EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF BRRI dhan38

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Nitrogen and Phosphorus on the Growth and Yield of BRRI dhan38'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Soil Science**, embodies the result of a piece of bonafide research work carried out by **Halima Akter**, Registration number: **06-02077** 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.

Dated:
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July to November, 2013 to study the effect of nitrogen and phosphorus on the growth and yield of BRRI dhan38. The experiment comprised of two factors- Factor A: Levels of nitrogen (4 levels); N_0: 0 kg N ha^{-1} i.e. control; N_1: 45 kg N ha^{-1}, N_2: 55 kg N ha^{-1}, N_3: 65 kg N ha^{-1}; Factors B: Levels of phosphorous (3 levels)- P_0: 0 kg P_2O_5 ha^{-1} i.e. control, P_1: 25 kg P_2O_5 ha^{-1} and P_2: 35 kg P_2O_5 ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data revealed that the tallest plant at 30, 45, 60, 75 DAT and at the time of harvest were found in case of treatments N_2, P_2 and treatment combination N_2P_2, whereas, the treatments N_0, P_0 and treatment combination N_0P_0 showed the smallest plant height in each case, respectively. Side by side, the highest number of effective tillers per hill, highest length of panicle and the maximum number of filled grains per panicle were found in N_2, P_2 treatments and N_2P_2 treatment combination. The highest weight of 1000 grains (18.35 g), grain yield (3.95 t ha^{-1}), straw yield (5.39 t ha^{-1}), biological yield (9.34 t ha^{-1}) and harvest index (42.24%) were found in the treatment combination N_2P_2 and also found highest in each individuals N_2 and P_2 treatments. N, P, K, S and Zn concentration in case of grain and straw were found the highest in N_2, P_2 treatments and N_2P_2 treatment combination. The organic matter content (1.34%) total N (0.067%), available P (40.78 ppm), exchangeable K (0.183 me%) were found as the highest in the N_2P_2 treatment combination and also found highest in each individual N_2 and P_2 treatment. Application of 120 kg N ha^{-1} and 35 kg P_2O_5 was more potential in regarding yield contributing characters and yield of BRRI dhan38.

TABLE OF CONTENTS

LIST OF TABLES

exchangeable K of post harvest soil

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than two billion people in Asia (Hien *et al.*, 2006). It is the most important food and widely grown in tropical and subtropical regions (Singh *et al.*, 2012). Rice provides per capita of dietary energy and protein around 21% and 15%, 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). At global level, rice is grown in a total area of 158.10 million hectare with a production of 447.42 million tonnes and having the average productivity of 4.22 t ha^{-1} (USDA, 2010).

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, 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. 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. Rice and rice based cropping system have important role in the Eastern Indo Gangetic Plain to increase food production for a rapidly growing population. Rice yields are either decelerating/stagnating/declining in post green revolution era mainly due to imbalance in fertilizer use, soil degradation, type of cropping system practiced, lack of suitable rice genotypes for low moisture adaptability and disease resistance (Prakash, 2010).

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. In Bangladesh, there is tendency to use indiscriminate amount of nitrogenous fertilizers and very limited amount of other nutrients' containing high analysis chemical fertilizers (Rahman *et al*., 2008). Due to intensification of crop and rapid adoption of improved cultivars has not only increased yield but also have significantly increased the output of nutrients and, where there has been an imbalance between outputs and inputs, has resulted in declining soil fertility and an increase in the incidence of deficiencies of certain plant nutrients, including sulfur and Zn. On an average to produce one tone of grain of high-yielding varieties of rice, remove about 22 kg N, 7 kg P_2O_5, 32 kg K_2O, 5 kg MgO, 4 kg CaO, 1 kg S and 40 g Zn from the soil (Chaudhary *et al*., 2007).

Among the fertilizers, optimum nitrogen (N) is essential for vegetative growth but excess N may cause excessive vegetative growth, prolong the growth duration and delay crop maturity with reduction in grain yield. Many research works revealed a significant response of rice to N fertilizer in different soils (Hussain *et al*., 1989). The efficient N management can increase crop yield and reduce production cost. An increase in the yield of rice by 70 to 80% may be obtained from proper application of N-fertilizer (IFC, 1982). Inadequate and improper applications of N are now considered one of the major reasons for low yield of rice in Bangladesh. The utilization efficiency of applied N by the rice plant is very low. The optimum dose of N fertilizer plays vital role for the growth and development of rice plant and its growth is seriously hampered when lower dose of N is applied, which drastically reduced yield; further, excessive N fertilization encourages excessive vegetative growth which make the plant susceptible to insect pests and diseases which ultimately reduces yield.

Phosphorus is also one of the important essential macro elements for the normal growth and development of plant. The phosphorus requirements for plant differ depending upon the nutrient content of the soil (Sahrawat *et al.*, 2001). Phosphorus shortage restricted the plant growth and remains immature and secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation. It is a major component in ATP, the molecule that provides ‘energy’ to that plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration (Li *et al.*, 2007). Phosphorus application to rice increased P accumulation but did not consistently increase rice yields because flooding decreased soil P sorption and increased P diffusion. The optimum proportion of phosphorus fertilizer enhances the growth and development of a crop as well as ensured the availability of other essential nutrients for the plant.

According to nitrogen and phosphorus importance on growth and yield, this study was conducted to determine the effects of nitrogen and phosphorus fertilizer on growth and yield with the following objectives:

- To find out the appropriate doses of N and P regarding to proper growth and higher production of BRRI dhan38; and
- To select the most advantageous treatment combination of N and P fertilizers concerning to growth and yield of BRRI dhan38.

CHAPTER II

REVIEW OF LITERATURE

Nitrogen and phosphorous fertilizer is the essential factor for sustainable soil fertility and crop productivity. Sole and combined use of nitrogen and phosphorus fertilizer stimulated plant growth, yield contributing characters and that leads to highest yield. Experimental information evidences that the use of nitrogen and phosphorus have an intimate effect on the yield and yield attributes of rice. The available relevant reviews that are related to the effect of nitrogen and phosphorus on the yield attributes, yield, nutrient concentration in grain & straw of rice and nutrient status of post harvest soil are reviewed below-

2.1 Nitrogen fertilizer on yield contributing characters and yield of rice

Of the 16 essential nutrient elements nitrogen is the major and primary elements for the growth and development and better yield of crops. Plants response best to nitrogen compared to other nutrient elements. Urea has been found to be very effective nitrogenous fertilizers. Nitrogen is play pivotal role at yield and yield attributes of rice.

BRRI (1992) reported that both grain and straw yields of rice were increased significantly up to 80 kg N ha^{-1}. Application of nitrogen from 120 to 160 kg nitrogen ha^{-1} significantly reduced the yield which was assumed to be due to excessive vegetative growth follower by lodging after flowering.

Ahmed and Hossain (1992) observed that plant height of wheat were 7939, 82.3 and 84.4 cm with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height increased with increasing nitrogen doses.

Awasthi and Bhan (1993) reported that increasing levels of nitrogen up to 60 kg ha^{-1} influenced LAI and dry matter production of rice. Patel and Upadhaya (1993) found that plant height of rice increased significantly with increasing rate of N up to 150 kg ha^{-1}.

Kumar *et al.* (1995) conducted a field experiment with four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that productive tillers increased significantly with the increase of N doses from 0-120 kg N ha^{-1}, but differences in productive tillers between 120 and 180 kg N ha^{-1} and they were not statistically significant.

Effective tillers m^{-2} responded significantly to the application of N fertilizer (Behera, 1995). Effective tillers increased significantly with increase the level of N fertilizer up to 80 kg N ha^{-1}. Patel and Upadhyay (1993) conducted an experiment with 3 levels of N (90, 120 and 150 kg ha^{-1}) and reported that total and effective tillers m^{-2} increased significantly with increasing rates of N up to 120 kg ha^{-1}.

Andrade and Amorim (1996) observed that increasing level of applied N increased plant height, panicle m^{-2}, grains $panicle^{-1}$ and grain yield significantly. Palm *et al.* (1996) conducted a field trial at Waraseoni in the 1989-90 rainy season and observed that yield of rice cv. R. 269 was the highest (4.47 t ha^{-1}) when 100 kg N ha^{-1} was applied 30% basally, 40% at tillering and 30% at panicle initiation stage.

Khanda and Dixit (1996) reported that the increased levels of applied nitrogen significantly influenced the grain yields. They found that maximum grain and straw yields of 4.58 and 6.21 t ha^{-1} were obtained from 90 kg N ha^{-1}, respectively.

Adhikary and Rhaman (1996) reported that rice grain yield ha^{-1} in various treatments of N showed significant effect. The highest yield was obtained from 100 kg N ha^{-1} (4.52 t ha^{-1}) followed by 120 kg N ha^{-1} (4.46 t ha^{-1}) and 80 kg N ha^{-1} (4.40 t ha^{-1}).

Verma and Achraya (1996) observed that LAI increased significantly at maximum tillering and flowering stages with increasing levels of nitrogen. BINA (1996) stated that the effect of different levels of nitrogen was significant only for number of tillers $hill^{-1}$, effective tillers $hill^{-1}$, straw yield and crop duration. The highest number of total and productive tillers hill^{-1} was obtained from the highest level (120 kg ha^{-1}) of N application.

Dwivedi (1997) noticed that application of nitrogen significantly increased in growth, yield and yield components, grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}. BRRI (1997) reported during *boro* and transplant *aman* to determined rice seed yield. The experiment was laid out with four nitrogen levels 0, 50, 100 and 150 kg ha^{-1} and noted that seed yield increased gradually with the gradual increase of nitrogen.

Islam and Bhuiya (1997) studied the effect of nitrogen and phosphorus on the growth, yield and nutrient uptake of deep-water rice and observed that nitrogen and phosphorus fertilization significantly increased the number of fertile tiller m^{-2} and also that of grains panicle^{-1}, which in turn resulted in significant increase in grain yield. The application of 60 kg N ha^{-1} alone gave 22% yield benefit over control.

Singh *et al.* (1998) studied the performance of three hybrids KHR 1, Pro Agro 103 and MGR 1 using Jaya and Rasi as standard checks at four levels of N (0, 60, 120, and 180 kg ha^{-1}). They observed that the varieties responded linearly to the applied N level up to 120 kg ha^{-1}.

Kumar and Sharma (1999) conducted a field experiment with 4 levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) and observed that dry matter accumulation in rice increased from 0-40 kg N ha^{-1} at 40 DAS, 0-120 kg N ha^{-1} at 60 DAS, 0-80 kg ha^{-1} at 80 DAS. Nitrogen application also hastened the growth and resulted in higher percentage of total dry matter accumulation in early stage of crop growth.

Bellido *et al*. (2000) evaluate a field experiment with 4 levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and reported that the amount of total dry matter was significantly greater at the N fertilizer rates of 100 and 150 kg nitrogen ha^{-1}.

BRRI (2000) reported that the grain yield was linearly increased with increasing nitrogen rates. Chopra and Chopra (2000) cited that seed yield increased linearly up to 80 kg N ha^{-1}. Castro and Sarker (2000) conducted field experiment to see the effects of N applications as basal (80, 60, and 45kg N ha^{-1}) and top dressing (10, 30 and 45 kg ha^{-1}) on the yield and yield components of Japonica rice and obtained high effective tiller, percentage of ripened grains and high grain yields from 45 kg N ha^{-1} (basal) and 45 kg N ha^{-1} (top dressing). Singh *et al.* (2000) stated that each increment dose of N significantly increased grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield (2647 kg ha^{-1}).

Pully *et al*. (2000) observed that increased yield associated with application of nitrogen stage, although booting stage nitrogen application had no effect or shoot growth or nitrogen uptake. These preliminary results suggested a single application of nitrogen is sufficient to maintain healthy rice growth, alleviating the need for additional N application after flooding. Rice may be responded to N applied as late as booting, but only when the rice is N limited and not severely N stressed. Geethdevi *et al*. (2000) found that 120 kg N ha^{-1} in the form of urea, 50% nitrogen was applied in four splits resulted in higher number of tillers, filled grains $panicle^{-1}$ and higher grain weight $hill^{-1}$.

Munnujan *et al*. (2001) treated 4 levels of nitrogen fertilizer (0, 40, 80, and 160 kg ha^{-1}) application at three levels each planting density (20, 40 and 80 hill m^{-1}) and conducted that the highest grain yield (3.8 t ha^{-1}) was obtained with 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

Sarker *et al.* (2001) obtained the nitrogen responses of a Japonica (Yumelvitachi) and an Indica (Takanari) rice variety with different nitrogen levels viz. 0, 40, 80, and 120 kg N ha^{-1}. They observed that application of nitrogen increased grain and straw yields significantly but harvest index was not increased significant.

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October to determine the best split application of 150 kg N ha^{-1} for rice cv. IR20. Data from the experiment revealed that that applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the highest grain (6189.4 kg ha^{-1}) and straw (8649.6 kg ha^{-1}) yields, response ratio (23.40) and agronomic efficiency (41.26).

Bayan and Kandasamy (2002) noticed that the application of recommended doses of nitrogen in four splits at 10 days after sowing active tillering, panicle initiation and at heading stages recorded significantly lower dry weight of weeds and increased crop growth viz. effective tillers m^{-2}.

Duhan and Singh (2002) conducted a field experiment and reported that the rice yield and uptake of nutrients increased significantly with increasing N levels. Moreover, the application along with various green manures (GM) showed additive effect on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg ha^{-1} than with lower level of nitrogen.

Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest number of panicle, number of grains $panicle^{-1}$, 1000-grain weight, straw yield and harvest index. Shrirame *et al.* (2000) conducted an experiment during the kharif 1996 in Nagpur, Maharastra, India on rice cv. TNRH-10, TNRH-13 and TNRH-18 were grown at 1, 2, and 3 seedlings $hill^{-1}$ one seedling $hill^{-1}$ showed significantly higher harvest index.

2.2 Phosphorus fertilizer on yield contributing characters and yield of rice

Hassan *et al.* (1993) carried out an experiment and observed the yield response of Basmati 385 rice to 0, 33, 66 and 99 kg/ha P. All treatments received 128-62-4.2 kg NKZn/ha. They observed that yield increased significantly up to 33 kg P/ha for all soil P test values, but significant response to the next higher dose was observed only when test values were less than or equal to 11 mg P/kg.

Subba *et al.* (1995) reported that phosphorus applied @50 mg P/kg soil as SSP increased the grain and straw yields significantly. Chen and Fan (1997) conducted a field experiment at Rice Research Institute of Yannan Agricultural University, Kunming on soils low in P and Zn using rice cultivars Xunza – 29, Hexi – 35 and Yungeng – 34 as test crop with 0, or 5 kg Zn/ha and 60, 150, or 200 kg P/ha and found that application of Zn and P significantly increased yield especially.

Ghosal *et al*. (1998) conducted a field experiment in Bihar on rice cv. Pankaj with 10–40 kg P/ha as triple super phosphate (TSP), highly reactive Morocco Rock Phosphate (HRMRP), Florida Rock Phosphate (FRP) and stated that yield increased with increasing P rates of four sources. They further proposed that grain yield was the highest with TSP followed by PAPR, HRMRP and FRP.

Sarkunan *et al*. (1998) conducted a pot experiment to find out the effect of P and S on yield of rice under flooded condition, on a P and S deficient sandy loam soil. They found increased yield with increasing level of P from 16.9 to 42.5 g/pot. Sulphur addition at 25 mg/kg resulted in 9% increase in grain yield. The treatment combination of 100 mg P and 10 mg S/kg soil gave significantly higher grain yield than other treatments.

Sahrawat *et al*. (2001) conducted a field experiment for six years (1993-1998) to determine the response of four promising upland rice cultivars with 0, 45, 90, 135, and 180 kg/ha as triple super phosphate (TSP). Only once used in 1993 and its residual value in 1994, 1995, 1996 and 1998 stated that grain yields of the rice cultivars were significantly increased by fertilizer P in 1993 and by the fertilizer P residues in the subsequent years although the magnitude of response decreased rapidly with time since the fertilizer was not applied.

Nair and Rajasree (2004) conducted a field experiment to assess comparative efficiency of super phosphate and PR (34/74) at different levels in the yield characters and composition of rice. The treatments were 30 and 45 kg P_2O_5 ha^{-1} in the form of superphosphate and PR (34/74) with and without organic matter (6 t ha^{-1}), green manure (10 t ha^{-1}) and iron pyrites (10% by weight). The results showed that high grade phosphate rock (M, 34/74) with organic manure performed well and were followed by PR (34/74) with iron pyrites and green manure. Thus, PR (34/74) performed well with organic matter, FeS_2 and green manure in deciding growth and yield of rice. Higher contents of N, P, K, Ca and Mg of grain and straw were obtained at higher levels of 45 kg P_2O_5 ha^{-1} treatment.

Moula (2005) conducted an experiment on T. aman rice with different phosphorus rates. He found that when four treatments (P_0, 60 kg ha^{-1} phosphate rock, 60 kg ha^{-1} TSP and 210 kg ha^{-1} phosphate rock) were applied, 210 kg phosphate rock (PR) showed better performance on yield contributing characters and nutrient content as well as nutrient uptake by rice over other treatments.

Das and Sinha (2006) conducted a field experiment on sandy loam soil during the kharif season to study the effects of the integrated use of organic manures and various rates of N (urea) on the growth and yield of rice cv. IR 68. Among the different sources of organic amendments, farmyard manure (FYM; 10 t ha^{-1}) was superior, followed by the incorporation of wheat straw (5 t ha^{-1}) along with the combined application of phosphates rock (40 kg P_2O_5 ha^{-1}) and N. Grain and straw yields were highest when FYM was applied with 90 kg N ha^{-1}, although this treatment was comparable with combined application of wheat straw, phosphate rock and 90 kg N ha^{-1}.

Li *et al.* (2007) conducted an experiment to evaluate the contributions of rice root morphology and phosphorus uptake kinetics to P uptake by rice from iron phosphates. The Fe-P treatment significantly decreased plant dry weight, P uptake per plant, and P concentration in plant dry matter of all cultivars in comparison with the control plants.

Dunn and Stevens (2008) conducted a field experiment to evaluate the effect of polymer coating of phosphate fertilizer on rice yield. Three rates of phosphate fertilizer, including polymer coated and non coated, were compared to an untreated check. Net return was calculated based on crop price and input costs. At the rate of 25 lb/acre P_2O_5 rate the polymer coated treatments produced greater yields than equivalent non coated treatments.

Islam *et al*. (2010) conducted a field experiment with five phosphorus rates (0, 5, 10, 20 and 30 kg P ha^{-1}) with four rice genotypes in Boro and T. Aman season. Phosphorus rates did not influence grain yield irrespective of varieties in T. aman season while in Boro season P response was observed among the P rates. Application of P @ 10 kg ha^{-1} significantly increased the grain yield. But when P was applied @ 20 and 30 kg P ha^{-1}, the grain yield difference was not significant. The optimum and economic rate of P for T. Aman was 20 kg P ha^{-1} but in Boro rice the optimum and economic doses of P were 22 and 30 kg ha^{-1}, respectively. Hybrid entries (EH_1 and EH_2) used P more efficiently than inbred varieties. A negative P balance was observed up to 10 kg P ha^{-1}.

Tang *et al*. (2011) conducted a field experiment on winter wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) crop rotations in Southwest China to investigate phosphorus (P) fertilizer utilization efficiency, including the partial factor productivity (PFP), agronomic efficiency (AE), internal efficiency (IE), partial P balance (PPB), recovery efficiency (RE) and the mass (input–output) balance. This study suggests that, in order to achieve higher crop yields, the P fertilizer utilization efficiency should be considered when making P fertilizer recommendations in wheat–rice cropping systems.

2.3 Soil fertility and properties for application of fertilizers

Organic materials are widely used to maintain soil fertility and improve soil properties in intensive cropping systems especially in traditional agriculture. Total N, exch. K and available P in soil increased by green manuring. The application of FYM increased organic C, total N, available P, Exchangeable K and CEC than GM (IRRI, 1979). Application of NPK at 100-150% based on the initial soil test showed appreciable improvement in available soil N, P, and K. Organic C content was highest under FYM treatment. Depletion of P was highest under 100% treatment and K under 100% N and P treatment (Singh and Nambiar, 1984).

Bair (1990) stated that sustainable production of crop can not be maintained by using chemical fertilizers only and similarly it is not possible to obtain higher crop yield by using organic manure alone. Sustainable crop production might be possible through the integrated use of organic manure and chemical fertilizers.

Prasad and Kerketta (1991) conducted an experiment to assess the soil fertility, crop production and nutrient removal for cropping sequences in the presence of recommended doses of fertilizers and cultural practices along with 5 t ha^{-1} compost applied to the crops. There was an overall increase in organic C, increase in total N (83.9%), available N (69.9%), available P (117.3%) and CEC (37.7%).

Bhandari *et al*. (1992) reported that an application of fertilizers or their combined use with organic manure increased the organic C status of soil. The NPK fertilizers at 100% level and their combined use with organic N also increased the available N and P by 5.22 kg and 0.8-3.8 kg ha^{-1} from their initial values.

Meelu *et al.* (1992) reported that organic C and total N increased significantly when *Sesbania* and *Crotolaria* were applied in the preceded rice crop for two wet seasons. Medhi *et al*. (1996) reported that incorporation of organic and inorganic sources of N increased soil solution NH_4-N to a peak and then declined to very low levels.

Nahar *et al*. (1995) had examined the soil condition after one crop cycle (rice wheat). Addition of organic matter during the rice crop doubled the organic C content compared to its original status. Total and available N contents were also significantly improved by addition of organic matter, but had less impact on soil exchangeable cations.

Palm *et al.* (1996) stated that organic materials influence nutrient availability nutrients added through mineralization – immobilization pattern as energy sources for microbial activities and as precursors to soil organic matter and by reducing P sorption of the soil.

Nimbiar (1997) views that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining healthy soil fertility status. Intensive crop production systems have witnessed serious problems associated with loss of soil fertility as a result of excessive soil mining of plant nutrients and consequently reduction in productivity. Application of external source of plant nutrients is a key element in optimal management of soil organic matter, crop residues and manure for ensuring the bio-availability, the cycling and the balance of nutrients in the soil - plant systems.

Mathew and Nair (1997) reported that cattle manure when applied alone or in combination with chemical fertilizer (NPK) increased the organic C content, total N, available P and K in rice soils. Sarker and Singh (1997) reported that organic fertilizers when applied alone or in combination with inorganic fertilizers increase the level of organic carbon in soil as well as the total N, P and K contents of soil.

Xu *et al.* (1997) observed that application of organic matters affect soil pH value as well as nutrient level.

Santhi *et al*. (1999) observed that application of 100% NPK plus FYM decreased the bulk density and increased the water holding capacity of soil. The decreased in bulk density in FYM treated plots might be ascribed to better aggregation. The water holding capacity was increased due to the improvement in structural condition of soil that was brought about mainly by the application of FYM in combination with NPK fertilizers.

Hemalatha *et al.* (2000) revealed that green manure significantly increased the soil fertility status, organic carbon, available soil N, P and K at post harvest soil. Zaman *et al.* (2000) reported that chemical properties like organic matter content CEC, total N, exchangeable K, available P and S were favorably influenced by the application of organic sources of nitrogen and potassium while the organic sources mostly did not show positive effect. Soil pH decreased slightly compared to the initial status.

The literature review discussed above indicates that nitrogen and phosphorus fertilizer greatly influence the yield contributing characters and yield of rice. The properties of soils are also influenced by the inclusion of nitrogen and phosphorus fertilizer.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July to November, 2013 to study the effect of nitrogen and phosphorus on the growth and yield of BRRI dhan38. 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 clay loam soil at the Sher-e-Bangla Agricultural University Farm, Dhaka. The morphological, physical and chemical characteristics of the soil are shown in the Table 1 and 2.

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 July to November 2013 have been presented in Appendix I.

3.3 Planting material

BRRI dhan38 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between Bashmoti (D) and BR5 in 1998. It is recommended for *Aman* season. Average plant height of the variety is around 125 cm at the ripening stage. The grains are long slender, fine and aromatic. It requires about 140 days completing its life cycle with an average grain yield of 3.5 t ha^{-1} (BRRI, 2013).

Table 1. Morphological characteristics of the experimental field

Morphology	Characteristics
Locality	SAU farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

Table 2. Initial physical and chemical characteristics of the soil (0-15 cm depth)

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	18.60
% Silt (0.02-0.002 mm)	45.40
% Clay (<0.002 mm)	36.00
Textural class	Silty Loam
Consistency	Granular and friable when dry
pH (1: 2.5 soil- water)	5.8
CEC (cmol/kg)	17.9
Organic C (%)	0.686
Organic Matter (%)	1.187
Total N (%)	0.06
Exchangeable K (mol kg^{-1})	0.12
Available P (mg kg^{-1})	19.85
Available S (mg kg^{-1})	14.40

3.4 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from three 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.

3.5 Treatment of the experiment

The experiment comprised of two factors

Factor A: Levels of nitrogen (4 levels)

i) N_0: 0 kg N ha^{-1} i.e. control

ii) N_1: 45 kg N ha^{-1}

iii) N_2: 55 kg N ha^{-1}

iv) N_3: 65 kg N ha^{-1}

Factors B: Levels of phosphorous (3 levels)

i) P_0: 0 kg P_2O_5 ha^{-1} i.e. control

ii) P_1: 25 kg P_2O_5 ha^{-1}

iii) P_2: 35 kg P_2O_5 ha^{-1}

There were in total 12 (4×3) treatment combinations such as N_0P_0, N_0P_1, N_0P_2, N_1P_0, N_1P_1, N_1P_2, N_2P_0, N_2P_1, N_2P_2, N_3P_0, N_3P_1 and N_3P_2.

3.6 Land preparation

The land was first opened on 03 July, 2013 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 seedling transplanting.

3.7 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into twelve unit plots as treatments combinations with raised bunds around. Thus the total numbers of plots were 36. The unit plot size was 3.0 m × 1.5 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 Figure 1.

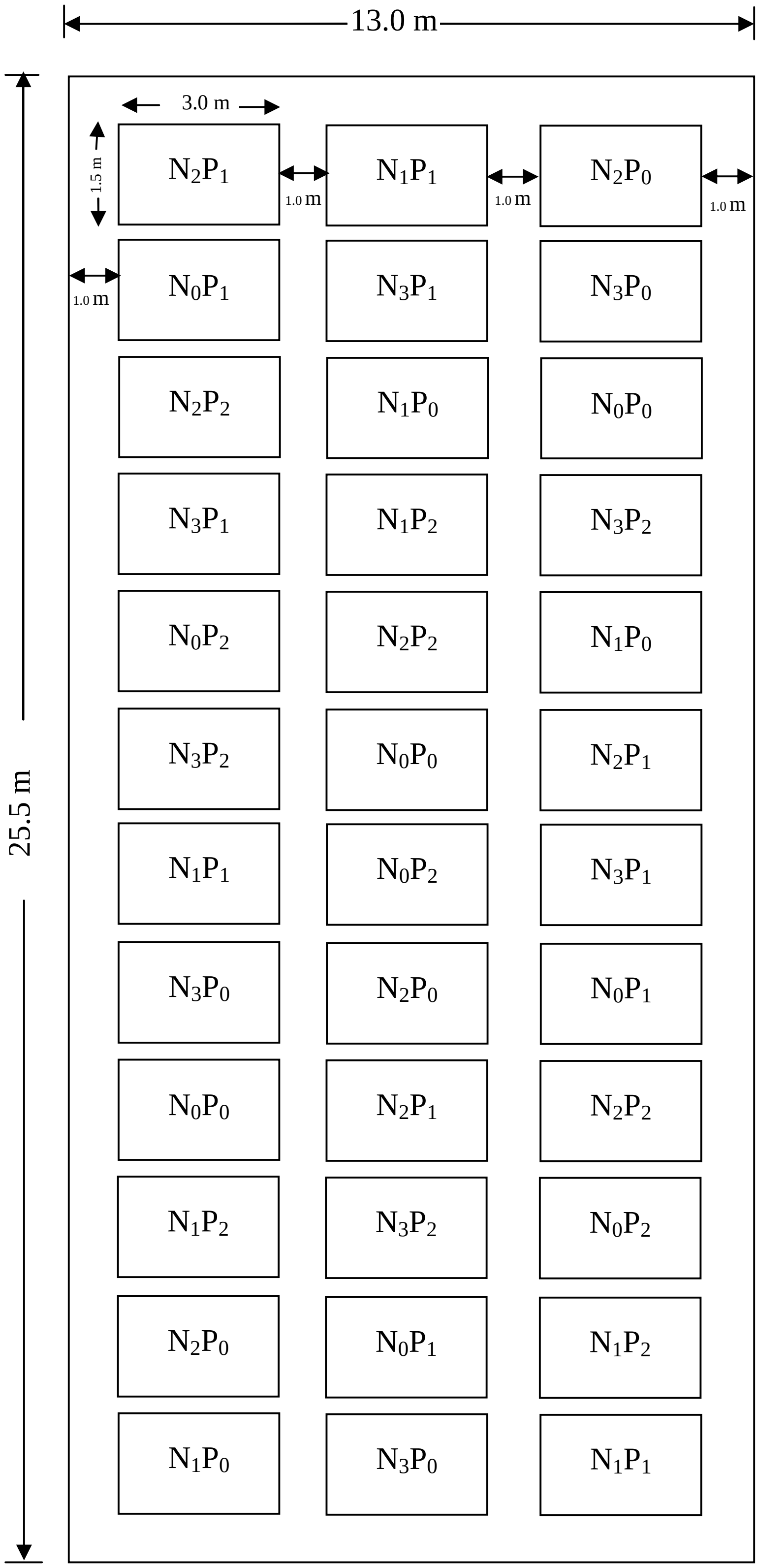
3.8 Fertilizer application

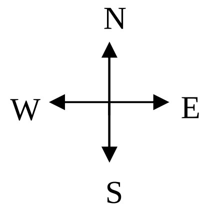
The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, Gypsum, zinc sulphate and borax, respectively were applied. The one third amount of urea and entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final preparation of land. Rest urea was applied in two equal installments at tillering and panicle initiation stages. The dose and method of application of fertilizers are presented in Table 3.

Table 3. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (ha^{-1})	Application (%)		
		Basal	1st installment	2nd installment
Cowdung	5 ton	100	--	--
Urea	As per treatment	33.33	33.33	33.33
TSP	As per treatment	100	--	--
MoP	120 kg	100	--	--
Gypsum	30 kg	100	--	--
Zinc sulphate	2.0 kg	100		
Borax	10 kg	100	--	--

Source: BRRI, 2013 (Adunik Dhaner Chash)





Plot size: 3.0 m × 1.5 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Levels of nitrogen (4 levels)

N_0: 0 kg N ha^{-1} i.e. control

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

Factors B: Levels of phosphorous (3 levels)

P_0: 0 kg P_2O_5 ha^{-1} i.e. control

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Figure 1. Layout of the experimental plot

3.9 Raising of seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 50 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.

3.10 Transplanting

Thirty days old seedlings of BRRI dhan38 were carefully uprooted from the seedling nursery and transplanted on 10 August, 2013 in well puddled plot. Two seedlings per hill 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.

3.11 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.

3.11.1 Irrigation

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

3.11.2 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.

3.11.3 Insect and pest control

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

3.12 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on 24 November, 2013. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor.

3.13 Collected data on yield components

3.13.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 45, 60, 75 days 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.

3.13.2 Effective tiller hill^{-1}

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

3.13.3 Non-effective tiller hill^{-1}

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

3.13.4 Total tiller hill^{-1}

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

3.13.5 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.

3.13.6 Filled grain 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 grain panicle^{-1} was recorded.

3.13.7 Unfilled grain 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 grain panicle^{-1} was recorded.

3.13.8 Total grain 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 grain panicle^{-1} was recorded.

3.13.9 Weight of 1000 seeds

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

3.13.10 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 t ha^{-1}.

3.13.11 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 t ha^{-1}.

3.13.12 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.

3.13.13 Harvest index

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

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

3.14 Chemical analysis of grain and straw samples

3.14.1 Collection of grain and straw samples

Grain and straw samples were collected after threshing. The samples were finely ground by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S.

3.14.2 Preparation of samples

The grain and straw samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine to pass through a 20-mesh sieve. The grain and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows:

3.14.3 Digestion of plant 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^{0}C and added 2.5 ml 30% H_2O_2 then heated was continued at 180^{0}C 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 indicator solution with 0.01N H_2SO_4.

3.14.4 Digestion of 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 and S were determined from this digest.

3.14.5 Determination of P, K, S and Zn from grain and straw samples

3.14.5.1 Phosphorus

Phosphorus was digested from the plant sample (grain and straw) with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.14.5.2 Potassium

Five milli-liter of digest sample for the grain and 10 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbance was measured by atomic absorption flame photometer.

3.14.5.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) with $CaCl_2$ (0.15%) solution as described by (Page *et al*., 1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.14.5.4 Zinc

Zinc content was determined from the digest of the grain and straw 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).

3.15 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.16 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P and exchangeable K contents. The soil samples were analyzed by the following standard methods as follows:

3.16.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.16.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.16.3 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% \text{ N} = (\text{T-B}) \times \text{N} \times 0.014 \times 100/\text{S}$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.16.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.16.5 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al.*, 1982).

3.17 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield contributing characters, yield and soil properties of BRRI dhan38. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was 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 nitrogen and phosphorus on the growth and yield of BRRI dhan38. The analyses of variance (ANOVA) of the data on different growth, yield parameters, yield nutrient concentration in grain and straw and nutrient status of post harvest soil are presented in Appendix II-VII. 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 dhan38 due to different levels of nitrogen at 30, 45, 60, 75 days after transplanting (DAT) and at harvest (Appendix II). Data revealed that at 30, 45, 60, 75 DAT and harvest, the tallest plant (30.96, 62.00, 84.70, 113.51 and 130.08 cm, respectively) was recorded from N_2 (55 kg N ha^{-1}) which were statistically similar (30.09, 60.90, 83.38, 110.70 and 128.18 cm, respectively) with N_3 (65 kg N ha^{-1}) and closely followed (29.78, 57.59, 79.97, 108.84 and 124.46 cm, respectively) by N_1 (45 kg N ha^{-1}), whereas the shortest plant (25.84, 52.60, 73.58, 103.46 and 115.28 cm, respectively) was found from N_0 i.e. control condition (Figure 2). It was revealed that with the increase of nitrogen fertilizer, plant height increased upto a certain level then decreases. Optimum nitrogen (N) is essential for vegetative growth but excess N may cause excessive vegetative growth, prolong the growth duration and delay crop maturity with reduction in grain yield. BRRI (1992) reported that application of nitrogen from 120 to 160 kg ha^{-1} was assumed to be due to excessive vegetative growth follower by lodging after flowering. Andrade and Amorim (1996) observed that increasing level of N increased plant height. Patel and Upadhaya (1993) found that plant height of rice increased significantly with increasing rate of urea up to 150 kg ha^{-1}.

Plant height of BRRI dhan38 varied significantly for different levels of phosphorus at 30, 45, 60, 75 DAT and harvest (Appendix II). At 30, 45, 60, 75 DAT and harvest, the tallest plant (30.46, 60.73, 82.89, 111.97 and 127.74 cm, respectively) were observed from P_2 (35 kg P_2O_5 ha^{-1}), which were statistically identical (30.13, 59.56, 82.38, 111.97, 127.74 cm, respectively) with P_1 (25 kg P_2O_5 ha^{-1}). On the other hand, the shortest plant (26.91, 54.53, 75.96, 103.96 and 118.47 cm, respectively) were observed from P_0 (0 kg P_2O_5 ha^{-1}) (Figure 3). It revealed that with the increase of application of phosphorus plant height showed increasing trend but after a certain level plant height increases very slowly.

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on plant height of BRRI dhan38 at 30, 45, 60, 75 DAT and harvest (Appendix II). At 30, 45, 60, 75 DAT and harvest, the tallest plant (33.77, 66.31, 91.27, 120.39 and 139.05 cm, respectively) were observed from N_2P_2 (55 kg N ha^{-1} and 35 kg P_2O_5 ha^{-1}) whereas, the shortest plant (23.12, 49.27, 70.90, 100.53 and 107.75 cm, respectively) were recorded at 30, 45, 60, 75 DAT and harvest, respectively from N_0P_0 (0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}) (Table 4).

4.1.2 Number of effective tillers $hill^{-1}$

Number of effective tillers $hill^{-1}$ of BRRI dhan38 showed statistically significant variation due to different levels of nitrogen (Appendix III). The maximum number of effective tillers $hill^{-1}$ (12.60) was found from N_2 which were statistically similar (12.47) with N_3 and closely followed (11.76) by N_1, while the minimum number of effective tillers $hill^{-1}$ (8.98) was recorded from N_0 i.e. control condition (Table 5). BINA (1996) stated that the effect of different levels of nitrogen was significant for number of effective tillers $hill^{-1}$.

Different levels of phosphorous varied significantly in terms of number of effective tillers $hill^{-1}$ of BRRI dhan38 (Appendix III). The maximum number of effective tillers $hill^{-1}$ (12.37) was obtained from P_2, which were statistically identical (12.13) with P_1 and the minimum number of effective tillers $hill^{-1}$ (9.85) was observed from P_0 i.e. control condition (Table 5).

Table 4. Interaction effect of different levels of nitrogen and phosphorous on plant height of BRRI dhan38

Treatment	Plant height (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
N_0P_0	23.12 f	49.27 f	70.90 e	100.53 c	107.75 i
N_0P_1	27.28 e	53.07 ef	75.07 de	104.23 c	118.16 h
N_0P_2	27.12 e	55.46 de	74.77 de	105.61 c	119.93 g
N_1P_0	28.43 de	54.97 def	77.01 cde	105.21 c	122.29 f
N_1P_1	30.28 bcd	58.13 cde	80.97 bcd	110.98 abc	126.63 d
N_1P_2	30.62 bc	59.66 bcd	81.94 bcd	110.33 abc	124.46 e
N_2P_0	27.26 e	54.94 def	75.62 de	101.39 c	116.99 h
N_2P_1	31.86 b	64.76 ab	87.21 ab	118.76 ab	134.20 b
N_2P_2	33.77 a	66.31 a	91.27 a	120.39 a	139.05 a
N_3P_0	28.82 cde	58.94 b-d	80.32 bcd	108.72 bc	126.83 d
N_3P_1	31.12 b	62.28 abc	86.25 ab	111.83 abc	130.18 c
N_3P_2	30.32 bcd	61.48 abc	83.57 bc	111.54 abc	127.53 d
$LSD_{(0.05)}$	1.913	5.413	6.934	9.812	1.191
Significance level	0.05	0.05	0.05	0.05	0.01
CV(%)	5.87	6.58	5.98	7.75	4.65

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Table 5. Effect of different levels of nitrogen and phosphorous on number of effective & non-effective tillers hill^{-1}, filled & unfilled grains panicle^{-1} and length of panicle of BRRI dhan38

Treatment	Number of effective tiller hill^{-1}	Number of non effective tiller hill^{-1}	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}	Length of panicle (cm)
Levels of nitrogen					
N_0	8.98 c	3.09 a	72.09 b	8.74 a	19.57 b
N_1	11.76 b	3.07 a	84.31 a	5.99 b	21.11 a
N_2	12.60 a	2.27 b	85.66 a	4.91 c	22.05 a
N_3	12.47 a	3.16 a	83.44 a	6.19 b	21.68 a
$LSD_{(0.05)}$	0.688	0.285	5.416	0.376	1.133
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of phosphorous					
P_0	9.85 b	2.67 b	70.97 b	8.15 a	18.76 b
P_1	12.13 a	2.90 ab	85.51 a	5.44 c	21.84 a
P_2	12.37 a	3.12 a	87.64 a	5.78 b	22.70 a
$LSD_{(0.05)}$	0.596	0.247	4.690	0.326	0.981
Significance level	0.01	0.01	0.01	0.01	0.01
CV(%)	6.15	10.06	6.81	5.96	5.49

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on number of effective tillers hill^{-1} of BRRI dhan38 (Appendix III). The maximum number of effective tillers hill^{-1} (13.87) was attained from N_2P_2, while the minimum number of effective tillers hill^{-1} (8.27) was found from N_0P_0 i.e. control condition (Table 6).

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 dhan38 due to different levels of nitrogen (Appendix III). The maximum number of non-effective tillers hill^{-1} (3.16) was found from N_3 which were statistically similar (3.09 and 3.07) with N_0 and N_1, while the minimum number of non-effective tillers hill^{-1} (2.27) was recorded from N_2 (Table 5).

Number of non-effective tillers hill^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The maximum number of non-effective tillers hill^{-1} (3.12) was recorded from P_2, which were statistically identical (2.90) with P_1, whereas the minimum number of non-effective tillers hill^{-1} (2.67) was found from P_0 i.e. control condition (Table 5).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on number of non-effective tillers hill^{-1} of BRRI dhan38 (Appendix III). The maximum number of non-effective tillers hill^{-1} (3.73) was observed from N_0P_2, while the minimum number of non-effective tillers hill^{-1} (2.13) was observed from N_2P_2 i.e. control condition (Table 6).

4.1.4 Number of total tillers hill^{-1}

Different levels of nitrogen showed statistically significant variation in terms of number of total tillers hill^{-1} of BRRI dhan38 (Appendix III). The maximum number of total tillers hill^{-1} (15.62) was attained from N_3 which were statistically similar (14.87 and 14.82) with N_2 and N_1. On the other hand, the minimum number of total tillers hill^{-1} (12.07) was observed from N_0 i.e. control condition (Figure 4). BINA (1996) stated that the effect of different levels of nitrogen was significant for number of tillers hill^{-1}.

Table 6. Interaction effect of different levels of nitrogen and phosphorous on number of effective & non-effective tillers hill^{-1}, filled & unfilled grains panicle^{-1} and length of panicle of BRRI dhan38

Treatment	Number of effective tiller hill^{-1}	Length of panicle (cm)	Number of non effective tiller hill^{-1}	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}
N_0P_0	8.27 e	16.99 e	2.60 cde	62.83 e	9.77 a
N_0P_1	9.07 de	20.49 cd	2.93 bc	71.03 de	7.90 b
N_0P_2	9.60 cd	21.22 cd	3.73 a	82.40 bc	8.57 b
N_1P_0	10.47 c	20.06 d	2.93 bc	75.63 cd	8.17 b
N_1P_1	12.40 b	20.79 cd	3.27 ab	88.13 ab	4.70 def
N_1P_2	12.40 b	22.48 bc	3.00 bc	89.17 ab	5.10 de
N_2P_0	10.33cd	17.91 e	2.33 de	70.00 de	6.10 c
N_2P_1	13.60 ab	23.64 ab	2.33 de	94.73 a	4.40 ef
N_2P_2	13.87 a	24.59 a	2.13 e	92.23ab	4.23 f
N_3P_0	10.33 cd	20.09 d	2.80 bcd	75.43 cd	8.57 b
N_3P_1	13.47 ab	22.45 bc	3.07 bc	88.13 ab	4.77 def
N_3P_2	13.60 ab	22.51 bc	3.60 a	86.77 ab	5.23 d
$LSD_{(0.05)}$	1.191	1.962	0.494	9.381	0.651
Significance level	0.05	0.05	0.01	0.05	0.05
CV(%)	6.15	5.49	10.06	6.81	5.96

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Statistically significant variation was observed in terms of number of total tillers hill^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The maximum number of total tillers hill^{-1} (15.48) was observed from P_2, which were statistically identical (15.03) with P_1 and the minimum number of total tillers hill^{-1} (12.52) was found from P_0 i.e. control condition (Figure 5).

Different levels of nitrogen and phosphorus showed significant variation due to their interaction effect of on number of total tillers hill^{-1} of BRRI dhan38 (Appendix III). The maximum number of total tillers hill^{-1} (17.20) was obtained from N_3P_2, while the minimum number of total tillers hill^{-1} (10.87) was found from N_0P_0 i.e. control condition (Figure 6).

4.1.5 Length of panicle

Statistically significant variation was recorded for number length of panicle of BRRI dhan38 due to different levels of nitrogen (Appendix III). The longest length of panicle (22.05 cm) was observed from N_2 which were statistically similar (21.68 cm and 21.11 cm) with N_3 and N_1, while the shortest length of panicle (19.57 cm) was found from N_0 i.e. control condition (Table 5). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest length of panicle.

Length of panicle of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The longest length of panicle (22.70 cm) was observed from P_2, which were statistically identical (21.84 cm) with P_1, whereas the shortest length of panicle (18.76 cm) was recorded from P_0 i.e. control condition (Table 5). Das and Sinha (2006) reported that 40 kg P_2O_5 ha^{-1} give the better performance in relation to length of panicle of rice.

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on length of panicle of BRRI dhan38 (Appendix III). The longest length of panicle (24.59 cm) was observed from N_2P_2 and the shortest length of panicle (16.99 cm) from N_0P_0 i.e. control condition (Table 6).

4.1.6 Number of filled grains panicle^{-1}

Statistically significant variation was recorded for number of filled grains panicle-^{1} of BRRI dhan38 due to different levels of nitrogen (Appendix III). The highest number of filled grains panicle^{-1} (85.66) was recorded from N_2 which were statistically similar (84.31 and 83.44) with N_1 and N_3. On the other hand, the lowest number of filled grains panicle^{-1} (72.09) was observed from N_0 i.e. control condition (Table 5).

Number of filled grains panicle^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The highest number of filled grains panicle^{-1} (87.64) was observed from P_2, which were statistically identical (85.51) with P_1, while the lowest number of filled grains panicle^{-1} (70.97) was observed from P_0 i.e. control condition (Table 5).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on number of filled grains panicle^{-1} of BRRI dhan38 (Appendix III). The highest number of filled grains panicle^{-1} (94.73) was observed from N_2P_1, whereas the lowest number of filled grains panicle^{-1} (62.83) was recorded from N_0P_0 i.e. control condition (Table 6).

4.1.7 Number of unfilled grains panicle^{-1}

Statistically significant variation was recorded for number of unfilled grains panicle-^{1} of BRRI dhan38 due to different levels of nitrogen (Appendix III). The highest number of unfilled grains panicle^{-1} (8.74) was observed from N_0 which were closely followed (6.19 and 5.99) by N_3 and N_1, whereas the lowest number of unfilled grains panicle^{-1} (4.91) from N_2 i.e. control condition (Table 5).

Number of unfilled grains panicle^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The highest number of unfilled grains panicle^{-1} (8.15) was obtained from P_0, which was followed (5.78) by P_2, while the lowest number of unfilled grains panicle^{-1} (5.44) from P_1 (Table 5).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on number of unfilled grains panicle^{-1} of BRRI dhan38 (Appendix III). The highest number of unfilled grains panicle^{-1} (9.77) was attained from N_0P_0 and the lowest number (4.23) from N_2P_2 (Table 6).

4.1.8 Number of total grains panicle^{-1}

Statistically significant variation was recorded for number of total grains panicle-^{1} of BRRI dhan38 due to different levels of nitrogen (Appendix III). The highest number of total grains panicle^{-1} (90.57) was recorded from N_2 which were statistically similar (90.30 and 89.63) with N_3 and N_1, while the lowest number of total grains panicle^{-1} (80.83) from N_0 i.e. control condition (Figure 7). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest number of grains panicle^{-1}.

Number of total grains panicle^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix III). The highest number of total grains panicle^{-1} (93.43) was observed from P_2, which were statistically identical (90.95) with P_1, whereas the lowest number of total grains panicle^{-1} (79.13) was observed from P_0 i.e. control condition (Figure 8). Das and Sinha (2006) reported that 40 kg P_2O_5 ha^{-1} give the better performance in relation to grains panicle^{-1} of rice.

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on number of total grains panicle^{-1} of BRRI dhan38 (Appendix III). The highest number of total grains panicle^{-1} (99.13) was observed from N_2P_1, while the lowest number of total grains panicle^{-1} (72.60) was recorded from N_0P_0 i.e. control condition (Figure 9).

4.1.9 Weight of 1000-grain

Statistically significant variation was recorded for weight of 1000- grains of BRRI dhan38 due to different levels of nitrogen (Appendix IV). The highest weight of 1000-grains (16.93 g) was observed from N_2 which were statistically similar (16.83 g and 16.18 g) with N_3 and N_1. On the other hand, the lowest weight of 1000-grains (14.82 g) was found from N_0 i.e. control condition (Table 7). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest 1000-grain weight.

Weight of 1000- grains of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix IV). The highest weight of 1000- grains (17.13 g) was recorded from P_2, which were statistically identical (16.45 g) with P_1, while the lowest weight of 1000-grains (15.00 g) was found from P_0 i.e. control condition (Table 7).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on weight of 1000- grains of BRRI dhan38 (Appendix IV). The highest number of unfilled grains $panicle^{-1}$ (18.35 g) was observed from N_2P_2 and the lowest weight of- grains (14.25 g) was recorded from N_0P_0 i.e. control condition (Table 8).

4.1.10 Grain yield ha^{-1}

Statistically significant variation was recorded for grain yield ha-^{1} of BRRI dhan38 due to different levels of nitrogen (Appendix IV). The highest grain yield (3.56 t ha^{-1}) was recorded from N_2 which were statistically similar (3.47 t ha^{-1}) with N_3 and closely followed (3.15 t ha^{-1}) by N_1, whereas the lowest grain yield (2.15 t ha^{-1}) was observed from N_0 i.e. control condition (Table 7). Dwibvedi (1997) noticed that application of nitrogen significantly increased in grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}. Adhikary and Rhaman (1996) reported that the highest yield obtained from 100 kg N ha^{-1} (4.52 t ha^{-1}) followed by 120 kg N ha^{-1} (4.46 t ha^{-1}) and 80 kg N ha^{-1} (4.40 t ha^{-1}).

Table 7. Effect of different levels of nitrogen and phosphorous on weight of 1000-grains, grain, straw, biological yield and harvest index of BRRI dhan38

Treatment	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Levels of nitrogen					
N_0	14.82 b	2.15 c	3.56 c	5.71 c	37.59 b
N_1	16.18 a	3.15 b	4.57 b	7.72 b	40.78 a
N_2	16.93 a	3.56 a	4.98 a	8.54 a	41.55 a
N_3	16.83 a	3.47 a	4.96 a	8.43 a	41.07 a
$LSD_{(0.05)}$	0.989	0.243	0.235	0.421	1.641
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of phosphorous					
P_0	15.00 b	2.81 b	4.22 b	7.03 b	39.75
P_1	16.45 a	3.18 a	4.64 a	7.82 a	40.35
P_2	17.13 a	3.25 a	4.69 a	7.94 a	40.63
$LSD_{(0.05)}$	0.856	0.211	0.204	0.364	--
Significance level	0.01	0.01	0.01	0.01	NS
CV(%)	6.25	8.11	5.33	5.66	4.17

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Table 8. Interaction effect of different levels of nitrogen and phosphorous on weight of 1000-grains, grain, straw, biological yield and harvest index of BRRI dhan38

Treatment	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0P_0	14.25 e	2.07 e	3.43 e	5.50 f	37.62 cd
N_0P_1	14.65 e	2.14 e	3.63 e	5.76 f	37.05 d
N_0P_2	15.57 cde	2.23 e	3.63 e	5.86 f	38.08 bcd
N_1P_0	15.45 de	2.96 cd	4.36 cd	7.31 de	40.47 abc
N_1P_1	15.93 b-e	3.21 bcd	4.61 bcd	7.82 cde	40.98 ab
N_1P_2	17.15 a-d	3.28 bcd	4.74 bc	8.03 cd	40.90 ab
N_2P_0	14.63 e	2.86 d	4.22 d	7.08 e	40.35 abc
N_2P_1	17.82 ab	3.87 a	5.33 a	9.20 ab	42.05 a
N_2P_2	18.35 a	3.95 a	5.39 a	9.34 a	42.24 a
N_3P_0	15.65 cde	3.37 bc	4.87 b	8.24 c	40.58 abc
N_3P_1	17.38 abc	3.51 ab	5.00 ab	8.52 bc	41.32 ab
N_3P_2	17.45 abc	3.52 ab	5.01 ab	8.53 bc	41.30 ab
$LSD_{(0.05)}$	1.713	0.422	0.408	0.728	2.842
Significance level	0.05	0.05	0.01	0.01	0.05
CV(%)	6.25	8.11	5.33	5.66	4.17

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Grain yield ha^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix IV). The highest grain yield (3.25 t ha^{-1}) was observed from P_2, which were statistically identical (3.18 t ha^{-1}) with P_1 and the lowest grain yield (2.81 t ha^{-1}) was observed from P_0 i.e. control condition (Table 7). Islam *et al*. (2010) reported that application of P @ 10 kg ha^{-1} significantly increased the grain yield but when P was applied @ 20 and 30 kg P ha^{-1}, the grain yield difference was not significant.

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on grain yield ha^{-1} of BRRI dhan38 (Appendix IV). The highest grain yield (3.95 t ha^{-1}) was observed from N_2P_2, whereas the lowest grain yield (2.07 t ha^{-1}) was recorded from N_0P_0 i.e. control condition (Table 8).

4.1.11 Straw yield ha^{-1}

Statistically significant variation was recorded for straw yield ha-[1] of BRRI dhan38 due to different levels of nitrogen (Appendix IV). The highest straw yield (4.98 t ha^{-1}) was observed from N_2 which were statistically similar (4.96 t ha^{-1}) with N_3 and closely followed (4.57 t ha^{-1}) by N_1, while the lowest straw yield (3.56 t ha^{-1}) was found from N_0 i.e. control condition (Table 7). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest straw yield.

Straw yield ha^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix IV). The highest straw yield (4.69 t ha^{-1}) was found from P_2, which were statistically identical (4.64 t ha^{-1}) with P_1 and the lowest straw yield (4.22 t ha^{-1}) was recorded from P_0 i.e. control condition (Table 7).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on straw yield ha^{-1} of BRRI dhan38 (Appendix IV). The highest straw yield (5.39 t ha^{-1}) was obtained from N_2P_2, whereas the lowest straw yield (3.43 t ha^{-1}) was recorded from N_0P_0 i.e. control condition (Table 8).

4.1.12 Biological yield ha^{-1}

Statistically significant variation was recorded for biological yield ha-^{1} of BRRI dhan38 due to different levels of nitrogen (Appendix IV). The highest biological yield (8.54 t ha^{-1}) was found from N_2 which were statistically similar (8.43 t ha^{-1}) with N_3 and closely followed (7.72 t ha^{-1}) by N_1. On the other hand, the lowest biological yield (5.71 t ha^{-1}) from N_0 i.e. control condition (Table 7).

Biological yield ha^{-1} of BRRI dhan38 varied significantly for different levels of phosphorous (Appendix IV). The highest biological yield (7.94 t ha^{-1}) was recorded from P_2, which were statistically identical (7.82 t ha^{-1}) with P_1, while the lowest biological yield (7.03 t ha^{-1}) was found from P_0 i.e. control condition (Table 7).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on biological yield ha^{-1} of BRRI dhan38 (Appendix IV). The highest biological yield (9.34 t ha^{-1}) was observed from N_2P_2, whereas the lowest biological yield (5.50 t ha^{-1}) from N_0P_0 i.e. control condition (Table 8).

4.1.13 Harvest index

Statistically significant variation was recorded for harvest index of BRRI dhan38 due to different levels of nitrogen (Appendix IV). The highest harvest index (41.55%) was recorded from N_2 which were statistically similar (41.07% and 40.78%) with N_3 and N_1, whereas the lowest harvest index (37.59%) was observed from N_0 i.e. control condition (Table 7). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest harvest index.

Harvest index of BRRI dhan38 varied non significantly for different levels of phosphorous (Appendix IV). The highest harvest index (40.63%) was observed from P_2 and the lowest harvest index (39.75%) was observed from P_0 i.e. control condition (Table 7).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on harvest index of BRRI dhan38 (Appendix IV). The highest grain yield

ha^{-1} (42.24%) was observed from N_2P_2, while the lowest number of unfilled grains $panicle^{-1}$ (37.05%) was recorded from N_0P_1 (Table 8).

4.2 N, P, K, S and Zn concentration in grain and straw

4.2.1 N, P, K, S and Zn concentration in grain

Statistically significant variation was recorded for N, P, K, S and Zn concentration in grain due to different levels of nitrogen (Appendix V). The highest N, P, K, S and Zn concentration in grain (0.743%, 0.287%, 0.364%, 0.167% and 0.0215%, respectively) was obtained from N_2, again the lowest N, P, K, S and Zn concentration in grain (0.484%, 0.230%, 0.237%, 0.108% and 0.0168%, respectively) was observed from N_0 i.e. control condition (Table 9).

N, P, K, S and Zn concentration in grain varied significantly for different levels of phosphorous (Appendix V). The highest N, P, K, S and Zn concentration in grain (0.716%, 0.272%, 0.350%, 0.160% and 0.0210%, respectively) was found from P_2, whereas the lowest N, P, K, S and Zn concentration in grain (0.602%, 0.229%, 0.275%, 0.126% and 0.0182%, respectively) from P_0 (Table 9).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on N, P, K, S and Zn concentration in grain (Appendix V). The highest N, P, K, S and Zn concentration in grain (0.804%, 0.330%, 0.418%, 0.192% and 0.0211%, respectively) was observed from N_2P_2 and the lowest N, P, K, S and Zn concentration in grain (0.451%, 0.214%, 0.223%, 0.101% and 0.0163%, respectively) was recorded from N_0P_0 i.e. control condition (Table 10).

4.2.2 N, P, K, S and Zn concentration in straw

Statistically significant variation was recorded for N, P, K, S and Zn concentration in straw due to different levels of nitrogen (Appendix VI). The highest N, P, K, S and Zn concentration in straw (0.475%, 0.064%, 1.22%, 0.079% and 0.0181%, respectively) was found from N_2, while the lowest N, P, K, S and Zn concentration in straw (0.400%, 0.045%, 1.00%, 0.068% and 0.0150%, respectively) was recorded from N_0 i.e. control condition (Table 11).

Table 9. Effect of different levels of nitrogen and phosphorous on N, P, K, S and Zn concentrations in grain of BRRI dhan38

Treatment	Concentration (%) in grain				
	N	P	K	S	Zn
Levels of nitrogen					
N_0	0.484 c	0.230 c	0.237 c	0.108 c	0.0168 b
N_1	0.665 b	0.253 bc	0.305 b	0.139 b	0.0193 ab
N_2	0.743 a	0.287 a	0.364 a	0.167 a	0.0215 a
N_3	0.716 a	0.272 ab	0.350 a	0.160 a	0.0210 a
$LSD_{(0.05)}$	0.031	0.031	0.031	0.010	0.003
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of phosphorous					
P_0	0.602 c	0.229 b	0.275 b	0.126 b	0.0182
P_1	0.654 b	0.271 a	0.326 a	0.149 a	0.0201
P_2	0.700 a	0.282 a	0.340 a	0.156 a	0.0206
$LSD_{(0.05)}$	0.027	0.027	0.027	0.008	--
Significance level	0.01	0.01	0.01	0.01	NS
CV(%)	4.79	9.08	10.29	10.47	6.17

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Table 10. Interaction effect of different levels of nitrogen and phosphorous on N, P, K, S and Zn concentrations in grain of BRRI dhan38

Treatment	Concentration (%) in grain				
	N	P	K	S	Zn
N_0P_0	0.451 f	0.214 d	0.223 f	0.101 f	0.0163 c
N_0P_1	0.485 ef	0.233 cd	0.237 f	0.107 ef	0.0167 c
N_0P_2	0.516 e	0.243 cd	0.252 f	0.115 ef	0.0173 bc
N_1P_0	0.613 d	0.244 cd	0.275 def	0.125 de	0.0182 abc
N_1P_1	0.662 cd	0.246 cd	0.311 cde	0.142 cd	0.0195 abc
N_1P_2	0.720 bc	0.269 bcd	0.328 cde	0.150 bc	0.0202 abc
N_2P_0	0.663 cd	0.217 d	0.271 ef	0.123 e	0.0180 abc
N_2P_1	0.762 ab	0.315 ab	0.403 ab	0.185 a	0.0230 ab
N_2P_2	0.804 a	0.330 a	0.418 a	0.192 a	0.0236 a
N_3P_0	0.680 c	0.242 cd	0.333 cd	0.152 bc	0.0204 abc
N_3P_1	0.708 bc	0.288 abc	0.354 bc	0.162 b	0.0211 abc
N_3P_2	0.759 ab	0.287 abc	0.362 bc	0.166 b	0.0215 abc
$LSD_{(0.05)}$	0.054	0.054	0.054	0.017	0.005
Significance level	0.05	0.05	0.05	0.05	0.05
CV(%)	4.79	9.08	10.29	10.47	6.17

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Table 11. Effect of different levels of nitrogen and phosphorous on N, P, K, S and Zn concentrations in straw of BRRI dhan38

Treatment	Concentration (%) in straw				
	N	P	K	S	Zn
Levels of nitrogen					
N_0	0.400 d	0.045 b	1.00 b	0.068 b	0.0150 c
N_1	0.428 c	0.055 a	1.18 a	0.074 ab	0.0168 b
N_2	0.475 a	0.064 a	1.22 a	0.079 a	0.0181 a
N_3	0.462 b	0.062 a	1.19 a	0.077 ab	0.0177 ab
$LSD_{(0.05)}$	0.010	0.010	0.054	0.010	0.001
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of phosphorous					
P_0	0.402 c	0.044 b	1.04 b	0.067 b	0.0158 b
P_1	0.452 b	0.062 a	1.18 a	0.078 a	0.0170 a
P_2	0.470 a	0.063 a	1.22 a	0.079 a	0.0179 a
$LSD_{(0.05)}$	0.008	0.008	0.046	0.008	0.001
Significance level	0.01	0.01	0.01	0.01	0.01
CV(%)	4.67	12.92	4.77	7.67	8.23

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

N_0: 0 kg N ha^{-1} (control)
N_1: 45 kg N ha^{-1}
N_2: 55 kg N ha^{-1}
N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)
P_1: 25 kg P_2O_5 ha^{-1}
P_2: 35 kg P_2O_5 ha^{-1}

N, P, K, S and Zn concentration in straw varied significantly for different levels of phosphorous (Appendix VI). The highest N, P, K, S and Zn concentration in straw (0.470%, 0.063%, 1.22%, 0.079% and 0.0179%, respectively) was found from P_2 and the lowest N, P, K, S and Zn concentration in straw (0.402%, 0.044%, 1.04%, 0.067% and 0.0158%, respectively) from P_0 i.e. control condition (Table 11).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on N, P, K, S and Zn concentration in straw (Appendix VI). The highest N, P, K, S and Zn concentration in straw (0.528%, 0.082%, 1.40%, 0.088% and 0.0204%, respectively) was recorded from N_2P_2, while the lowest N, P, K, S and Zn concentration in straw (0.386%, 0.036%, 0.98%, 0.059% and 0.0139%, respectively) was found from N_0P_0 i.e. control condition (Table 12).

4.3 pH, organic matter, total N, available P and exchangeable K in post harvest soil

4.3.1 pH

Statistically non significant variation was recorded for pH in post harvest soil due to different levels of nitrogen (Appendix VII). The highest pH (6.26) was observed from N_2, whereas the lowest pH (6.16) was found from N_0 i.e. control condition (Table 13).

Different levels of phosphorous varied non significantly in terms of pH (Appendix VII). The highest pH (6.29) was recorded from P_2, and the lowest pH (6.14) from P_0 i.e. control condition (Table 13).

Interaction effect of different levels of nitrogen and phosphorus showed non significant variation on pH (Appendix VII). The highest pH (6.34) was observed from N_2P_2, whereas the lowest pH (6.11) from N_0P_0 (Table 14).

4.3.2 Organic matter

Statistically non significant variation was recorded for organic matter in post harvest soil due to different levels of nitrogen (Appendix VII). The highest organic matter (1.27%) was found from N_2 and the lowest organic matter (1.20%) was recorded from N_0 i.e. control condition (Table 13).

Table 12. Interaction effect of different levels of nitrogen and phosphorous on N, P, K, S and Zn concentrations in straw of BRRI dhan38

Treatment	Concentration (%) in straw				
	N	P	K	S	Zn
N_0P_0	0.386 g	0.036 ef	0.98 g	0.059 b	0.0139 e
N_0P_1	0.397 g	0.049 def	0.99 g	0.069 ab	0.0150 de
N_0P_2	0.418 ef	0.048 def	1.02 fg	0.075 ab	0.0161 cd
N_1P_0	0.401 fg	0.053 c-f	1.10 ef	0.075 ab	0.0171 c
N_1P_1	0.427 e	0.053c-f	1.20 cd	0.072 ab	0.0162 cd
N_1P_2	0.455 d	0.058 bcd	1.25 bc	0.075 ab	0.0171 c
N_2P_0	0.387 g	0.035 f	0.94 g	0.063 b	0.0149 de
N_2P_1	0.509 b	0.075 ab	1.31 ab	0.087 a	0.0190 ab
N_2P_2	0.528 a	0.082 a	1.40 a	0.088 a	0.0204 a
N_3P_0	0.432 e	0.054 cde	1.15 de	0.072 ab	0.0172 c
N_3P_1	0.474 c	0.069 abc	1.23 bcd	0.084 a	0.0179 bc
N_3P_2	0.479 c	0.062 bcd	1.21 cd	0.076 ab	0.0179 bc
$LSD_{(0.05)}$	0.017	0.017	0.093	0.017	0.002
Significance level	0.01	0.01	0.01	0.01	0.05
CV(%)	4.67	12.92	4.77	7.67	8.23

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

N_0: 0 kg N ha^{-1} (control) P_0: 0 kg P_2O_5 ha^{-1} (control)

N_1: 45 kg N ha^{-1} P_1: 25 kg P_2O_5 ha^{-1}

N_2: 55 kg N ha^{-1} P_2: 35 kg P_2O_5 ha^{-1}

N_3: 65 kg N ha^{-1}

Table 13. Effect of different levels of nitrogen and phosphorous on pH, organic matter, total N, available P and exchangeable K of post harvest soil

Treatment	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)
Levels of nitrogen					
N_0	6.16	1.20	0.013 c	23.17 c	0.130 c
N_1	6.23	1.25	0.042 b	26.32 b	0.153 b
N_2	6.26	1.27	0.053 a	31.50 a	0.165 a
N_3	6.21	1.25	0.050 ab	28.11 b	0.163 ab
$LSD_{(0.05)}$	--	--	0.010	2.978	0.010
Significance level	NS	NS	0.01	0.01	0.01
Levels of phosphorous					
P_0	6.14	1.18	0.032 b	15.65 b	0.138 b
P_1	6.22	1.27	0.043 a	32.70 a	0.156 a
P_2	6.29	1.29	0.045 a	33.48 a	0.164 a
$LSD_{(0.05)}$	--	--	0.008	2.579	0.008
Significance level	NS	NS	0.01	0.01	0.01
CV(%)	4.73	8.53	15.56	11.17	6.45

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

N_0: 0 kg N ha^{-1} (control)
N_1: 45 kg N ha^{-1}
N_2: 55 kg N ha^{-1}
N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)
P_1: 25 kg P_2O_5 ha^{-1}
P_2: 35 kg P_2O_5 ha^{-1}

Table 14. Interaction effect of different levels of nitrogen and phosphorous on pH, organic matter, total N, available P and exchangeable K of post harvest soil

Treatment	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)
N_0P_0	6.11	1.15	0.008 e	15.03 d	0.123 f
N_0P_1	6.16	1.21	0.017 de	26.60 c	0.128 ef
N_0P_2	6.21	1.22	0.016 de	27.87 bc	0.138 def
N_1P_0	6.15	1.19	0.039 c	15.00 d	0.144 de
N_1P_1	6.21	1.26	0.043 bc	31.73 bc	0.151 bcd
N_1P_2	6.33	1.29	0.046 bc	32.23 b	0.164 abc
N_2P_0	6.12	1.17	0.033 cd	14.40 d	0.135 def
N_2P_1	6.32	1.31	0.059 ab	39.32 a	0.177 a
N_2P_2	6.34	1.34	0.067 a	40.78 a	0.183 a
N_3P_0	6.17	1.18	0.048 bc	18.17 d	0.150 cd
N_3P_1	6.18	1.28	0.052 abc	33.14 b	0.169 ab
N_3P_2	6.27	1.29	0.049 bc	33.04 b	0.170 ab
$LSD_{(0.05)}$	--	--	0.017	5.159	0.017
Significance level	NS	NS	0.01	0.01	0.05
CV(%)	4.73	8.53	15.56	11.17	6.45

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

N_0: 0 kg N ha^{-1} (control)

N_1: 45 kg N ha^{-1}

N_2: 55 kg N ha^{-1}

N_3: 65 kg N ha^{-1}

P_0: 0 kg P_2O_5 ha^{-1} (control)

P_1: 25 kg P_2O_5 ha^{-1}

P_2: 35 kg P_2O_5 ha^{-1}

Organic matter varied non significantly for different levels of phosphorous (Appendix VII). The highest organic matter (1.29%) was observed from P_1, which were statistically identical (1.18%) with P_2, whereas the lowest organic matter (1.31%) was found from P_0 i.e. control condition (Table 13).

Interaction effect of different levels of nitrogen and phosphorus showed non significant variation on organic matter (Appendix VII). The highest organic matter (1.34%) was observed from N_2P_2, while the lowest organic matter (1.15%) was recorded from N_0P_0 i.e. control condition (Table 14).

4.3.3 Total nitrogen

Statistically significant variation was recorded for total nitrogen in post harvest soil due to different levels of nitrogen (Appendix VII). The highest total nitrogen (0.053%) was found from N_2 which were statistically similar (0.050%) with N_3 and closely followed (0.042%) by N_1, whereas the lowest total nitrogen (0.013%) was observed from N_0 i.e. control condition (Table 13).

Total nitrogen varied significantly for different levels of phosphorous (Appendix VII). The highest total nitrogen (0.045%) was observed from P_2, which were statistically identical (0.043%) with P_1, while the lowest total nitrogen (0.032%) was observed from P_0 i.e. control condition (Table 13).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on total nitrogen (Appendix VII). The highest total nitrogen (0.067%) was observed from N_2P_2, whereas the lowest total nitrogen (0.008%) was recorded from N_0P_0 i.e. control condition (Table 14).

4.3.4 Available P

Statistically significant variation was recorded for available P in post harvest soil due to different levels of nitrogen (Appendix VII). The highest available P (31.50 ppm) was recorded from N_2 which was closely followed (28.11 ppm and 26.32 ppm) by N_3 and N_1 and they were statistically similar. On the other hand, the lowest available P (23.17 ppm) from N_0 i.e. control condition (Table 13).

Total nitrogen varied significantly for different levels of phosphorous (Appendix VII). The highest available P (33.48 ppm) was obtained from P_2, which were statistically identical (32.70 ppm) with P_1, while the lowest available P (15.65 ppm) was found from P_0 i.e. control condition (Table 13).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on available P (Appendix VII). The highest available P (40.78 ppm) was recorded from N_2P_2, whereas the lowest available P (15.03 ppm) was recorded from N_0P_0 i.e. control condition (Table 14).

4.3.5 Exchangeable K

Statistically significant variation was recorded for exchangeable K in post harvest soil due to different levels of nitrogen (Appendix VII). The highest exchangeable K (0.165 me%) was found from N_2 which were statistically similar (0.163 me%) with N_3 and closely followed (0.153 me%) by N_1, while the lowest exchangeable K (0.130 me%) was recorded from N_0 i.e. control condition (Table 13).

Total nitrogen varied significantly for different levels of phosphorous (Appendix VII). The highest exchangeable K (0.164 me%) was found from P_2, which were statistically identical (0.156 me%) with P_1, again the lowest exchangeable K (0.138%) was obtained from P_0 i.e. control condition (Table 13).

Interaction effect of different levels of nitrogen and phosphorus showed significant variation on exchangeable K (Appendix VII). The highest exchangeable K (0.177 me%) was found from N_2P_2 and the lowest exchangeable K (0.123 me%) was observed from N_0P_0 i.e. control condition (Table 14).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July to November, 2013 to study the effect of nitrogen and phosphorus on the growth and yield of BRRI dhan38. BRRI dhan38 was used as the test crop in this experiment. The experiment comprised of two factors- Factor A: Levels of nitrogen (4 levels); N_0: 0 kg N ha^{-1} i.e. control; N_1: 45 kg N ha^{-1}, N_2: 55 kg N ha^{-1}, N_3: 65 kg N ha^{-1}; Factors B: Levels of phosphorous (3 levels)- P_0: 0 kg P_2O_5 ha^{-1} i.e. control, P_1: 25 kg P_2O_5 ha^{-1} and P_2: 35 kg P_2O_5 ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications.

Data revealed that at 30, 45, 60, 75 DAT and harvest, the tallest plant (30.96, 62.00, 84.70, 113.51 and 130.08 cm, respectively) was recorded from N_2, whereas the shortest plant (25.84, 52.60, 73.58, 103.46 and 115.28 cm, respectively) was found from N_0. The maximum number of effective tillers $hill^{-1}$ (12.60) was found from N_2, while the minimum number of effective tillers $hill^{-1}$ (8.98) was recorded from N_0 treatment. The maximum number of non-effective tillers $hill^{-1}$ (3.16) was found from N_3, while the minimum number of non-effective tillers $hill^{-1}$ (2.27) was recorded from N_2 treatment. The maximum number of total tillers $hill^{-1}$ (15.63) was attained from N_3 and the minimum number of total tillers $hill^{-1}$ (12.07) was observed from N_0. The longest length of panicle (22.05 cm) was observed from N_2, while the shortest length of panicle (19.57 cm) was found from N_0. The highest number of filled grains $panicle^{-1}$ (85.66) was recorded from N_2 and the lowest number of filled grains $panicle^{-1}$ (72.09) was observed from N_0. The highest number of unfilled grains $panicle^{-1}$ (8.74) was observed from N_0, whereas the lowest number of unfilled grains $panicle^{-1}$ (4.91) from N_2. The highest number of total grains $panicle^{-1}$ (90.57) was recorded from N_2, while the lowest number of total grains $panicle^{-1}$ (80.83) from N_0. The highest weight of 1000-grains (16.93 g) was observed from N_2 and the lowest weight of 1000-grains (14.82 g) was found from N_0. The highest grain yield (3.56 t ha^{-1}) was recorded from N_2, whereas the lowest grain yield (2.15 t ha^{-1}) was observed from N_0. The highest straw yield (4.98 t ha^{-1}) was observed from N_2, while the lowest straw yield (3.56 t ha^{-1}) was found from N_0. The highest biological yield (8.54 t ha^{-1}) was found from N_2 and the lowest biological yield (5.71 t ha^{-1}) from N_0. The highest harvest index (41.55%) was recorded from N_2, whereas the lowest harvest index (37.59%) from N_0.

The highest N, P, K, S and Zn concentration in grain (0.743%, 0.287%, 0.364%, 0.167% and 0.0215%, respectively) was obtained from N_2, again the lowest (0.484%, 0.230%, 0.237%, 0.108% and 0.0168%, respectively) was observed from N_0. The highest N, P, K, S and Zn concentration in straw (0.475%, 0.064%, 1.22%, 0.079% and 0.0181%, respectively) was found from N_2, while the lowest (0.400%, 0.045%, 1.00%, 0.068% and 0.0150%, respectively) was recorded from N_0. The highest pH (6.26) was observed from N_2, whereas the lowest pH (6.16) was found from N_0. The highest organic matter (1.27%) was found from N_2 and the lowest organic matter (1.20%) was recorded from N_0. The highest total nitrogen (0.053%) was found from N_2, whereas the lowest total nitrogen (0.013%) was observed from N_0. The highest available P (31.50 ppm) was recorded from N_2 and the lowest available P (23.17 ppm) was observed from N_0. The highest exchangeable K (0.165 me%) was found from N_2, while the lowest exchangeable K (0.130 me%) was recorded from N_0 treatment.

At 30, 45, 60, 75 DAT and harvest, the tallest plant (30.46, 60.73, 82.89, 111.97 and 127.74 cm, respectively) were observed from P_2 and the shortest plant (26.91, 54.53, 75.96, 103.96 and 118.47 cm, respectively) were observed from P_0. The maximum number of effective tillers $hill^{-1}$ (12.37) was obtained from P_2, and the minimum number of effective tillers $hill^{-1}$ (9.85) was observed from P_0. The maximum number of non-effective tillers $hill^{-1}$ (3.12) was recorded from P_2, whereas the minimum number of non-effective tillers $hill^{-1}$ (2.67) was found from P_0. The maximum number of total tillers $hill^{-1}$ (15.48) was observed from P_2, and the minimum number of total tillers $hill^{-1}$ (12.52) was found from P_0. The longest length of panicle (22.70 cm) was observed from P_2, whereas the shortest length of panicle (18.76 cm) was recorded from P_0. The highest number of filled grains panicle^{-1} (87.64) was observed from P_2, while the lowest number of filled grains panicle^{-1} (70.97) was observed from P_0. The highest number of unfilled grains panicle^{-1} (8.15) was obtained from P_0, while the lowest number of unfilled grains panicle^{-1} (5.44) was found from P_1. The highest number of total grains panicle^{-1} (93.43) was observed from P_2, whereas the lowest number of total grains panicle^{-1} (79.13) was observed from P_0. The highest weight of 1000- grains (17.13 g) was recorded from P_2, while the lowest weight of 1000-grains (15.00 g) was found from P_0. The highest grain yield (3.25 t ha^{-1}) was observed from P_2, and the lowest grain yield (2.81 t ha^{-1}) was observed from P_0. The highest straw yield (4.69 t ha^{-1}) was found from P_2 and the lowest straw yield (4.22 t ha^{-1}) was recorded from P_0. The highest biological yield (7.94 t ha^{-1}) was recorded from P_2, while the lowest biological yield (7.03 t ha^{-1}) was found from P_0. The highest harvest index (40.63%) was observed from P_2 and the lowest harvest index (39.75%) was observed from P_0.

The highest N, P, K, S and Zn concentration in grain (0.716%, 0.272%, 0.350%, 0.160% and 0.0210%, respectively) was found from P_2, whereas the lowest (0.602%, 0.229%, 0.275%, 0.126% and 0.0182%, respectively) was attained from P_0. The highest N, P, K, S and Zn concentration in straw (0.470%, 0.063%, 1.22%, 0.079% and 0.0179%, respectively) was found from P_2 and the lowest (0.402%, 0.044%, 1.04%, 0.067% and 0.0158%, respectively) was obtained from P_0. The highest pH (6.29) was recorded from P_2, and the lowest pH (6.14) was found from P_0. The highest organic matter (1.29%) was observed from P_1, whereas the lowest organic matter (1.18%) was found from P_0. The highest total nitrogen (0.045%) was observed from P_2, while the lowest total nitrogen (0.032%) was observed from P_0. The highest available P (33.48 ppm) was obtained from P_2, while the lowest available P (15.65 ppm) was found from P_0. The highest exchangeable K (0.164 me%) was found from P_2, again the lowest exchangeable K (0.138%) was obtained from P_0.

At 30, 45, 60, 75 DAT and harvest, the tallest plant (33.77, 66.31, 91.27, 120.39 and 139.05 cm, respectively) were observed from N_2P_2 whereas, the shortest plant (23.12, 49.27, 70.90, 100.53 and 107.75 cm, respectively) were recorded from N_0P_0. The maximum number of effective tillers hill^{-1} (13.87) was attained from N_2P_2, while the minimum number of effective tillers hill^{-1} (8.27) was found from N_0P_0 i.e. control condition. The maximum number of non-effective tillers hill^{-1} (3.73) was observed from N_0P_2, while the minimum number of non-effective tillers hill^{-1} (2.13) was observed from N_2P_2. The maximum number of total tillers hill^{-1} (17.20) was obtained from N_3P_2, while the minimum number of total tillers hill^{-1} (10.87) was found from N_0P_0. The longest length of panicle (24.59 cm) was observed from N_2P_2 and the shortest length of panicle (16.99 cm) from N_0P_0 i.e. control condition. The highest number of filled grains panicle^{-1} (94.73) was observed from N_2P_1, whereas the lowest number of filled grains panicle^{-1} (62.83) was recorded from N_0P_0. The highest number of unfilled grains panicle^{-1} (9.77) was attained from N_0P_0 and the lowest number of unfilled grains panicle^{-1} (4.23) was recorded from N_2P_2. The highest number of total grains panicle^{-1} (99.13) was observed from N_2P_1, while the lowest number of total grains panicle^{-1} (72.60) was recorded from N_0P_0. The highest number of unfilled grains panicle^{-1} (18.35 g) was observed from N_2P_2 and the lowest weight of- grains (14.25 g) was recorded from N_0P_0. The highest grain yield (3.95 t ha^{-1}) was observed from N_2P_2, whereas the lowest grain yield (2.07 t ha^{-1}) was recorded from N_0P_0. The highest straw yield (5.39 t ha^{-1}) was obtained from N_2P_2, whereas the lowest straw yield (3.43 t ha^{-1}) was recorded from N_0P_0. The highest biological yield (9.34 t ha^{-1}) was observed from N_2P_2, whereas the lowest biological yield (5.50 t ha^{-1}) from N_0P_0. The highest grain yield ha^{-1} (42.24%) was observed from N_2P_2, while the lowest number of unfilled grains panicle^{-1} (37.05%) was recorded from N_0P_1.

The highest N, P, K, S and Zn concentration in grain (0.804%, 0.330%, 0.418%, 0.192% and 0.0211%, respectively) was observed from N_2P_2 and the lowest N (0.451%, 0.214%, 0.223%, 0.101% and 0.0163%, respectively) was recorded from N_0P_0. The highest N, P, K, S and Zn concentration in straw (0.528%, 0.082%, 1.40%, 0.088% and 0.0204%, respectively) was recorded from N_2P_2, while the lowest (0.386%, 0.036%, 0.98%, 0.059% and 0.0139%, respectively) was found from N_0P_0. The highest pH (6.34) was observed from N_2P_2, whereas the lowest pH (6.11) was obtained from N_0P_0. The highest organic matter (1.34%) was observed from N_2P_2, while the lowest organic matter (1.15%) was recorded from N_0P_0. The highest total nitrogen (0.067%) was observed from N_2P_2, whereas the lowest total nitrogen (0.008%) was recorded from N_0P_0. The highest available P (40.78 ppm) was recorded from N_2P_2, whereas the lowest available P (15.03 ppm) was recorded from N_0P_0. The highest exchangeable K (0.177 me%) was found from N_2P_2 and the lowest exchangeable K (0.123 me%) from N_0P_0.

Conclusion

It was revealed that application of 55 kg N ha^{-1} & 35 kg P_2O_5 ha^{-1} was more potential in regarding yield contributing characters and yield of BRRI dhan38.

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 organic, inorganic and also macro nutrients.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from July to November 2013

Month (2013)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
July	36.0	24.6	83	563	3.1
August	36.0	23.6	81	319	4.0
September	34.8	24.4	81	279	4.4
October	26.5	19.4	81	22	6.9
November	25.8	16.0	78	00	6.8

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

Appendix II. Analysis of variance of the data on plant height of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.875	2.140	1.049	4.826	0.595
Levels of nitrogen (A)	3	46.532**	160.313**	222.221**	161.817**	389.041**
Levels of phosphorus (B)	2	46.306**	130.149**	178.774**	240.724**	328.217**
Interaction (A×B)	6	4.078*	13.158*	27.489*	50.437*	76.078*
Error	22	1.276	4.351	10.220	16.770	33.576

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

Appendix III. Analysis of variance of the data on effective, non-effective & total tillers plant^{-1}, length of panicle, filled, unfilled and total grains of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

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)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Number of total grains panicle^{-1}
Replication	2	0.003	0.014	0.004	0.948	10.672	0.023	11.591
Levels of nitrogen (A)	3	25.684**	1.589**	21.966**	10.783**	352.375**	23.740**	197.387**
Levels of phosphorus (B)	2	23.203**	0.608**	30.674**	51.530**	987.093**	26.106**	700.892**
Interaction (A×B)	6	1.251*	0.347*	2.223*	4.467*	78.248*	1.152**	68.356*
Error	22	0.495	0.085	0.677	1.343	30.690	0.148	31.079

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

Appendix IV. Analysis of variance of the data on weight of 1000 grains, grain, straw & biological yield and harvest index of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		Weight of 1000 grains (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.014	0.000	0.033	0.035	0.429
Levels of nitrogen (A)	3	8.491**	3.762**	4.002**	15.516**	29.186**
Levels of phosphorus (B)	2	14.239**	0.651**	0.806**	2.904**	2.404
Interaction (A×B)	6	2.556*	0.194*	0.221**	0.827*	0.803*
Error	22	1.023	0.062	0.058	0.185	2.816

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

Appendix V. Analysis of variance of the data on N, P, K, S and Zn concentration in grain of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		Nutrient concentration in grain (%)				
		N	P	K	S	Zn
Replication	2	0.0001	0.0001	0.0001	0.0001	0.0001
Levels of nitrogen (A)	3	0.122**	0.005**	0.029**	0.006**	0.0001**
Levels of phosphorus (B)	2	0.029**	0.009**	0.014**	0.003**	0.0001**
Interaction (A×B)	6	0.003**	0.002**	0.003**	0.001**	0.0001**
Error	22	0.001	0.001	0.001	0.000	0.00001

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

Appendix VI. Analysis of variance of the data on N, P, K, S and Zn concentration in straw of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

Source of variation	Degrees of	Mean square
		Nutrient concentration in straw (%)

	freedom	N	P	K	S	Zn
Replication	2	0.0001	0.0001	0.003	0.0001	0.0001
Levels of nitrogen (A)	3	0.010**	0.001**	0.090**	0.0001**	0.0001**
Levels of phosphorus (B)	2	0.015**	0.001**	0.104**	0.001**	0.0001**
Interaction (A×B)	6	0.002**	0.0001**	0.032**	0.0001**	0.0001**
Error	22	0.0001	0.0001	0.003	0.0001	0.00001

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

Appendix VII. Analysis of variance of the data on N, P, K, S and Zn concentration in straw of BRRIdhan38 as influenced by different levels of nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)
Replication	2	0.017	0.005	0.0001	5.066	0.0001
Levels of nitrogen (A)	3	0.205	0.049	0.003**	109.092**	0.002**
Levels of phosphorus (B)	2	0.296	0.128	0.001**	1218.149**	0.002**
Interaction (A×B)	6	0.093	0.050	0.0001**	34.215**	0.000**
Error	22	0.335	0.115	0.0001	9.282	0.000

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