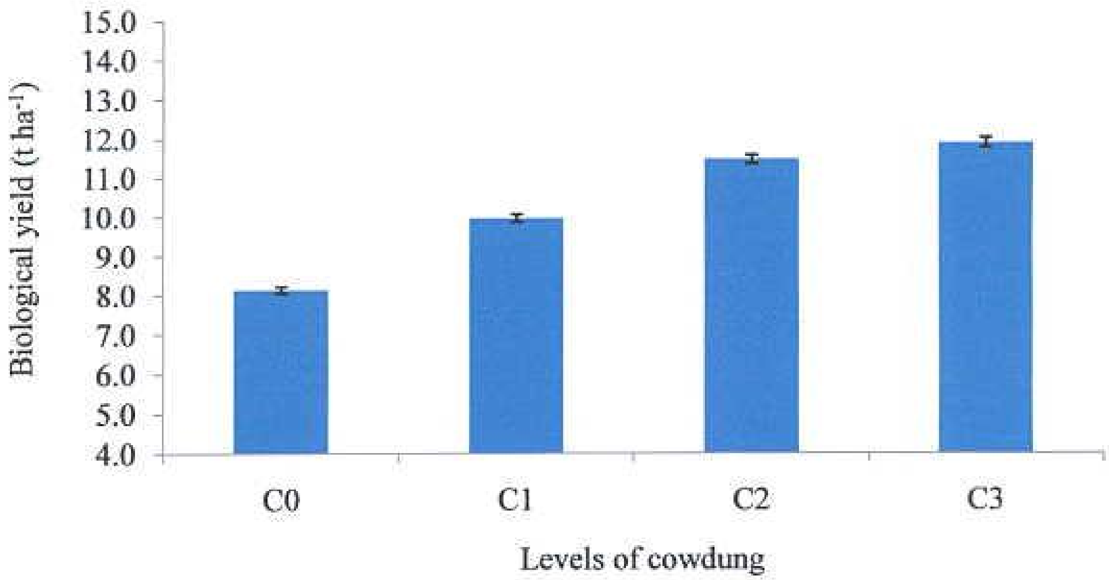
Harvest index of BRRI dhan33 varied significantly due to the interaction effect of different levels of zinc and cowdung (Table 5). The highest harvest index (47.08%) was observed from Zn_1C_2, while the lowest harvest index (35.30%) from Zn_0C_2.



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1} Zn_3: 4.0 kg Zn ha^{-1}

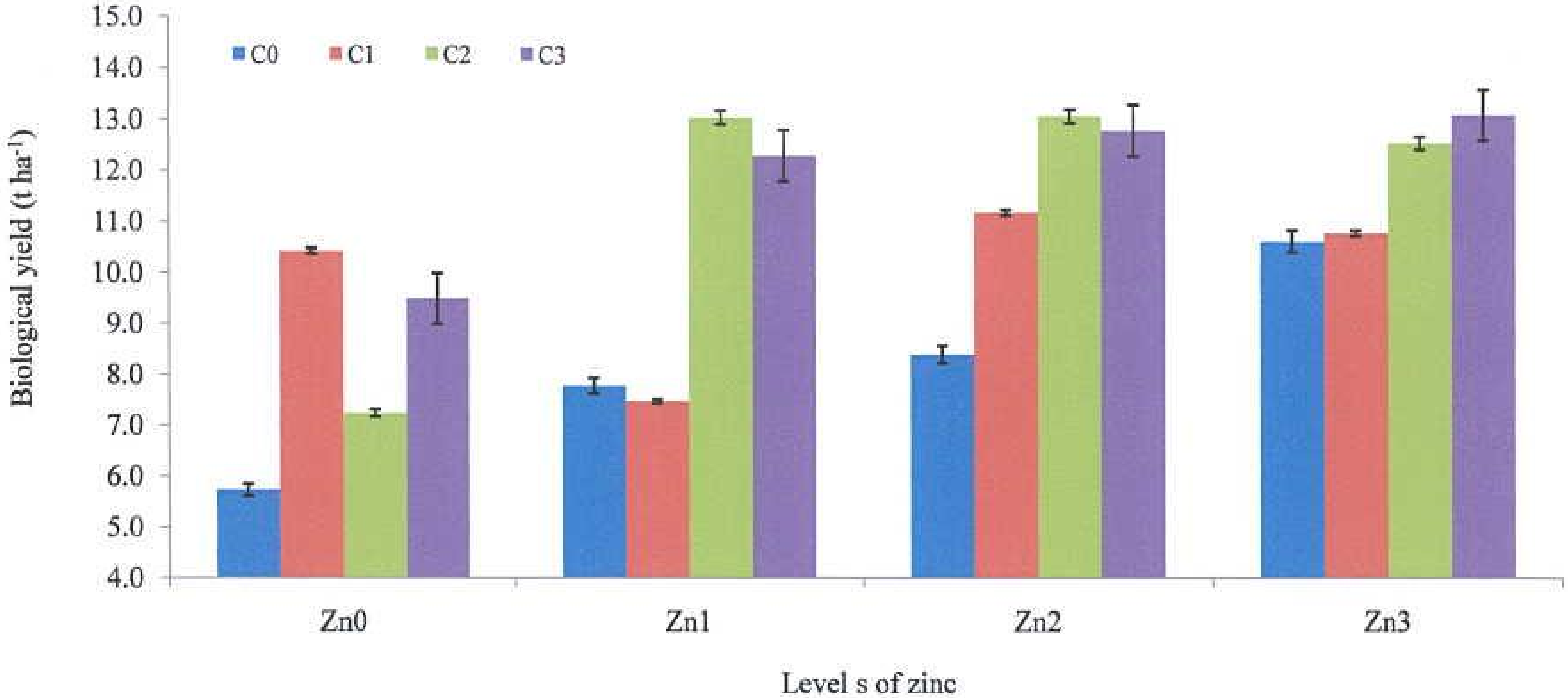
Figure 6. Effect of different levels of zinc on biological yield of BRRI Dhan33



C_0: 0 ton cowdung ha^{-1} (control) C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1} C_3: 5.5 ton cowdung ha^{-1}

Figure 7. Effect of different levels of cowdung on biological yield BRRI dhan33



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 2.0 kg Zn ha^{-1} C_0: 0 ton cowdung ha^{-1} (control) C_1: 4.5 ton cowdung ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1} Zn_3: 4.0 kg Zn ha^{-1} C_2: 5.0 ton cowdung ha^{-1} C_3: 5.5 ton cowdung ha^{-1}

Figure 8. Interaction effect of different levels of zinc and cowdung on biological yield of BRRI dhan33

4.2 Mineral content in grain

4.2.1 N content in grain

N content in grain of BRRI dhan33 varied significantly due to different levels of zinc (Table 6). The highest N content (1.35%) in grain was found from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1 and the lowest (1.16%) from Zn_0. Yadi *et al.* (2012) reported nitrogen content in grain were highest with application of 40 and 20 kg Zn ha^{-1}.

Data revealed that N content in grain of BRRI dhan33 varied significantly for different levels of cowdung (Table 6). The highest N content (1.39%) in grain was observed from C_3, which was statistically identical with C_2 and closely followed by C_1, while the lowest (1.10%) from C_0. Sharma and Mitra (1991) reported a significant increase in N content and also the nutritional status of soil with 5 t ha^{-1} of FYM of rice based cropping system. Sharma and Mitra (1991) reported a significant increase in N, P and K content and also the nutritional status of soil with 5 t ha^{-1} of FYM of rice based cropping system. Sharma and Mitra (1991) reported a significant increase in N content and with 5 t ha^{-1} of FYM of rice based cropping system.

The interaction effect of different levels of Zinc and cowdung showed significant variation on N content in grain of BRRI dhan33 (Table 7). The highest N content (1.54%) in grain was attained from Zn_3C_3, whereas the lowest (1.07%) was recorded from Zn_0C_0.

4.2.2 P content in grain

Statistically significant variation was recorded for P content in grain of BRRI dhan33 due to different levels of zinc (Table 6). The highest P content (0.290%) in grain was observed from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, while the lowest (0.195%) from Zn_0. Yadi *et al.* (2012) reported phosphorus content in grain were highest with application of 40 and 20 kg Zn ha^{-1}.

Table 6. Effect of different levels of zinc and cowdung on nutrient content in grain of transplanted aman rice BRRI dhan33

Zinc level	Content (%) in grain				
	N	P	K	S	Zn
Zn_0	1.16 c	0.195 c	0.543 c	0.112 c	0.0175 c
Zn_1	1.27 b	0.245 b	0.580 b	0.125 b	0.0236 b
Zn_2	1.32 ab	0.270 ab	0.622 a	0.131 ab	0.0268 a
Zn_3	1.35 a	0.290 a	0.639 a	0.136 a	0.0276 a
$LSD_{(0.05)}$	0.059	0.026	0.026	0.008	0.003
Level of significance	**	**	**	**	**
CV(%)	5.78	9.92	6.31	4.92	4.95
Cowdung level					
C_0	1.10 c	0.191 c	0.537 c	0.113 b	0.0204 b
C_1	1.27 b	0.236 b	0.576 b	0.127 a	0.0242 a
C_2	1.33 a	0.283 a	0.626 a	0.130 a	0.0249 a
C_3	1.39 a	0.291 a	0.647 a	0.133 a	0.0259 a
$LSD_{(0.05)}$	0.059	0.026	0.026	0.008	0.003
Level of significance	**	**	**	**	**
CV(%)	5.78	9.92	6.31	4.92	4.95

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 2.0 kg Zn ha^{-1}
Zn_2: 3.0 kg Zn ha^{-1}
Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)
C_1: 4.5 ton cowdung ha^{-1}
C_2: 5.0 ton cowdung ha^{-1}
C_3: 5.5 ton cowdung ha^{-1}

** → Significant at 0.01 level of probability

Table 7. Interaction effect of different levels of zinc and cowdung on nutrient content in grain of transplanted aman rice BRRI dhan33

Zinc and Cowdung		Content (%) in grain				
		N	P	K	S	Zn
Zn_0	C_0	1.07 h	0.135 d	0.535 fg	0.103 d	0.0126 g
	C_1	1.16 f-h	0.214 c	0.514 g	0.116 cd	0.0215 c-f
	C_2	1.17 f-h	0.213 c	0.540 e-g	0.113cd	0.0166 fg
	C_3	1.23 e-g	0.219 c	0.583 d-f	0.118 cd	0.0192 ef
Zn_1	C_0	1.10 h	0.202 c	0.520 g	0.112 cd	0.0208 d-f
	C_1	1.17 f-h	0.185 cd	0.550 e-g	0.118 cd	0.0190 ef
	C_2	1.40 b-d	0.300 a	0.655 bc	0.139 a	0.0276 ab
	C_3	1.42 a-c	0.294 ab	0.596 c-e	0.130 a-c	0.0268 a-c
Zn_2	C_0	1.11 gh	0.221 c	0.549 e-g	0.118 cd	0.0229 b-e
	C_1	1.31 c-e	0.243 bc	0.618 b-d	0.138 ab	0.0283 ab
	C_2	1.48 ab	0.309 a	0.655 bc	0.132 a-c	0.0278 ab
	C_3	1.36 b-e	0.307 a	0.667 b	0.137 ab	0.0280 ab
Zn_3	C_0	1.14 gh	0.204 c	0.543 e-g	0.120 b-d	0.0251 a-d
	C_1	1.45 ab	0.301 a	0.620 b-d	0.138 ab	0.0278 ab
	C_2	1.28 d-f	0.311 a	0.653 bc	0.137 ab	0.0279 ab
	C_3	1.54 a	0.345 a	0.741 a	0.148 a	0.0295 a
$LSD_{(0.05)}$		0.118	0.053	0.053	0.017	0.005
Level of significance		**	**	*	*	**
CV(%)		5.78	9.92	6.31	4.92	4.95

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 2.0 kg Zn ha^{-1}
Zn_2: 3.0 kg Zn ha^{-1}
Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)
C_1: 4.5 ton cowdung ha^{-1}
C_2: 5.0 ton cowdung ha^{-1}
C_3: 5.5 ton cowdung ha^{-1}

* ➔ Significant at 0.05 level of probability

** ➔ Significant at 0.01 level of probability

P content in grain of BRRI dhan33 varied significantly for different levels of cowdung (Table 6). The highest P content (0.291%) in grain was recorded from C_3, which was statistically identical with C_2 and closely followed by C_1, whereas the lowest (0.191%) was observed from C_0. Sharma and Mitra (1991) reported a significant increase in P content and also the nutritional status of soil with 5 t ha^{-1} of FYM of rice based cropping system.

Interaction effect of different levels of zinc and cowdung showed significant variation on P content in grain of BRRI dhan33 (Table 7). The highest P content (0.345%) in grain was found from Zn_3C_3 and the lowest (135%) was recorded from Zn_0C_0.

4.2.3 K content in grain

Significant variation was observed for K content in grain of BRRI dhan33 due to different levels of zinc (Table 6). The highest K content (0.639%) in grain was recorded from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, again the lowest (0.543%) from Zn_0. Yadi *et al.* (2012) reported potassium content in grain were highest with application of 40 and 20 kg Zn ha^{-1}.

K content in grain of BRRI dhan33 varied significantly for different levels of cowdung (Table 6). Data revealed that the highest K content (0.647%) in grain was observed from C_3, which was statistically identical with C_2 and closely followed by C_1, while the lowest (0.537%) from C_0. Sharma and Mitra (1991) reported a significant increase in K content and also the nutritional status of soil with 5 t ha^{-1} of FYM of rice based cropping system.

Statistically significant variation was observed due to the interaction effect of different levels of zinc and cowdung on K content in grain of BRRI dhan33 (Table 7). The highest K content (0.741%) in grain was observed from Zn_3C_3 and lowest (0.514%) from Zn_0C_1.

4.2.4 S content in grain

Statistically significant variation was recorded for S content in grain of BRRI dhan33 due to different levels of zinc (Table 6). The highest S content (0.136%) in grain was attained from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, whereas the lowest (0.113%) from Zn_0. Yadi *et al.* (2012) reported sulphur content in grain were highest with 40 and 20 kg Zn ha^{-1}.

S content in grain of BRRI dhan33 varied significantly for different levels of cowdung (Table 6). The highest S content (0.133%) in grain was observed from C_3, which was statistically identical with C_2 and C_1, again the lowest (0.113%) was found from C_0.

Interaction effect of different levels of zinc and cowdung showed significant variation on S content in grain of BRRI dhan33 (Table 7). The highest S content (0.148%) in grain was observed from Zn_3C_3, while the lowest (0.103%) was recorded from Zn_0C_0.

4.2.5 Zn Content in grain

Different levels of zinc showed statistically significant for Zn content in grain of BRRI dhan33 (Table 6). The highest Zn content (0.0276%) in grain was recorded from Zn_3 which was statistically similar with Zn_2 and closely followed by Zn_1, while the lowest (0.0175%) from Zn_0. Ullah *et al.* (2001) reported the highest concentration of Zn in grain (73.33 ppm) with 20 kg zinc sulfate ha^{-1}.

Statistically significant variation was recorded for Zn content in grain of BRRI dhan33 due to different levels of cowdung (Table 6). The highest Zn content (0.0259%) in grain was observed from C_3, which was statistically identical with C_2 and C_1, whereas the lowest (0.0204%) was observed from C_0.

Different levels of zinc and cowdung showed significant variation on Zn content in grain of BRRI dhan33 for their interaction effect (Table 7). The highest Zn content (0.0295%) in grain was observed from Zn_3C_3, while the lowest (0.0126%) was recorded from Zn_0C_0.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November 2012 to study the effect of zinc and cowdung on growth, yield and nutrient content of transplanted aman rice (BRRI dhan33). BRRI dhan33 was used as the test crop in this experiment. The experiment consisted of two factors. Factor A: 4 levels of zinc (Zn_0: 0 kg Zn ha^{-1} (control), Zn_1: 2.0 kg Zn ha^{-1}, Zn_2: 3.0 kg Zn ha^{-1}, Zn_3: 4.0 kg Zn ha^{-1}) and Factor B: 4 levels of cowdung (C_0: 0 ton cowdung ha^{-1} (control), C_1: 4.5 ton cowdung ha^{-1}, C_2: 5.0 ton cowdung ha^{-1} and C_3: 5.5 ton cowdung ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications.

For different level of zinc, at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.12, 41.09, 58.90, 75.03 and 88.34 cm, respectively) were recorded from Zn_3, whereas the shortest plant (19.95, 33.52, 51.08, 65.25 and 80.50 cm, respectively) from Zn_0. The maximum number of effective tillers $hill^{-1}$ (13.30) was attained from Zn_3, again the minimum number (10.18) from Zn_0. The maximum number of non-effective tillers $hill^{-1}$ (3.25) was obtained from Zn_0 and the minimum number (2.63) from Zn_3. The maximum number of total tillers $hill^{-1}$ (16.83) was recorded from Zn_3, while the minimum number (13.26) from Zn_0. The longest panicle (22.72 cm) was recorded from Zn_3, whereas the shortest panicle (19.12 cm) from Zn_0. The highest weight of 1000-grain (22.21 g) was attained from Zn_3, while the lowest weight (19.74 g) from Zn_0. The maximum number of filled grains $panicle^{-1}$ (84.27) was recorded from Zn_3 again the minimum filled grains (72.27) from Zn_0. The maximum number of unfilled grains $panicle^{-1}$ (10.63) was observed from Zn_0, whereas the minimum unfilled grains (7.90) from. The maximum number of total grains $panicle^{-1}$ (92.17) was observed from Zn_3 again the minimum total grains (82.90) from Zn_0. The highest grain yield ha^{-1} (5.11 ton) was found from Zn_3 and the lowest grain yield ha^{-1} (3.28 ton) from Zn_0. The highest straw yield ha^{-1} (6.64

ton) was recorded from Zn_3 and the lowest straw yield ha^{-1} (4.93 ton) from Zn_0. It was observed that the highest biological yield ha^{-1} (11.76 ton) was recorded from Zn_3, while the lowest biological yield ha^{-1} (8.22 ton) from Zn_0. The highest harvest index (43.59 %) was recorded from Zn_3, whereas the lowest harvest index (39.32%) from Zn_0. The highest N content in grain (1.35%) was found from Zn_3 and the lowest (1.16%) from Zn_0. The highest P content (0.290%) in grain was observed from Zn_3, while the lowest (0.195%) from Zn_0. The highest K content (0.639%) in grain was recorded from Zn_3, again the lowest (0.543%) from Zn_0. The highest S content (0.136%) in grain was attained from Zn_3, whereas the lowest (0.113%) from Zn_0. The highest Zn content (0.0276%) in grain was recorded from Zn_3, while the lowest (0.0175%) from Zn_0.

In case of cowdung, at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.29, 40.91, 58.20, 74.47 and 88.57 cm, respectively) was observed from C_3, again the shortest plant (20.00, 34.07, 52.61, 66.13 and 79.65 cm, respectively) was observed from C_0. The maximum number of effective tillers $hill^{-1}$ (13.38) was observed from C_3, while the minimum number (10.23) was found from C_0. The maximum number of non-effective tillers $hill^{-1}$ (3.77) was recorded from C_0, again the minimum number (2.37) was observed from C_3. The maximum number of total tillers $hill^{-1}$ (16.83) was found from C_3, whereas the minimum number (13.26) from C_0. The longest panicle (22.12 cm) was observed from C_3, again the shortest panicle (20.12 cm) was found from C_0. The highest weight of 1000 grains (21.88 g) was found from C_3, whereas the lowest weight (20.17 g) was observed from C_0. The maximum number of filled grains $panicle^{-1}$ (83.73) was found from C_3, while gain the minimum filled grains (72.88) was observed from C_0. The maximum number of unfilled grains $panicle^{-1}$ (10.15) was observed from C_0, again the minimum unfilled grains (8.02) was found from C_3. The maximum number of total grains $panicle^{-1}$ (91.75) was attained from C_3, while the minimum total grains (83.03) from C_0. The highest grain yield ha^{-1} (5.18 ton) was observed from C_3, while the lowest grain yield ha^{-1} (3.29 ton) was observed from C_0. The highest straw yield ha^{-1} (6.72 ton) was observed from C_3, again the lowest straw yield ha^{-1} (4.84 ton) was observed from C_0. The highest biological yield ha^{-1}

(11.91 ton) was found from C_3, and the lowest biological yield ha^{-1} (8.13 ton) was observed from C_0. The highest harvest index (43.44%) was observed from C_3, again the lowest harvest index (39.81%) from C_0. The highest N content (1.39%) in grain was observed from C_3, while the lowest (1.10%) from C_0. The highest P content (0.291%) in grain was recorded from C_3, whereas the lowest (0.191%) was observed from C_0. Data revealed that the highest K content (0.647%) in grain was observed from C_3, while the lowest (0.537%) from C_0. The highest S content (0.133%) in grain was observed from C_3, again the lowest (0.113%) was found from C_0. The highest Zn content (0.0259%) in grain was observed from C_3, whereas the lowest (0.0204%) from C_0.

Due to the interaction effect of different level of zinc and cowdung, at 30, 50, 70, 90 DAT and harvest, the tallest plant (27.27, 43.50, 61.00, 78.70 and 92.11 cm, respectively) was observed from Zn_3C_3, while the shortest (16.23 cm, 28.13 cm, 46.97 cm, 57.67 cm and 70.43 cm, respectively) was recorded from Zn_0C_0. The maximum number of effective tillers $hill^{-1}$ (14.60) was recorded from Zn_3C_3, whereas the minimum number (8.93) was found from Zn_0C_0. The maximum number of non-effective tillers $hill^{-1}$ (4.33) was found from Zn_0C_0, whereas the minimum number (2.20) was recorded from Zn_3C_3. The maximum number of total tillers $hill^{-1}$ (16.83) was recorded from Zn_3C_3 and the minimum number (13.26) was recorded from Zn_0C_0. The longest panicle (23.40 cm) was recorded from Zn_2C_3, while the shortest panicle (17.47 cm) was recorded from Zn_0C_0. The highest weight of 1000-grain (22.74 g) was attained from Zn_3C_3, while the lowest weight (18.37 g) was found from Zn_0C_0. The maximum number of filled grains $panicle^{-1}$ (91.80) was found from Zn_1C_2. On the other hand, the minimum filled grains (60.47) from Zn_0C_0. The maximum number of unfilled grains $panicle^{-1}$ (13.80) was observed from Zn_0C_0, while the minimum (7.27) was attained from Zn_1C_2. The maximum number of total grains $panicle^{-1}$ (99.07) was observed from Zn_1C_2 and the minimum total grains (74.27) was found from Zn_0C_0. The highest grain yield ha^{-1} (6.13 ton) was attained from Zn_2C_2, whereas the lowest grain yield ha^{-1} (2.14 ton) from Zn_0C_0. The highest straw yield ha^{-1} (7.52 ton) was observed from Zn_3C_3. On the other hand, the lowest straw yield ha^{-1} (3.59 ton) was recorded from Zn_0C_0. The highest biological yield ha^{-1} (13.32 ton) was observed from Zn_2C_2, whereas the lowest biological yield ha^{-1} (5.73 ton) was recorded from Zn_0C_0. The highest harvest index (47.08%) was observed from Zn_1C_2, while the lowest harvest index (35.30%) was recorded from Zn_0C_2. The highest N content (1.54%) in grain was attained from Zn_3C_3, whereas the lowest (1.07%) was recorded from Zn_0C_0.The highest P content (0.345%) in grain was found from Zn_3C_3 and the lowest (0.135%) was recorded from Zn_0C_0. The highest K content (0.741%) in grain was observed from Zn_3C_3 and lowest (0.514%) from Zn_0C_1. The highest S content (0.148%) in grain was observed from Zn_3C_3, while the lowest (0.103%) was recorded from Zn_0C_0. The highest Zn content (0.0295%) in grain was observed from Zn_3C_3, while the lowest (0.0126%) was recorded from Zn_0C_0.

It was observed that, zinc and cowdung application have significant positive effect on growth and yield of BRRI dhan33. Application of 3 kg Zn ha^{-1} showed statistically similar result with 4 kg Zn ha^{-1} for most of the yield parameters. On the other hand, 5 t ha^{-1} cowdung and 5.5 t ha^{-1} cowdung showed statistically same grain yield. From the above results, it can be concluded that combination of 3.0 kg Zn ha^{-1} and 5.0 ton cowdung ha^{-1} can be more beneficial for farmers to get better yield and economic return.

Considering the above results of this experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

2. More experiments may be carried out with other level of zinc and other fertilizers.

3. More experiments may be carried out with different organic manure with different doses.

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APPENDICES

Appendix I. Characteristics of experimental field soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Exprimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

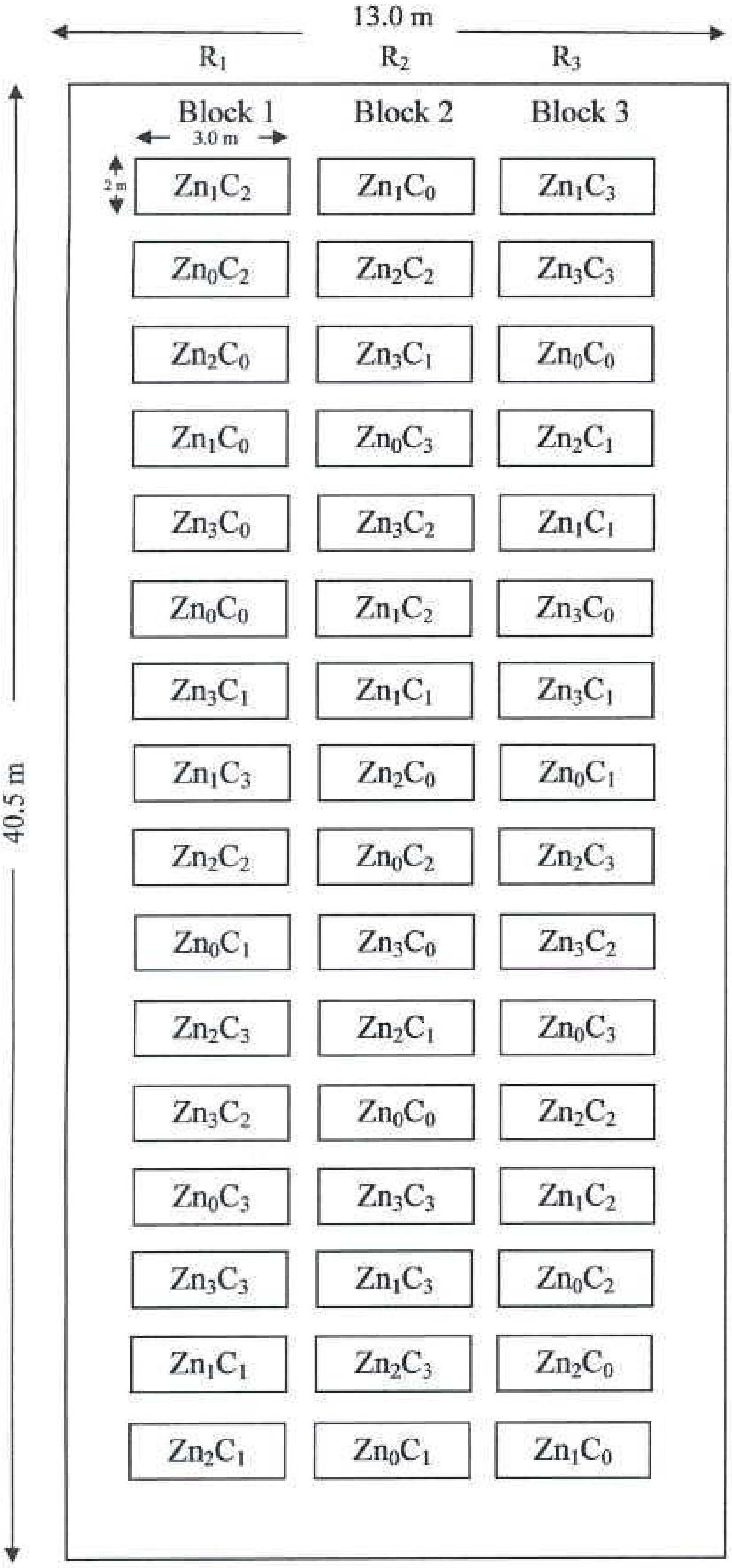
Source: SRDI

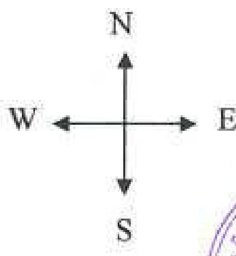
Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from June to Novenber 2012

Month	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
June, 2012	35.4	22.5	80	577	4.2
July. 2012	36.0	24.6	83	563	3.1
August, 2012	36.0	23.6	81	319	4.0
September, 2012	34.8	24.4	81	279	4.4
October, 2012	26.5	19.4	81	22	6.9
November, 2012	25.8	16.0	78	00	6.8

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1212*

Appendix III. Field layout of two factor experiment in Randomized Complete Block Design (RCBD)





Plot size = 3.0 m ×2.0 m

Block spacing: 1.0 m

Plot Spacing: 0.5 m

Factor A: Level of zinc)

Zn_0: 0 kg Zn ha^{-1} (Control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

Factor B: Level of cowdung

C_0: 0 t ha^1 (Control)

C_1: 4.5 t ha^{-1}

C_2: 5.0 t ha^{-1}

C_3: 5.5 t ha^{-1}

Appendix IV. Analysis of variance of the data on plant height of *aman* rice CV. BRRI dhan33 as influenced by different levels of zinc and cowdung

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.433	0.267	3.618	0.055	2.076
Level of zinc (A)	3	66.498**	149.721**	154.406**	257.477**	158.244**
Level of cowdung (B)	3	71.127**	117.499**	79.528**	173.185**	202.511**
Interaction (A×B)	9	4.335*	13.073*	11.808*	35.901*	49.980*
Error	30	1.843	5.357	5.373	14.334	18.885

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on effective, non-effective & total tillers plant^{-1} and length of panicle of *aman* rice CV. BRRI dhan33 as influenced by different levels of zinc and cowdung

Source of variation	Degrees of freedom	Mean square			
		Effective tiller hill^{-1}	Non-effective tiller hill^{-1}	Total tiller hill^{-1}	Length of panicle (cm)
Replication	2	0.031	0.020	0.050	0.019
Level of zinc (A)	3	23.543**	0.783**	16.507**	29.453**
Level of cowdung (B)	3	24.710**	5.372**	7.347**	9.275**
Interaction (A×B)	9	2.503**	0.194**	2.779z*	4.029*
Error	30	0.474	0.065	0.547	1.595

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on filled, unfilled & total grains and weight of 1000 grains of *aman* rice CV. BRRI dhan33 as influenced by different levels of zinc and cowdung

Source of variation	Degrees of freedom	Mean square			
		Number of filled grains plant^{-1}	Number of unfilled grains plant^{-1}	Number of total grains plant^{-1}	Weight of 1000 grains (g)
Replication	2	14.598	0.516	10.163	0.453
Level of zinc (A)	3	350.914**	19.672**	206.450**	16.094**
Level of cowdung (B)	3	308.347**	11.699**	203.843**	6.843**
Interaction (A×B)	9	170.570**	6.794**	118.932**	1.660**
Error	30	19.371	0.557	17.391	0.567

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on grain, straw & biological yield and harvest index of *aman* rice CV. BRRI dhan33 as influenced by different levels of zinc and cowdung

Source of variation	Degrees of freedom	Mean square			
		Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.101	0.053	0.294	0.452
Level of zinc (A)	3	7.942**	7.268**	30.311**	39.929**
Level of cowdung (B)	3	9.100**	8.497**	35.129**	30.479*
Interaction (A×B)	9	2.841**	1.272**	7.532**	39.396**
Error	30	0.136	0.215	0.358	9.435

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on N, P, K, S and Zn concentration in grain of *aman* rice CV. BRRI dhan33 as influenced by different levels of zinc and cowdung

Source of variation	Degrees of freedom	Mean square				
		Nutrient concentration in grain (%)				
		N	P	K	S	Zn
Replication	2	0.000	0.000	0.001	0.000	0.0001
Level of zinc (A)	3	0.084**	0.020**	0.022**	0.001**	0.0001**
Level of cowdung (B)	3	0.181**	0.026**	0.029**	0.001**	0.0001**
Interaction (A×B)	9	0.026**	0.002**	0.004**	0.000*	0.0001**
Error	30	0.005	0.001	0.001	0.000	0.00001

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix IX. Effect of different levels of zinc and cowdung on plant height of transplanted aman rice BRRI dhan33

Zinc level	Plant height (cm) at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Zn_0	19.95 c	33.52 c	51.08 c	65.25 c	80.50 b
Zn_1	23.80 b	37.90 b	55.48 b	70.12 b	84.65 a
Zn_2	24.65 ab	40.88 a	58.38 a	74.83 a	87.93 a
Zn_3	25.13 a	41.09 a	58.90 a	75.03 a	88.34 a
$LSD_{(0.05)}$	1.132	1.930	1.933	3.157	3.623
Level of significance	**	**	**	**	**
Cowdung level					
C_0	20.00 c	34.07 c	52.61 c	66.13 c	79.65 b
C_1	23.23 b	37.96 b	55.29 b	70.83 b	85.07 a
C_2	25.02 a	40.44 a	57.74 a	73.80 ab	88.13 a
C_3	25.29 a	40.91 a	58.20 a	74.47 a	88.57 a
$LSD_{(0.05)}$	1.132	1.930	1.933	3.157	3.623
Level of significance	**	**	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

** ► Significant at 0.01 level of probability

Appendix X. Effect of different levels of zinc and cowdung on number of total grains panicle^{-1} and biological yield of transplanted aman rice BRRI dhan33

Level of zinc and cowdung	Number of total grains panicle^{-1}	Biological yield (t ha^{-1})
Zn_0	82.90 c	8.22 c
Zn_1	88.33 b	10.14 b
Zn_2	91.12 ab	11.35 a
Zn_3	92.17 a	11.76 a
$LSD_{(0.05)}$	3.477	0.499
Level of significance	**	**
C_0	83.03 c	8.13 c
C_1	88.02 b	9.96 b
C_2	91.72 a	11.47 a
C_3	91.75 a	11.91 a
$LSD_{(0.05)}$	3.477	0.499
Level of significance	**	**
Zn_0C_0	74.27 f	5.73 f
Zn_0C_1	92.53 ab	10.42 bc
Zn_0C_2	80.33 ef	7.24 e
Zn_0C_3	84.47 cde	9.48 c
Zn_1C_0	83.00 de	7.77 de
Zn_1C_1	77.20 ef	7.47 de
Zn_1C_2	99.07 a	12.61 a
Zn_1C_3	94.07 ab	12.28 a
Zn_2C_0	84.03 cde	8.39 d
Zn_2C_1	92.63 ab	11.17 b
Zn_2C_2	93.30 ab	13.32 a
Zn_2C_3	94.50 ab	12.93 a
Zn_3C_0	90.83 bc	10.61 b
Zn_3C_1	89.70 bcd	10.77 b
Zn_3C_2	94.17 ab	12.54 a
Zn_3C_3	93.97 ab	13.10 a
$LSD_{(0.05)}$	6.954	0.998
Level of significance	**	**
CV(%)	4.71	5.77

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 2.0 kg Zn ha^{-1}

Zn_2: 3.0 kg Zn ha^{-1}

Zn_3: 4.0 kg Zn ha^{-1}

C_0: 0 ton cowdung ha^{-1} (control)

C_1: 4.5 ton cowdung ha^{-1}

C_2: 5.0 ton cowdung ha^{-1}

C_3: 5.5 ton cowdung ha^{-1}

** Significant at 0.01 level of probability