EFFECT OF PHOSPHORUS DOSE WITH ADDED NITROGEN ON RICE (*Oryza sativa* L.) *cv.* BR23 IN KHULNA DISTRICT

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Khulna University

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November 2019

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Approved as to style and content

By

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PROF. DR. MD. YASIN ALI

(supervisor)

PROF. DR. MD. SARWAR JAHAN

(Co-supervisor)

PROF. DR. SARDER SAFIQUL ISLAM

CHAIRMAN, EXAMINATION COMMITTEE

AND

HEAD, AGROTECHNOLOGY DISCIPLINE

KHULNA UNIVERSITY, KHULNA

November 2019

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ABSTRACT

A field experiment was carried out at the Professor Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna university, Khulna during the period of August, 2018 to December, 2018 to determine the effect of phosphorus dose with added nitrogen on BR23 rice in Khulna district. The experiment was laid out on split plot design with three replications having nitrogen fertilizer in the main plot and phosphorus fertilizer in the sub plot. There were two nitrogen fertilizers *viz.*, N_0=no nitrogen, N_1=93 kg N ha^{-1} and four phosphorus fertilizer doses *viz.*, P_0=no phosphorus, P_1=8 kg P ha^{-1}, P_2=16 kg P ha^{-1} and P_3=24 kg P ha^{-1}. Experimental data on growth characters yield contributing characters yield parameters were collected and analyzed statistically. At harvest, tallest plant, (136.75 cm), tillers $hill^{-1}$ (11.83), total dry matter $hill^{-1}$ (76.92 g), effective tillers $hill^{-1}$ (12.92), filled grains $panicle^{-1}$ (125.83), 1000-grain weight (41.08 g), grain yield (5.56 t ha^{-1}), straw yield (6.67 t ha^{-1}) and harvest index (50.86%) were obtained from N_1 (93 kg N ha^{-1}) treatment. P_3 (24 kg P ha^{-1}) treatment showed similar result at all growth and yield contributing characters. P_2 (16 kg P ha^{-1}) treatment showed maximum grain and straw yield and harvest index. Interaction effect of N_1P_3 (93 kg N ha^{-1}+24 kg P ha^{-1}) treatment combination showed highest grain yield, straw yield and biological yield. N_1 treatment (93 kg N ha^{-1}) and P_3 treatment (24 kg P ha^{-1}) and N_1P_3 (93 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination showed effective result in all parameters.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), of Gramineae family, is the most important food in tropical and subtropical regions (Singh *et al.*, 2012). It is grown in most of the countries in the world with a total area of about 160 million hectares, every year producing more than 700 million tons (IRRI, 2013). More than three billion people in the world are taking rice as their main food (IRRI, 2009). In Asia, more than 90% of all produced rice has been consumed (FAO, 2006). In Bangladesh 10.4 million hectares of land is used for rice production which is about 84.67% of total cropped area, with annual production of 30.42 million tons (BBS, 2014). Bangladesh ranks 4th in both area and production and 6th in the production of per hectare yield of rice (Sarkar *et al.*, 2016).

Bangladesh is an agrarian country. Rice production is the most important business as it is the main staple food in this country. Over its long history, rice production in Bangladesh has gradually changed in terms of yield potentials, cultivation techniques and cropping patterns. Despite pressure from overpopulation, the country has reached self-sufficiency in rice production. The net cultivable area at present is about 8.50 M ha and net cultivated area is 7.45 million ha (BBS, 2012). Rice grows in all the three crop growing seasons of the year and occupies about 77% (11.42 M ha) of the total cropped area of about 14.94 M ha. At present, rice alone constitutes about 93% of the total food grains produced annually in the country (BER, 2013). It also ensures political stability for the country and provides a sense of food security to the people.

Rice is the dominant staple food for many countries of the world (Mobasser *et al.*, 2007). Rice is grown in Bangladesh in three distinct growing seasons namely *Aus*, *Aman* and *Boro* rice covers the area of 5.66 million hectares with a production of 13.3 million tons (AIS, 2012). In Bangladesh, transplanted *aman* rice is the first largest crop in respect of area cultivation (56,79,456 ha) and second largest crop after *boro* rice in respect of its production (2.464 M ton ha^{-1}) (BBS, 2017).

Nitrogen and phosphorus fertilizer are the major essential plant nutrients and key input for increasing crop yield (Alinajoati Sisie and Mirshekari, 2011; Alam *et al.*, 2009). Nitrogen is one of the most important nutrients for plant growth and a major factor that limits agricultural yields

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(Xia *et al.*, 2011). Many workers have reported a significant response of rice to nitrogen in different soils in Bangladesh (Bhuiya *et al.*, 1989; Hussain *et al.*, 1989 and Islam *et al.*, 1990). Nitrogen is the essential component of many compounds of plant such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins. When sufficient nitrogen is applied to the crop, the demand for other nutrients such as P and K increases. It is required in adequate amount at early, at mid-tillering and panicle initiation stage for better grain development (Ahmed *et al.*, 2005).

Among three primary elements (NPK), phosphorus is one of the most important nutrient elements for plant life. Adequate quantity of available P is vital for the growth, reproduction, yield and quality of many crops. Phosphorus is relatively absorbed by the plants in small amount. Phosphorus deficiency results in decreased leaf number, leaf blade, reduced panicles plant^{-1}, grain panicle^{-1} and reduced filled grain panicle^{-1} (Aide and Picker,1996). Phosphorus plays a crucial role in the root proliferation, consistent grain filling, higher grain yield and quality and being involved in many processes such as photosynthesis, mitotic activities, nitrogen fixation, flowering, fruiting and maturation. Phosphorus deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant phosphorus use efficiency (Alinajoati Sisie and Mirshekari, 2011). This element tends to be concentrated in the seed and stimulates early root formation and growth of the plant. Its deficiency in soil extends the lifespan of rice plants, delayed flowering and maturity. Without adequate supply of P plant cannot reach its maximum yield. Since in many soils much of the available P is derived through the mineralization of organic matter, the repeated addition of P fertilizer appears to be the only satisfactory way of supplying plant needs for this very important nutrient. It is reported to be a critical factor of many crop production systems due to its limited availability in soluble forms. The phosphorus deficiency is common in almost all the soils and crops (Raju *et al.*, 2005). Hence available phosphorus status in our country is very low.

The optimum proportion of nitrogen and phosphorus fertilizer enhances the growth and development of a crop as well as ensures the availability of other essential nutrients for the plant. This effect of nitrogen on phosphorus uptake is important from the standpoint of utilization of both soil and applied phosphorus. For instance, some soils are relatively well supplied with available phosphorus. Applied nitrogen will often result in a greater uptake of soil phosphorus. On other soils, both nitrogen and phosphorus often give profitable responses. Applied nitrogen

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often this instance may result in a more efficient utilization of the applied phosphorus. Decrease in N concentration with increasing P limitation may be mediated by a decrease in leaf cytokinin levels and is less likely due to decreased energy availability at low P conditions.

The major cropping pattern in Bangladesh agriculture mostly consists of rice based cereal crops (Haque, 1998). More than 60% of the total cropped area covered by *Boro*- T. *aman* rice cropping pattern in Bangladesh (FRG, 1997). This is the dominant cropping pattern in medium high land area of Khulna region under high ganges river floodplain. Khulna locates in AEZ-13 region. Here the major land type is medium highland. General fertility level is high with medium to high organic matter content (Krishi Projukti Hatboi, 2010) but nitrogen and phosphorus ranges from very low to low (BRRI, 2010). The major part of this region is affected by different gradient of salinity. In this region, soil is also characterized by very low to low nitrogen and phosphorus nutrients. Fertilizer recommendation for crops in a cropping pattern of a particular AEZ needs change after a certain period of time. Application of imbalance fertilizer to individual crop commonly found among the farmers of Khulna region, is detrimental to soil. Efficient fertilizer management gave higher yield of crop and reduced fertilizer cost (Hossain and Islam, 2006). For rice, BRRI recommended fertilizers for all over the country not AEZ based while BARC recommended fertilizers are AEZ based, not for specific crop variety. It is needed to determine the optimum dose of phosphorus for HYV *aman* rice in the N and P deficit soil like AEZ-13 and to find out the role of phosphorus doses with deficient as well as sufficient soil nitrogen on growth and yield of T. *aman* rice.

Keeping all the points in mind mentioned above, the present research work was under taken with the following objectives:

- To observe the effect of phosphorus level with added nitrogen on growth and yield of BR23 rice and
- To determine the optimum dose of phosphorus for better growth and higher yield on BR23 rice in a low phosphorus containing soil of Khulna district.

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CHAPTER II

REVIEW OF LITERATURE

Use of different chemical fertilizers are increasing rice production but soil health is degrading day by day. It may be due to use of imbalance fertilizer and intensification of crops, which causes degradation of soil, increase soil acidity, increase salinity, arsenic pollution, removing of soil nutrients, depletion of surface and underground water, environment pollution and other heavy metal pollution. Among the improved cultural practices, to ensure proper growth, large amount of chemical fertilizers are applied in different crops field (Shakouri *et al.*, 2012). Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Alam *et al.*, 2009). So, the appropriate fertilizer input that is not only for getting high grain yield but also for attaining maximum profit (Khuang *et al.*, 2008). In our country, farmers are most willing to apply urea (nitrogen) and TSP (phosphorus) fertilizers as nitrogen is an essential component of proteins, hormones, chlorophyll, vitamins and enzymes and phosphorus is a vital constituent of major biomolecules such as deoxyribonucleic acid, ribonucleic acid, adenosine triphosphate, phosphate esters and phospholipids (Marschner, 2012). But application of excess fertilizer is responsible to yield loss and soil health hampers. So, it is very important to find out the optimum dose of phosphorus with added nitrogen on T. *aman* rice. However, many works were done at home and abroad are briefly reviewed here.

2.1 Effect of nitrogen

Nitrogen absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation (Bufogle *et al.* 1997; Norman *et al.*, 1992). Nitrogen is very essential for the growth and development of crops. It enhances biomass and seed yield subject to the efficient water supply.

2.1.1 Effect on growth character

2.1.1.1 Plant height

Ahmed *et al.*, (2005) showed that different agronomic characteristics varied significantly among the treatments (The levels of nitrogen 0, 20, 40, 60 and 80 kg ha^{-1}). Higher N dose produced

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higher plant height and the height decreased gradually with decreased levels of nitrogen fertilizer application.

BRRI (1992) reported that 120 to 160 kg N ha^{-1} was assumed to be due to excessive vegetative growth followed by lodging after flowering.

Geethadevi *et al.*, (2000) conducted an experiment in India to determine the effect of different nitrogen rates (0, 50, 100 and 150 kg ha^{-1}) and spacing (15 x 10 or 20 x 10 cm) on the growth and yield of hybrid rice. Among N rates, treatment with 150 kg N ha^{-1} recorded the highest values for plant height (87.20 cm).

Imrul *et al.*, (2016) observed that at 30 and 60 days after transplanting (DAT) and at the time of harvest the tallest plants were observed in the treatments N_2 (120 kg N ha^{-1}) whereas, the treatments N_0 showed the smallest plant height.

Jan *et al.*, (2018) carried out a field experiment entitled "Effect of nitrogen and silicon on growth and yield attributes of transplanted rice (*Oryza sativa* L.). The experiment was laid out in Factorial Randomized Completely Block Design assigning combinations of three nitrogen levels (N_1: 120, N_2: 150, N_3: 180 kg ha^{-1}) and four silicon applications (Si_0: Control, Si_1: 5%, Si_2: 10% and Si_3:15%) with four replications. The plant height as affected by different treatments at 15DAT, non-significant difference was recorded with respect to nitrogen levels *viz.*, 120 kg N ha^{-1}, 150 kg N ha^{-1} and 180 kg N ha^{-1} during 2014 and 2015. But from 30DAT upto harvest, significantly taller plants were observed with 180 kg N ha^{-1} followed by 150 kg N ha^{-1}. This could be attributed to the fact that nitrogen induced maximum vegetative growth at higher doses.

Kumar *et al.*, (2018) carried out an experiment and found that nitrogen scheduling affected the plant height up to significant level at successive growth stages. Plant height increased with variation in N-levels in different nitrogen schedules and at harvest maximum plant height was recorded with N_3-LCC-5 due to more availability of nitrogen which might have encouraged higher protein synthesis and higher leaf color chart (LCC) values means more chlorophyll content leading to higher photosynthesis. These resulted in to rapid cell elongation and enlargement and ultimately higher plant height.

Meena *et al.*, (2003) reported that application of 200 kg N ha^{-1} significantly increased the plant height (127.9 cm) of rice while they applied another dose, 100 kg N ha^{-1}.

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Pramanik and Bera (2013) found that the maximum plant height (103.81 cm and 112.84 cm) when 10 days old seedlings were transplanted and nitrogen was applied @ 200 kg ha^{-1}, while minimum plant height (91.38 cm and 81.63 cm) was observed with the seedlings of 30 days age and with no nitrogen application.

Rajendran and Veeraputhiran (1999) conducted an experiment to study the effects of 4 nitrogen levels (0, 75, 150 and 225 kg ha^{-1}) and 3 sowing rates in the nursery (10, 20 and 30 g m^{-2}) on hybrid rice ADTRH1. Nitrogen was applied at 3 equal splits namely: 7 days after transplanting, active tillering and panicle initiation stages. Observation upon harvest revealed that plant height was found with 225 kg N ha^{-1}.

Saha *et al.*, (2017) carried out an experiment during *kharif* seasons of 2008 in rice crop with the different levels of nitrogen and various cultivars to find out best rice cultivars and optimum dose of nitrogen under terai region of West Bengal. It was found that plant height increased continuously with the advancement of crop growth and varied significantly with different levels of nitrogen and cultivars. Among the levels of nitrogen N_3 (90 kg N ha^{-1}) achieved significantly tallest plant (24.47, 62.67, 76.93 and 86.06 cm at 20 DAT, 40 DAT, 60 DAT and at harvest respectively).

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height was recorded about 92.81 cm with 70 kg N ha^{-1}.

Wang *et al.*, (2002) conducted a pot experiment to determine the effect of nitrogen levels no nitrogen, low nitrogen, medium nitrogen, high nitrogen and super high nitrogen on the growth of plants and leaves in hybrid rice Shanyou 64 and conventional rice Kinmaze. They found that the plant height increased with increasing nitrogen levels.

2.1.1.2 Tiller number plant^{-1}

Arif *et al.*, (2018) found that exogenous application of 2% N+ Zn at tillering stage produced significantly higher number of tillers per plant (21.28). Lower number of fertile tillers per plant (14.03) was observed with foliar spray of 2% N+ Zn at booting stage.

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Bayan and Kandasamy (2002) reported that tillers hill^{-1} increased with the application of nitrogen fertilizer.

Biswas *et al.,* (2005) conducted an experiment with different nitrogen levels, light intensities and tiller separation from the mother crop to find out their individual and combined effects on tiller production of a photo-neutral modern rice variety BR23. The number of tillers increased gradually during early and intermediate stages of vegetative growth and decreased thereafter. Higher doses of nitrogen significantly increased the tillers number until harvest, whereas, zero nitrogen resulted with lower number of tillers throughout its life cycle. N rate increasing from 75 to 120 kg ha^{-1} also gave a significant increase in number of tillers.

BRRI (2008) conducted an experiment to study the comparative study of some promising lines with BRRI modern rice varieties to different nitrogen levels *viz*., 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. It was reported that tiller production with N @ 120 kg ha^{-1} produced significantly higher tiller than those of lower N levels.

Dey *et al.*, (2014) carried out an experiment and found that tillering increased steadily due to increasing level of nitrogen application during the study. The result showed that the highest number of tillers m^{-2} were recorded in crop receiving 240 kg N (N_{240}), but was comparable to those of its immediate lower (N_{180}) level (180 kg N ha^{-1}). Both the above nitrogen levels produced significantly greater number of tillers m^{-2} than those recorded at lower nitrogen level (N_0). At low nitrogen (N_0) level produced the lowest number of tillers m^{-2} among all other nitrogen treatments.

Haque *et al.,* (2012) carried out an experiment and recorded that total tillers hill^{-1}was significantly affected by both the nitrogen application at different growth stage and the amount of nitrogen applied at all dates of sampling. At 45 DAT, the highest tillers hill^{-1} (14.85) was found when N was applied at transplanting stage. At 60 DAT and 75 DAT, the highest tillers hill^{-1} were observed (11.82) when N applied at maximum tillering and panicle initiation stage respectively. Total tillers hill^{-1} gradually decreased first reached at a peak and there after it with advancement of age after 40 DAT. At all the DAT (45, 60 and 75), total tillers hill^{-1} was found 15.31, 11.81 and 9.37 respectively in 25% higher N level than recommended dose. In general, the increasing trend of total tillers hill^{-1} was observed up to 45 and then declined up to 75 DAT.

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Irfan *et al.*, (2016) found that the highest number of tillers $hill^{-1}$ (17) was produced at 150 kg N + 75 kg P_2O_5 ha^{-1} treatment combination.

Jahan *et al.*, (2014) conducted an experiment and recorded that nitrogen dose of 120 kg ha^{-1} produced the highest number of tillers which was statistically similar with 90 kg N ha^{-1}, 60 kg N ha^{-1} and 30 kg N ha^{-1} respectively. The lowest number of total tillers was found from control plot which was statistically similar with 30 kg N ha^{-1}.

Jisan *et al.*, (2014) conducted an experiment and found that highest number of total tillers $hill^{-1}$ (12.34) was obtained from 75 kg N ha^{-1} and the lowest values were obtained from control (N_0) on BRRI dhan52.

Lang *et al.*, (2003) conducted a field experiment to study the effect of different fertilizer application rates on seedling of Jinyou 207, Guihuanian and Teyou 524 were sown in no-tillage plots situated in 3 different counties in Guangxi, China. At an early stage of growth, the seedlings were subjected to one of three nitrogen fertilizer treatments. Treatment A used a conventional application rate (CAR) of 157-5-172.5 kg ha^{-1} N, treatments B and C used CAR + 10% and CAR + 20%, respectively. They found that the increase in nitrogen fertilizer application rate increased the speed of seedling establishment and tillering peak.

Ndaeyo *et al.*, (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600 kg ha^{-1}). The results showed that 600 kg ha^{-1} NPK (15:15:15) fertilizer rate significantly increased tillers per plant.

Pramanik *et al.*, (2004) carried out an experiment and recorded that application of different levels of nitrogen had significant influence on plant height and number of tillers $hill^{-1}$. The tallest plant and the highest number of tillers $hill^{-1}$ were obtained when the crop was fertilized with 80 kg N ha^{-1} but the highest number of effective tillers $hill^{-1}$ was obtained when the crop was fertilized with 40 kg N ha^{-1}. However, almost similar plant height and number of tillers $hill^{-1}$ were observed when the crop was fertilized with 40, 60 and 80 kg N ha^{-1} respectively. Plant height and number of tillers $hill^{-1}$ were the lowest in no nitrogen control treatment.

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2.1.1.3. Total dry matter production

Arunakumari *et al.*, (2018) showed that the highest plant height, dry matter accumulation, yield attributes and grain yield were observed with green manuring in situ with dhaincha along with PSB + 150% RDP to rice.

Chen *et al.*, (2012) conducted a four-year experiment and found that dynamic total dry matter accumulations in different N managements were determined for direct seeded rice (DSR) and transplanting rice (TPR) methods. Before mid tillering (MT), dry matter accumulation was generally greater in DSR than in TPR but the opposite was found from mid-tillering to heading stage (HS) in all years except for F1 in 2007 and F2 in 2009. On average, dry matter accumulated in DSR was 43% greater than in TPR before MT, and 23% less from MT to HS. Little difference in dry matter accumulation was found between total nitrogen amount of 150 and 225 kg N ha^{-1} in both DSR and TPR regardless of growth periods.

Fu *et al.*, (2000) conducted a field experiment in Zhejiang Province, China to evaluate the nitrogen fertilizers *viz.*, 0, 100, 150, 180, 225, 270, and 300 kg N ha^{-1} as urea, two-thirds top-dressed as basal and one third top dressed 7 days after transplanting, on dry matter and N partitioning in hybrid rice 518. They reported that higher N applications significantly increased dry matter partitioning of leaf at the vegetative stage. Partitioning of dry matter to leaves decreased as the N concentration in the leaves decreased. Leaf partitioning of absorbed N, compared to dry matter was higher and varied little during early vegetative growth but varied greatly from panicle initiation onwards, probably due to competition for N among leaves, stem and the developing panicle.

Geethadevi *et al.*, (2000) conducted an experiment in Karnataka, India to determine the effect of different nitrogen rates (0, 50, 100 and 150 kg N ha^{-1}) and spacing (15 cm x 10 cm or 20 cm x 10 cm) on the growth and yield of hybrid rice. Among N rates, treatment with 150 kg N ha^{-1} recorded the highest values for total dry matter per plant (57.08 g).

Javeed *et al.*, (2017) observed that among different graded levels of N, P & K application of Nitrogen at 60 kg ha^{-1} recorded significantly higher growth parameters (plant height and dry matter accumulation) as well as grain and straw yield than 30 kg and 40 kg ha^{-1} of N.

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Kashem *et al.*, (2015) conducted an experiment of sugar beet and found that the highest total dry matter 2262.96 g m^{-2} was produced with 150 kg N ha^{-1} followed by 2113.69 g m^{-2} with 100 kg N ha^{-1}. The dry matter production gradually decreased with lower level of nitrogen.

Khatun *et al.*, (2018) conducted an experiment with six N rates: 0, 50, 100, 150, 200 and 250 kg ha^{-1}. At all growth stages, the increase in dry matter with the increase of N rates. In BRRI dhan28, the highest N uptake (4.8 kg ha^{-1}) contributed to the highest dry matter production (72 kg ha^{-1}) and in BRRI dhan29, the highest N uptake (8.8 kg ha^{-1}) contributed to the highest dry matter production (151 kg ha^{-1}).

Kipgen *et al.*, (2018) conducted a field experiment at West Bengal using RCBD design and the treatments comprised of 4 nitrogen levels (0, 100, 120 and 140 kg N ha^{-1}) and three planting geometry (15 cm x 15 cm, 20cm x 15 cm and 20 cm x 20 cm). N_3 recorded highest dry matter accumulation (815.58 g m^{-2}) followed by N_2 (807.51 g m^{-2}) and N_1 (783.81 g m^{-2}) but were statistically at par with each other. The higher total dry matter production was attributed to better plant growth which resulted in higher dry matter accumulation in leaves and stem at early growth stages and better translocation to ear heads during later stages.

Sing and Modgal, (2005) noted that dry matter accumulation (DMA) and concentration and uptake of nitrogen increased with increasing level of N at all the stages of crop growth.

Xie *et al.*, (2007) reported that increased split application of N from control to 140 kg N ha^{-1} increased dry matter accumulation (DMA) of different growth stages of Jinzao22 and Shanyou63 rice varieties and after that dose the DMA reduced due to the losses of N by volatilization.

2.1.1.4 Crop growth rate

Das and Panda, (2004) conducted an experiment in Bhubaneswar, Orissa, India, to study the effects of N (0, 60, 120 or 180 kg ha^{-1}) and K (0, 40, 80 or 120 kg ha^{-1}) on the growth rate of rice. N (urea) was applied as a basal dressing (25%) and as a top dressing at 18 days after transplanting (DAT; 50%) and at the panicle initiation stage (25%). K (K_2O) was applied during transplanting. Irrespective of treatment difference, Crop growth rate (CGR) was greater at 40-60 DAT and lower at 20-40 DAT. The increase in the N rate increased CGR. The highest CGR (22.52 g day^{-1} m^{-2}) was obtained with 80 kg K_2O ha^{-1}.

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Kumar *et al.*, (2017) conducted a field experiment with six treatments of nitrogen of organic sour viz. 100% N through 1/3 vermicompost+1/3 FYM+1/3 poultry manure at basal (T_1), 100% N through vermicompost at basal (T_2), 100% N through poultry manure at basal (T_3), 100% N through 1/2 poultry manure as basal + 1/2 vermicompost at 30 DAT (T_4), 100% N through 1/2 vermicompost as basal+ 1/2 vermicompost at 30 DAT (T_5) and Control - No application of any nutrients (T_6). Among various organic nitrogen sources, T_1 treatment at 0-30 DAT, 30-60 DAT and 60-90 DAT recorded significantly higher crop growth rate as compared to others.

Rahman *et al.*, (2007) conducted an experiment including four treatments *viz.*, 0, 60, 80 and 100 kg N ha^{-1}. The data revealed that the highest CGR (15.26 gm^{-2} d^{-1}) was produced when 100 kg N ha^{-1} was applied on DAT. The CGR values increased rapidly along with LAI up to 60-90 DAT and there after decreased markedly. CGR values increased with the increase in nitrogen level.

Tajul *et al.*, (2013) conducted an experiment of maize with four doses of N (100, 140, 180, and 220 kg ha^{-1}) and planting density at different growth stages (D_1= 53,000 plant ha^{-1}, D_2= 66,000 plant ha^{-1}, D_3= 80,000 plant ha^{-1}). It was found that among the N-levels, 220 kg N ha^{-1} showed maximum CGR throughout growth period followed by 180 kg N ha^{-1}.The highest CGR was associated with the combination of D_3N_4 followed by D_3N_3, while the lowest CGR was in the plants at D_1N_1 treatment. In general, increase in planting density increased CGR in all the N-levels; CGR response to population density and N-rates followed a linear relationship suggesting that 97% and 99% of total variation in CGR could be accounted for by the linear function of N and population density, respectively. Therefore, the functional relationship suggests that higher the N-levels and population density, the greater was the CGR of maize plant.

Valadabadi *et al.*, (2009) using nitrogenous fertilizer including 520, 400 and 280 kg urea ha^{-1} showed that nitrogenous fertilizer significantly increased physiological growth indices in maize which indicates that the highest CGR (31.2 g m^{-2}day^{-1}).

2.1.1.5 Relative growth rate

Kumar *et al.*, (2017) conducted a field experiment with six treatments of nitrogen of organic source *viz.*, 100% N through 1/3 vermicompost+1/3 FYM+1/3 poultry manure at basal (T_1), 100% N through vermicompost at basal (T_2), 100% N through poultry manure at basal (T_3), 100% N through 1/2 poultry manure as basal + 1/2 vermicompost at 30 DAT (T_4), 100% N

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through 1/2 vermicompost as basal+ 1/2 vermicompost at 30 DAT (T_5) and Control - No application of any nutrients (T_6). He found that T_1 treatment produced highest RGR.

Rahman *et al.*, (2007) conducted an experiment including four treatments *viz.*, 0, 60, 80 and 100 kg N ha^{-1}. RGR was significantly influenced by nitrogen level at 30-45 DAT, 45-60 DAT and 75-90 DAT but insignificant at 60-75 DAT. The highest RGR (38.37 mg $g^{-1}d^{-1}$) at the early vegetative stage from 60 kg N ha^{-1} and trend similar in 80 kg ha^{-1} (38.11mg g^{-1} d^{-1}) at 45-60 DAT.

Tajul *et al.*, (2013) conducted an experiment of maize with four doses of N (100, 140, 180 and 220 kg ha^{-1}) and planting density at different growth stages (D_1= 53,000 plant ha^{-1}, D_2= 66,000 plant ha^{-1}, D_3= 80,000 plant ha^{-1}). It was found that populated plants with 100 kg N ha^{-1} (D_1N_1) gave the highest RGR, while the lowest RGR was found in densely populated plants (80,000 ha^{-1}) with higher N-rates (220 kg ha^{-1}).

Valadabadi *et al.*, (2009) using nitrogenous fertilizer including 520, 400 and 280 kg urea ha^{-1} showed that nitrogenous fertilizer significantly increased physiological growth indices in maize which indicates that the highest RGR (0.08 g g^{-1} day^{-1}).

2.1.1.6 Leaf Weight Ratio

Alam (2014) conducted an experiment with two methods of planting *viz.*, conventional and bed planting, four wheat varieties namely Protiva, Sourav, Shatabdi and Prodip and four levels of nitrogen *viz.*, 0, 60, 110 and 160 kg N ha^{-1}. Leaf weight ratio significantly affected by nitrogen level. The highest leaf weight ratio was found at tillering stage. At tillering stage the highest specific leaf area was observed at 160 Kg N ha^{-1} followed by 110 kg N ha^{-1} and 60 kg N ha^{-1}. The second highest weight ratio was noted at crown root initiation stage and thereafter it declined at the successive growth stages up to grain filling stage.

Islam *et al.*, (2015) conducted a two years experiment with two sets of treatments: (i) green manure application (*Crotalaria jusncea, Sesbania aculeata, Sesbania rostrata, Vigna radiata,* and *Phaseolus mungo*) and (ii) application of different nitrogen levels (0, 40, 80, and 120 kg ha^{-1}). The results indicate that all green manures in combination with higher N levels accelerate LWR. The highest LWR at flowering stage (FS) was recorded in *C. juncea*, *S. rostrata*, and *P.*

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mungo with 120 kg ha^{-1} N in both years. *S. aculeata* with all levels of additional N demonstrated higher LWR in year 2. The highest LWR at grain filling stage (GFS) was found in *C. juncea* with 40, 80, and 120 kg ha^{-1} N, *S. aculeata* with 80 and 120 kg ha^{-1} N, *S. rostrata* with 120 kg ha^{-1} N, and *P. mungo* with 120 kg ha^{-1} N in year 1. More or less similar responses were noted in year 2.

2.1.2 Effect on yield contributing character

2.1.2.1 Effective tillers $hill^{-1}$

Adhikari *et al.*, (2018) found that the highest number of effective tillers $hill^{-1}$ (6.18), panicle length (21.98 cm), number of grains $panicle^{-1}$ (114.20), grain yield (4.00 t ha^{-1}), straw yield (5.25 t ha^{-1}) and biological yield (9.25 t ha^{-1}) were recorded in N_2 (80 kg N ha^{-1}) treatment.

Awan *et al.*, (2011) conducted an experiment to study the effect of different nitrogen levels (110, 133 and 156 kg N ha^{-1}) in combination with different row spacing (15 cm, 22.5 cm and 30 cm). They noted that maximum level of N (156 kg N ha^{-1}) produced maximum effective tillers irrespective of spacing.

BINA (1996) stated that different nitrogen levels significantly influenced the number of effective tillers $hill^{-1}$.

Chopra and Chopra (2004) reported that nitrogen had significant effects on yield attributes of effective tillers $hill^{-1}$ with increasing levels of N up to 120 kg N ha^{-1} in rice.

Islam and Bhuiya (1997) showed that N and P significantly increased the number of fertile tiller m^{-2} and grain $panicle^{-1}$. The application of 60 kg N ha^{-1} gave 44% yield increase over control.

Meena *et al.*, (2002) studied the response of hybrid rice to nitrogen (0, 100 and 200 kg ha^{-1}) and potassium application (0, 75 and 150 kg ha^{-1}) at the research farm of the IARI, New Delhi. They observed that application of nitrogen significantly increased the effective tillers.

Rabin *et al.*, (2016) showed that effective tillers $hill^{-1}$ results with 75% urea top dressing and 10% urea with magic growth as foliar spray. Moreover, 75% urea top dressing and 10% urea of the recommended dose with magic growth as foliar spray increased all the growth attributes with a saving of 15% of the recommended nitrogen fertilizer compared to recommended practice.

Rahman *et al.*, (2007) obtained that the highest number of effective tillers $hill^{-1}$ (9.20), maximum grains $panicle^{-1}$ (100.80) and highest grain yield (5.34 t ha^{-1}) were obtained with 80 kg N ha^{-1}.

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Rajendran and Veeraputhiran (1999) observed that productive tillers m^{-2} increased as the N rate increased.

Rasheed *et al.,* (2003) reported that the number of effective tillers per hill was increased when NP levels were increased.

Ray *et al*., (2015) found that BRRI dhan49 in combination with 25 cm ×15 cm spacing and 80 kg N ha^{-1} gave the highest number of effective tillers $hill^{-1}$.

Singh and Shivay (2003) conducted an experiment at the Research Farm of the Indian Agricultural Research Institute, New Delhi, India to study the effect of coating prilled urea with eco-friendly neem formulations in improving the efficiency of nitrogen use in hybrid rice. Two rice cultivars, hybrid rice (NDHR-3) and Pusa $Basmati^{-1}$, formed the main plots, with the levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and various forms of urea at 120 kg N ha^{-1} in the subplots. They found that increasing levels of nitrogen significantly increased the number of effective tillers $hill^{-1}$.

2.1.2.2 Panicle length

Asif *et al*., (2000) reported that NPK levels significantly increase the panicle length, number of primary and secondary branches $panicle^{-1}$ when NPK fertilizer applied in 180-90-90 kg ha^{-1} this might be attributed to the adequate supply of NPK.

Azad *et al*., (1995) observed that panicle length increased significantly with the increased of nitrogen levels from 0 to 75 kg N ha^{-1}.

Irfan *et al*., (2016) found that the highest panicle length (25 cm) was recorded at 120-90 kg N-P_2O_5 ha^{-1}.

Islam *et al*., (2008) conducted an experiment to study the effect of nitrogen and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan33). They noted that panicle length, number of grain $panicle^{-1}$ increased with the application rate of N up to 100 kg ha^{-1} and then declined.

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Mannan *et al*., (2010) observed that number of tillers and panicles, panicle length, spikelet sterility and straw yield increased most by the application of 75-40-40 kg NPK ha^{-1} than other doses with lesser yield at lower as well as higher doses than this.

Meena *et al*., (2002) observed that increase in nitrogen fertilizer application rate enhanced length and weight of panicles of hybrid rice.

Salahuddin *et al*., (2009) observed that a gradual increase in panicle length (24.50 cm), grains $panicle^{-1}$ 110) and grain yield (4.91 t ha^{-1}) were observed with the increase in nitrogen levels up to 150 kg ha^{-1} and declined thereafter.

Singh and Shivay (2003) found that increasing levels of nitrogen significantly increased the panicle length.

Tomar *et al*., (2018) reported that length of panicle, of rice were maximum under 75% NPK+25% FYM which was at par with 100% NPK during course of investigation.

2.1.2.3 Filled grains $panicle^{-1}$ and unfilled grains $panicle^{-1}$

Ahmed *et al*., (2005) showed that different agronomic characteristics varied significantly among the treatments (the levels of nitrogen 0, 20, 40, 60 and 80 kg ha^{-1}). Higher N dose produced filled grains $panicle^{-1}$ with 40 kg N ha^{-1}.

Edwin and Krishnarajan (2005) studied the effects of irrigation and N fertilizer treatments on the yield of rice hybrid variety CoRH2 in Coimbatore, Tamil Nadu, India. They suggested that N supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest filled grains.

Haque (1988) found that spikelet sterility induced by low temperature at the reproductive stage of rice increased further with the increase of nitrogen supply. Spikelet sterility in Fujisaka-5 did not increase due to low temperature when nitrogen supply was increased from 10 to 40ppm and at 80ppm nitrogen supply it was less affected than IR36.

Hasanuzzaman *et al*., (2012) observed that maximum filled grains $panicle^{-1}$ (154.67) was obtained from the application of urea super granules.

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Imrul *et al.*, (2016) observed that at 30 and 60 days after transplanting (DAT) and at the time of harvest the maximum filled grains panicle^{-1} was observed from N_2 (120 kg N ha^{-1}), P_2 (35 kg P ha^{-1}) and treatment combination N_2P_2 (120 kg N and 35 kg P ha^{-1}).

Islam *et al.*, (2014) showed that the highest number of sterile spikelet panicle^{-1} (27.92) was obtained in control treatment and the lowest number of sterile spikelet panicle^{-1} (14.31) was recorded in the treatment with two pellets of USG 4 hills^{-1} providing 60 kg N ha^{-1}.

Lang *et al.*, (2003) found that the increase in nitrogen fertilizer application rate enhanced grains per panicle, effective panicles per plant, and total florets per plant.

Masum *et al.*, (2010) reported that placement of N fertilizer in the form of urea super granules @ 58 kg N ha^{-1} produced the highest number of effective tillers hill^{-1}, filled grains panicle^{-1} which ultimately gave the higher grain yield than split application of urea.

Meena *et al.*, (2002) noted that increase in nitrogen fertilizer application rate enhanced number of grains and filled grains of hybrid rice.

2.1.2.4 1000-grain weight

Ahmed *et al.*, (2005) showed that different agronomic characteristics varied significantly among the treatments (the levels of nitrogen 0, 20, 40, 60 and 80 kg ha^{-1}). Higher N dose produced higher 1000-grain weight. The highest 1000-grain weight was obtained with 40 kg N ha^{-1}.

Jisan *et al.*, (2014) found that 1000-grain weight (24.55 g) was obtained from 75 kg N ha^{-1} and the lowest values were obtained from control on BRRI dhan52.

Maitti *et al.*, (2003) conducted an experiment to study the effects of nitrogen fertilizer rate (0, 120, and 140 kg ha^{-1}) on the performance of 1 cultivar (IET-4786) and 4 hybrid varieties (ProAgro 6Y213, ProAgro 6Y3024, ProAgro 6111N, and ProAgro 6201) of rice in Mohanpur, West Bengal, India. The nitrogen fertilizer was applied during transplanting (50%) and at the tillering and panicle initiation stages (50%). They reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%), and 1000-grain weight (5.80%) over the control, and the highest nitrogen (136.701 kg ha^{-1}), phosphorus (132.029 kg ha^{-1}) and potassium (135.167 kg ha^{-1}) uptake.

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Rahman *et al.*, (2007) showed that the maximum grains panicle^{-1} (100.80) and highest grain yield (5.34 t ha^{-1}) were obtained with 80 kg N ha^{-1}. The highest straw yield (6.98 t ha^{-1}) was obtained at the highest nitrogen level (100 kg N ha^{-1}).

Singh and Shivay (2003) found that increasing levels of nitrogen significantly increased the grain and straw yields.

Verma *et al.*, (2004) conducted an experiment in Madhya Pradesh, India to investigate the effect of planting date (20 July; and 5 and 20 August) and N rates (50, 100 and 150 kg ha^{-1}). They revealed that N at 100 and 150 kg ha^{-1} resulted in the highest yield.

Wan *et al.*, (2007) conducted an experiment in China to study the effects of different nitrogen (N) fertilizer application regimes (basal and panicle applications) on the yield, quality and N use efficiency of super japonica hybrid rice cv. Changyou 1. They indicated that yield was significantly influenced by the different N fertilizer application regimes. The regime with the highest yield was at the basal to panicle application ratio of 58.34:41.66 and equal split panicle applications at the fourth and second leaf age from the top.

2.2 Effect of phosphorus

Phosphorus is very important for crop growth and yield development. Phosphorus is remains in soil as unavailable form. For these reason, inorganic phosphorus fertilizer is necessary to apply in the rice field. Phosphorus application resulted in normal growth, early ripening and increased yield. Phosphorus enhanced the photosynthetic efficiency of leaves, increased the grain yield and shortened the growth period of rice. It is suggested that P application could enhance the absorption and use of nitrogen and potassium by hybrid rice (Liu, 1996).

2.2.1 Effect on growth character

2.2.1.1 Plant height

Alam *et al.*, (2009) conducted an experiment at the Agronomic field of the Sher-e-Bangla Agricultural University to study the relative performance of inbreed and hybrid rice varieties at different levels of P. Three varieties of inbreed and hybrid (BRRI dhan48, Aloron and Hira 2) and five levels of P (0, 24, 48, 72 and 96 kg P ha^{-1}) were used as treatment. They reported that

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plant height and growth rate varied significantly due to variation of P and tallest plant was obtained with 96 kg P ha^{-1}.

Alvi *et al.*, (2004) to evaluate how much P should be applied to the rice and wheat crops under rice-wheat cropping system. Nitrogen and potassium were applied uniformly to all the plots at the rate of 120 and 60 kg ha^{-1} respectively. They reported that plant height was influenced significantly by the application of P.

Conde *et al.*, (2016) showed that sufficient P application increased plant height, shoot biomass, tiller number, and panicle dry weight compared to that of no P fertilization. Rice-soybean rotation with optimal P supply is a suitable agricultural mode on acid soils, and rotating with the P efficient soybean genotype could benefit more in soil nutrient status, which might increase the agriculture sustainability on acid soils.

Devi *et al.*, (2018) showed that maximum plant height, number of effective tillers per hill, panicle length and dry matter production were recorded with 60 kg each of P_2O_5 and K_2O ha^{-1} which remain at par with 40 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} respectively.

Fageria and Baligar (1997) carried out an experiment to evaluate on the growth and P use efficiency of 20 upland rice cultivars at low (0 mg P kg^{-1}), medium (75 mg P kg^{-1}) and high (150 mg P kg^{-1}) levels of applied P on an Oxisol. Plant height was influenced significantly by the application of P.

Fageria *et al.*, (2013) found that plant height was obtained with the application of 175 mg P kg^{-1} of soil.

Imrul *et al.*, (2016) observed that at 30 and 60 days after transplanting (DAT) and at the time of harvest the tallest plants were observed in the treatments P_2 (35 kg P ha^{-1}) and treatment combination N_2P_2 (120 kg N and 35 kg P ha^{-1}) whereas, the treatments P_0 and treatment combination N_0P_0 (without N and P) showed the smallest plant height in each case, respectively.

2.2.1.2 Tillering pattern

Alam *et al.*, (2009) reported that tiller production differed significantly with the application of P fetrilizer and 72 kg P ha^{-1} showed to produce better tiller production and fertility.

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Fageria *et al.*, (2013) found that tiller number was obtained with the application of 192 mg P kg^{-1} of soil.

Uddin *et al.*, (2014) found that all the traits were statistically significant due to Phosphorus whereas 40 kg P ha^{-1} recorded the maximum tillers $hill^{-1}$ (17.58) at 85 DAT.

Vejchasarn *et al.*, (2016) reported that tiller number, number of nodal roots and shoot phosphorus content were reduced under low phosphorus availability.

2.2.1.3 Total dry matter production

Ahmmed *et al.*, (2014) showed that maximum dry matter yield was recorded in phosphate rock (PR) @ 210 kg P ha^{-1} treatment (935.20 kg ha^{-1}) and the minimum dry matter yield was recorded in control treatment (909.53 kg ha^{-1}).

Alam *et al.*, (2009) found that dry matter partitioning in different part plants varied significantly due to variation of P.

Brasil *et al.*, (2002) showed that the soils received three rates of phosphorus (40, 80 and 120 mg P kg^{-1} of soil) plus the control treatment. Highest dry matter was obtained in soils fertilized with triple super phosphate.

Fageria *et al.*, (2013) found that Dry matter was significantly ($P < 0.01$) influenced by P fertilization.

Islam *et al.*, (2008) found that the P content at different growth stages increased progressively with an increase of P levels. The grain of rice content P also increased 2.96 mg g^{-1} dry weight at high P application.

Sharma *et al.*, (2012) reported that increasing phosphorus levels up to 45 kg P ha^{-1} significantly increased growth parameters such as plant height, flag leaf area, dry matter accumulation.

Slaton *et al.*, (2004) observed that whole-plant P concentration and dry-matter accumulation at the mid-tillering stage generally increased as P-fertilizer rate increased.

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2.2.2 Effects on yield contributing characters

Alam *et al.*, (2009) suggested that filled grain panicle^{-1}, unfilled grain panicle^{-1}, spikelet sterility, 1000-grain weight had a significant effect with the application of P fertilizer.

Das and Sinha (2005) reported that 40 kg P_2O_5 ha^{-1} give the better performance in relation to length of panicle of rice.

Devi *et al.*, (2018) showed that maximum number of effective tillers per hill, panicle length and dry matter production were recorded with 60 kg each of P_2O_5 and K_2O ha^{-1} which remain at par with 40 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} respectively.

Duhan and Singh (2002) reported that 40 kg P_2O_5 ha^{-1} give the better performance in relation to length of panicle of rice.

Haque (1988) found that the effect of phosphorus on the spikelet sterility induced by low temperature at reproductive stage was not clear except that at the highest phosphorus (P) level (10 ppm) the spikelet sterility increased both in Fujisaka-5 and IR36. Spikelet sterility induced by low temperature at the reproductive stage of rice decreased with the increase of potassium (K) supply in both Fujisaka-5 and IR36.

Jiang *et al.*, (1999) conducted an experiment on whitish lacustrine soil, rice was given 0, 2, 4, 6 and 8 kg P_2O_5 mu^{-1}. The total number of panicles and grain number panicle^{-1} increased with up to 6 kg P_2O_5 mu^{-1}.

Khan *et al.*, (2009) reported that 1000 grain weight was significantly increased with P application over control. The application of P significantly increases number of spike plant^{-1} and spike length over control, however no statistical difference was recorded among the treatment.

Mondal *et al.*, (2003) conducted a field experiment to investigate the effect of P application on rice cv. IET-5656- lathyrus cv. The treatments comprised 4 fertilizer management levels, i.e. fertilizer application as per farmers practice (40:20:20 kg N: P_2O_5:K_2O ha^{-1}) to rice and no fertilizer application to lathyrus (T_1); 100% of recommended dose of fertilizer (RDF) both rice and lathyrus (T_2); 100% of RDF to rice + recommended dose of P for lathyrus to rice (T_3) and RDF for lathyrus + recommended dose of P for rice to lathyrus at sowing (T_4). The RDF for rice was 80:40:40: kg N: P_2O_5:K_2O ha^{-1} and that for lathyrus was 10:20:20 kg N: P_2O_5:K_2O ha^{-1}.

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They reported that highest number of effective tiller m^{-2} (425.0), number grains $panicle^{-1}$ (92.8) of rice were obtained from T_3 treatment.

Ortega and Rojas (1999) reported that the P application decreased floret sterility.

Sahar *et al.*, (2003) reported that increasing the rate of P compound $panicle^{-1}$, increasing the rate of grain number $panicle^{-1}$.

Shah (2002) examined the P deficiency in control plots caused stunted growth with limited tillers and decreased filled spikelet percentage $panicle^{-1}$.

Shar and Burbey (2003) conducted a field experiment at farmer fields in dry season, from June to September 2001 with six NPK compound doses (0, 50, 100, 150, 200 and 250 kg NPK ha^{-1}). Results showed that increasing rate of NPK compound significantly affected the grain number $panicle^{-1}$, unfilled grain percentages, 1000 grain weight and grain yield. The highest grain yield was found by applying 100 kg Urea + 250 kg NPK compound, following by 82.5 kg N + 37.5 kg P_2O_5 ha^{-1}+ 37.5 kg K_2O ha^{-1}.

Sharma *et al.*, (2012) reported that increasing phosphorus levels up to 45 kg P ha^{-1} significantly increased yield components (such as number of panicles m^{-2} and number of grain $panicle^{-1}$) grain and straw yields.

Uddin *et al.*, (2014) showed that phosphorus @ 40 kg ha^{-1} recorded the greater results on effective tillers $hill^{-1}$ (13.67), panicle length (22.04 cm), filled grains $panicle^{-1}$ (138.60), 1000-grain weight (30.75 g) while without phosphorus obtained the lower results on the above.

Ye *et al.*, (2019) observed that the grain numbers per panicle increased by 31.4%, 23.9% and 48.2% and the panicle numbers increased by 55.1%, 29.2% and 6.7% after application of N, P, K fertilizers respectively.

Yosefi *et al.*, (2011) also reported that number of grains $panicle^{-1}$ was significantly influenced by phosphorus fertilizer.

Yosef Tabar (2013) showed that spikelet number, fertile spikelet, fertile spikelet percentage (%), Spikelet sterility percentage (%), biological and grain yield increased significantly with nitrogen and phosphorus fertilizer.

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2.2.3 Effects on yield parameters

2.2.3.1 Grain and straw yield

Alam *et al.*, (2009) observed that application of 72 kg P ha^{-1} produced the highest grain yield of rice (7.23 t ha^{-1}), while plants grown without phosphorus fertilizer gave the lowest grain yield (4.99 t ha^{-1}).

Amanullah *et al.*, (2016) showed that the increase in P levels in both experiments (animal manure vs. plant residues) resulted in higher rice productivity (90 > 60 > 30 > 0 kg P ha^{-1}).

Das *et al.*, (2003) showed that increasing phosphorus levels increase both grain and straw yields of rice thus increase the economic return.

Dwivedi *et al.*, (2006) reported that phosphorus and potassium, higher doses each of 80 kg ha^{-1} P_2O_5 and K_2O were found to be better to obtain higher production and good quality (protein) of hybrid rice. The maximum grain yield was recorded with 200 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1}.

Fairhurst *et al.*, (2007) showed that the thumb rule is where the soil P supply is small, apply 8.7 kg P ha^{-1} for each tone of target grain yield increase (difference between yield target and yield in no-P plot).

Hasanuzzaman *et al.*, (2012) observed that phosphorus at 50 kg P_2O_5 gave the highest grain yield (7.85 t ha^{-1}).

Hussain *et al.*, (1994) conducted a pot experiment on rice and wheat crops to see their response to P application. Phosphorus as SSP was applied @ 0, 13,20,26 and 0,11,22,23,33 mg kg^{-1} soil to rice and wheat respectively. Grain and straw yields and productive tillers of rice and wheat increased significantly with P application.

Hye *et al.*, (2019) showed that the highest grain yield (5.97 t ha^{-1}) and straw yield (11.50 t ha^{-1}) were obtained from Zn_{10} P_{50} treatment. Phosphorus application significantly increased the P content in grain and straw but zinc content significantly decreased while effect of zinc significantly decreased the P content in grain and straw but increased the Zn content.

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Iqbal (2004) stated that a positive effect on rice biomass and grain yield for P application was observed which varied from 5.8 to 7.8 t ha^{-1}.

Islam *et al.*, (2010) showed 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. The optimum and economic rate of P for T. *aman* was 20 kg P ha^{-1}.

Islam *et al.*, (2008) showed that a considerable response of Chili and T. *aman* rice to N, P and K was observed. The results indicated that fertilizer nutrient dose that maximized yield of Chili and T. *aman* rice were 119-97-92 kg ha^{-1} and 63-20-37 kg ha^{-1} NPK, respectively while 117-93-89 kg ha^{-1} NPK for chili and 60-19-36 kg ha^{-1} NPK for T. *aman* rice were in respect of yield and economics.

Khan *et al.*, (2009) reported that paddy yield was increased significantly by P application up to 75% over control.

Lal *et al.*, (2002) conducted a field experiment to study the individual and interactive effects of P (0, 11, 22, and 33 kg ha^{-1}) and Zn (0, 6 and 12 kg ha^{-1}) on the yield and P uptake of lowland rice. They reported that maximum grain yield (33.35 q ha^{-1}) and P uptake (10.06 kg ha^{-1}) were observed with the combined application of 33 kg P and 12 kg Zn ha^{-1}. Available P in soil samples after harvest increased considerably with increasing rates of P and Zn application.

Mahajan *et al.*, (1994) conducted a plot experiment on utilization of fertilizer phosphorus by some rice varieties as influenced by phosphorus fertilization in black soil. Grain yield was the highest with 80 kg P_2O_5 ha^{-1}.

Massawe *et al.*, (2017) showed that the P fertilizers applications increased rice yield components as the levels of P increased from 0 to 60 kg P ha^{-1} for all P sources. The yield components increased significantly ($P<0.05$) with increasing rates of P application.

Nadeem and Ibrahim (2002) showed that rice crop was 100 kg P_2O_5 and 120 kg N ha^{-1} and highest paddy yield was obtained from the treatment where 37.5 kg (50%) P was applied. It showed that when wheat received its recommended dose of P then for rice only 50% of the recommended rate (75%) is enough to achieve the optimum yield of rice.

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of fertilizer the grain and straw yield was 4.363 and 4.877 t ha^{-1} and for 50% increase of fertilizer the grain and straw yield was 4.90 and 5.390 t ha^{-1}, respectively.

Uddin *et al.*, (2014) found that all the traits were statistically significant due to Phosphorus whereas 40 kg P ha^{-1} the maximum weight of grain, straw and biological yield 5.12, 8.39 and 13.51 t ha^{-1}, respectively and harvest index (37.85%) at harvest.

Zubaida and Munir (2002) conducted an experiment with phosphorus fertilizer on rice. They found that phosphorus application by P-starter (20 kg SP_{36} ha^{-1}) is more economical and more benefit over phosphorus application of 100 kg SP_{36} ha^{-1} and reduce fertilizer application 80 kg SP_{36} ha^{-1} and gave yield of paddy rice 4.236 and 4.320 t ha^{-1} respectively.

From the literatures presented above, it can be concluded that nitrogen, phosphorus and their interaction play a remarkable role for growth, yield and yield components of rice. Presence or absence of one element influences the uptake of other elements and thereby growth and yield of rice.

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CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, experimental site, climatic condition, soil, crop or planting materials, seedling raising, experimental design and layout, treatments, crop growing procedure, general observation of the field, harvesting and post harvesting operation, data collection, experimental measurement and statistical analysis.

3.1 Experimental period

The experiment was conducted during the period from August, 2018 to December, 2018 in *aman* season.

3.2 Experimental site

The experiment was conducted at Professor Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna. The experiment site under the agro-ecological zone Ganges Tidal Flood Plain (AEZ-13).

3.3 Climate

The experimental area was characterized by medium temperature, high humidity, during Aman season with low clouds or sometimes scattered clouds causes rainfall with gusty winds. The weather data during experimental period at the experimental site are shown in Appendix I.

3.4 Soil

The soil in the experimental site was medium low land. Well drained and silty loam. Soil samples from 0-15 cm depths were collected from experimental field. The analysis was done at Soil Resource and Development Institute (SRDI), Khulna. The chemical properties of the soil are presented in Appendix II.

3.5 Collection and preparation of initial soil sample

Before land preparation initial soil sample was collected. Three samples were collected from different locations of the field and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves, other inert particles etc. were picked up and

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removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.6 Planting material

BR23, a high yielding variety of rice, developed by BRRI was used as the test crop. This variety was considered as local farmers were interested to cultivate this variety. This variety grown in *Aman* season. It is tolerant to salinity and water stagnant condition (to some extent). Maximum height is about120 cm, life cycle is about150 days and grain yield is about 5.5 t ha^{-1}.

3.7 Seed collection and sprouting

Seeds of BR23 were collected from authentic seed dealer of Khulna city. Seeds were dipped in water in a bucket for 24 hrs. After 24 hrs seeds were taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.8 Raising of seedlings

Seedlings were raised in well prepared seedbed near the experimental field. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. After sprouting the seeds were sown in the wet seedbed. The sprouted seeds were sown uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.9 Preparation of experimental land

The experimental land was ploughed by a power tiller and was leveled carefully to get a well puddle soil. All kinds of weeds and residues of previous crop were removed from the field. According to the split-plot design, field layout was done in 19 August, 2018.

3.10 Fertilizer management

The experimental plots were fertilized with muriate of potash (MOP), gypsum, zinc sulphate @ 34, 22.5 and 5 kg ha^{-1} respectively as basal dose (BRRI, 2010). As muriate of potash, gypsum, zinc sulphate is the source of potassium, sulphur and zinc, respectively. TSP and urea were given as basal following treatment variable.

3.11 Experimental treatments

Treatment was considered of two factors like

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Factor A: Nitrogen Level (N): Two levels

1) $N_0 = 0$ kg N ha^{-1}

2) $N_1 = 93$ kg N ha^{-1} (As BRRI recommended)

Factor B: Phosphorus Level (P): Four levels

1) $P_0 = 0$ kg P ha^{-1}

2) $P_1 = 8$ kg P ha^{-1}

3) P_2=16 kg P ha^{-1} (As BRRI recommended)

4) $P_3 = 24$ kg P ha^{-1}

3.12 Experimental design

The experiment was laid out in a split plot design, with three replications having urea in the main plot and phosphorus in the sub-plot. There were 24 treatments combinations. Plot size was 3 m x 2 m = 6 m^2. The distance between replication to replication, main plot to main plot, sub-plot to sub-plot were 75 cm, 50 cm and 50 cm, respectively. The distance between line to line and plant to plant in plot was 25 cm and 15 cm, respectively.

3.13 Transplanting of seedlings

Thirty days old seedlings were uprooted carefully. In previous day the seed beds were made wet by application of water for easy uprooting of the seedlings. Seedlings were transplanted giving 2 or 3 seedlings hill^{-1} as per treatment on 20 August, 2018.

3.14 Intercultural operations

3.14.1 Gap filling: Gap filling was done where it was necessary with the same age of seedlings.

3.14.2 Weeding: The experimental field was kept weed free throughout the growing period. Two hand weeding was done to check weed infestation at 30 and 50 DAT.

3.14.3 Plant protection measures: Rice stem borer was controlled by using nitro on 17 October, 2018. Furadon 5G @ 9.9 kg ha^{-1} was applied to control ufra disease. Melathion @ 1.00 L ha^{-1} was applied to control green leaf hopper and thrips.

3.15 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment from plot to plot and replication to replication. Observation on weed, disease infestation, insect and pest

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infestation were done to keep the field crops safe for better growth of the crop to get maximum yield. No bacterial and fungal disease was observed.

3.16 Harvesting and post-harvest operation: The crops were harvested at their fully maturity when 90% of the grain turned golden yellow color. Harvesting of all plots were done in a day on 12 December, 2018. Before harvesting 5 hills were uprooted randomly from each plot for taking yield attributes data. Then the rest crops from each plot were harvested carefully, bundled separately, tagged properly as their plot number and brought to the clean threshing floor. Grain and straw yield were recorded from whole plot basis and the weights were converted into ton ha^{-1}. The grain and straw weight were adjusted to 14% moisture level.

3.17 Recording of data

Data on the following growth and yield parameters were collected.

A. Crop growth characters

1. Plant height: Plant height (cm) was recorded at 15 days interval started from 40 DAT to harvest. The height of the plant was determined by measuring the length from the top to root.
2. Tiller number $hill^{-1}$: Tillers number $hill^{-1}$ was recorded at 15 days interval started from 40 DAT to harvest. These was recorded from 5 hills and the mean was calculated. It might be includes both effective tiller and non- effective tiller.
3. Dry matter $hill^{-1}$: Dry matter $hill^{-1}$ was recorded at 15 days interval started from 40 DAT to harvest. Two hills were uprooted and sundried for 3 days then oven dried at 70□ for 72 hours. After that weight was taken to calculate the dry matter accumulation $hill^{-1}$.
4. Crop growth rate (CGR): CGR was recorded from oven dried plant at five (5) growth stages started from 40DAT. Crop growth rate (CGR) was calculated by the formula given by Beadle (1987).

$$CGR = \frac{W2-W1}{T2-T1} \text{ g hill}^{-1} \text{ day}^{-1}$$

Where, W_1= Dry weight of 1^{st} time plant uptaking T_1= 1^{st} Time of uptaking

W_2= Dry weight of 2^{nd} time plant uptaking T_2= 2^{nd} time of uptaking

5. Relative growth rate (RGR): RGR was recorded from the oven dry weight of plant started from 40DAT. RGR was calculated by following formula given by Evans (1972).

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$$RGR = \frac{\log W2 - \log W1}{T2 - T1} \text{ mg g}^{-1} \text{ day}^{-1}$$

6. Leaf weight ratio (LWR): LWR was recorded from the weight of the leaves and whole plants started from 40DAT. Leaf weight ratio was expressed as the dry weight of leaves to whole plant dry weight and was expressed in g g^{-1}. LWR was calculated by following formula:

$$LWR = \frac{\text{Leaf weight (g)}}{\text{Total plant weight (g)}}$$

B. Yield contributing characters

1. Effective tillers $hill^{-1}$: The tillers with panicle which have at least one grain were considered as effective tiller. That was counted from 5 hills and the mean was calculated.
2. Panicle length (cm): Panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.
3. Filled grains $panicle^{-1}$: If food materials were present in grain it was considered as filled grains. The number of filled grains was counted from 10 panicles and was calculated mean.
4. Unfilled grains $panicle^{-1}$: When any food materials were absent it was considered as unfilled grain. The unfilled grain number was counted similarly as of filled grain counting.
5. 1000- grains weight: 1000 clean and fully developed dried grains were collected from each plot separately and weighted by an electric balance and the weight was adjusted at 14% moisture level.

C. Yield parameters

1. Grain yield (t ha^{-1}): Grain yield obtained from whole plot while the 5 hills grains were weighted separately and finally added to the whole grain weight. The weight was adjusted to 14% moisture level. The weight of grains of each plot was converted to ton ha^{-1}.
2. Straw yield (t ha^{-1}): Total straw yield of each plot was determined and converted the yield to ton ha^{-1}. The weights were adjusted at 14% moisture level.

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3. Biological yield (t ha^{-1}): Grain yield and straw yield were all together regarded as biological yield. The biological yield was calculated with the following formula- Biological yield = Grain yield + Straw yield

4. Harvest index (%): The harvest index is expressed as the percent and calculated by the ratio between the economic yield and biological yield.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.18 Analysis of data: Quantitative information on growth and yield performance of rice was subjected to analysis of variance (ANOVA) using 'Statistics 10' software and means of the treatments were compared using Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

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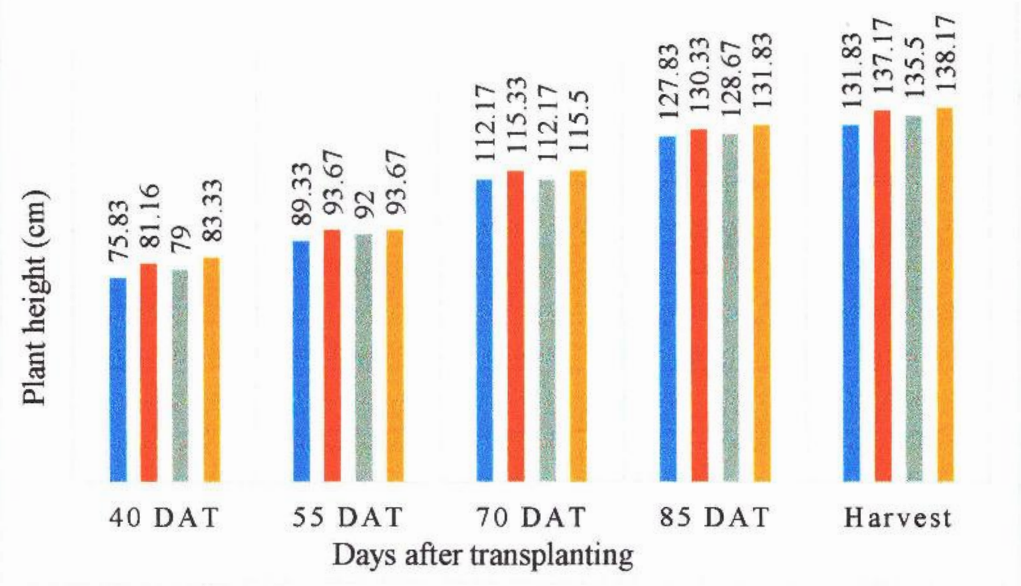

Figure 2: Effect of phosphorus dose on plant height of BR23 rice at different days after transplanting (DAT)

[P_0 = 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.1.1.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus levels on plant height was statistically significant except 40 DAT and 85 DAT (Table 1 and appendix III). Except at harvest, all the growth stages had the longest plant height in N_1P_1 treatment but at harvest it was in N_0P_3 treatment combination. N_0P_0 treatment produced shortest plants in all growth stages. Other treatment combinations produced statistically similar plant height at all growth stages. Saito *et al*., (2005) conducted an experiment and reported that application of 90 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave highest plant height.

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Table 1. Interaction effect of nitrogen and phosphorus on plant height (cm) of BR23 rice at different days after transplanting (DAT)

Treatment combination	Plant height (cm)				
	40 DAT	55 DAT	70 DAT	85 DAT	Harvest
N_0P_0	69.33	83.00 b	105.67 b	123.67	129.67 b
N_0P_1	74.67	85.67 b	109.33 ab	125.67	133.33 ab
N_0P_2	75.00	87.33 ab	108.00 ab	125.00	133.00 ab
N_0P3	82.00	91.67 ab	113.67 ab	131.00	142.33 a
N_1P_0	82.33	95.67 ab	118.67 ab	132.00	142.33 ab
N_1P_1	87.67	101.67 a	121.33 a	135.00	141.00 ab
N_1P_2	83.00	96.67 ab	117.33 ab	132.33	138.00 ab
N_1P_3	84.67	95.67 ab	116.33 ab	132.67	134.00 ab
LS	NS	*	*	NS	*
CV (%)	7.07	5.98	5.30	3.95	3.87

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = control treatment N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}; * indicates treatments were significant at 0.05% level; NS= non-significant]

4.1.2 Total tiller number hill^{-1}

4.1.2.1 Effect of nitrogen

Tiller number hill^{-1} was not significantly influenced by the nitrogen levels at all growth stages except 85 DAT (Figure 3 and Appendix IV). Tiller number hill^{-1} was found highest at 40 DAT and there after declined. At 40 DAT, 55 DAT,70 DAT and at harvest, tiller number hill^{-1} was not significantly different between N dose but higher with 93 kg N ha^{-1} (N_1). Significant variation in tiller number were not observed in most of the growth stages with the application of nitrogen doses might be due to the power to supply nitrogen to the tiller primordium controls tillering (Tanaka *et al.*, 1964). The lowest tiller number was obtained from control treatment (N_0). At 85 DAT, the highest tiller number (12.25) was obtained from 93 kg N ha^{-1} (N_1) and the lowest tiller number (10.66) was obtained from control treatment (N_0). At this stage tiller number varied

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significantly. It may be due to adequate supply of nitrogen to plant. However, a general trend was observed that the number of total tillers hill^{-1} were higher with the application of nitrogen. The improvement in the formation of tillers with N application in the present experiment might be due to increase of nitrogen availability which enhanced tillering. The lowest number of effective tillers was obtained when no N fertilizer was applied. Similar results have been obtained by Singh and Arya (1992) and Jasim *et al.*, (1984), Awan *et al.*, (2011). Jisan *et al.*, (2014) found that highest number of total tiller hill^{-1} were observed from 75 kg N ha^{-1} and the lowest values were obtained from control on BRRI dhan52.

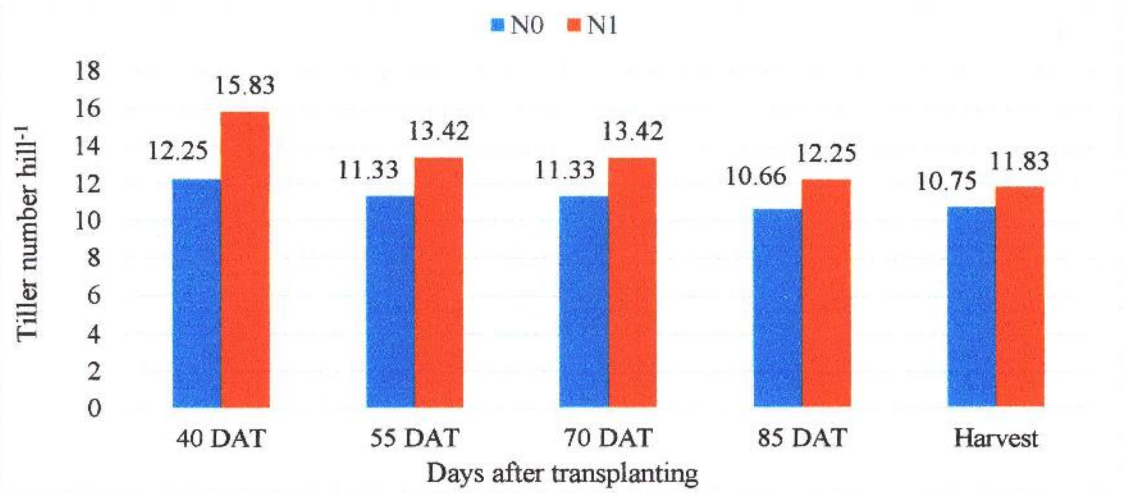

Figure 3: Effect of nitrogen on tiller number hill^{-1} of BR23 rice at different days after transplanting (DAT) [N_0= control treatment, N_1= 93 kg N ha^{-1}]

4.1.2.2 Effect of phosphorus

Significant variation in tiller number hill^{-1} was not observed due to different levels of phosphorus at all growth stages (Figure 4 and Appendix IV). Tiller number was maximum at 40 DAT and then decline. At 40 DAT, highest tiller hill^{-1} (14.83) was obtained with 16 kg P ha^{-1} (P_2) and minimum tiller number hill^{-1} (13.50) was observed with 24 kg P ha^{-1}(P_3). At 55 DAT, highest tiller number (12.83) was obtained from 24 kg P ha^{-1} (P_3) and lowest tiller number (12.00) was obtained from 8 kg P ha^{-1} (P_1). At 70 DAT, the highest tiller number (12.67) was obtained from both control (P_0) and 16 kg P ha^{-1} (P_2) and lowest tiller number per hill (11.83) was obtained from 8 kg P ha^{-1} (P_1). At 85 DAT, the highest tiller number per hill (11.83) was obtained from 16 kg P ha^{-1} (P_2) and minimum tiller number (10.67) was obtained from 8 kg P ha^{-1} (P_1). At harvest, the highest tiller number (11.50) was obtained from 24 kg P ha^{-1} (P_3) and lowest tiller number

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(11.17) was obtained from both control and 8 kg P ha^{-1} (P_0 and P_1). As our experimental soil was clay type and had a higher cation exchange capacity (CEC), so in the soil with a large CEC, the growth of rice plants is made vigorous in the latter half of the growing period by the application of phosphate fertilizer. But in this case it is unthinkable that the CEC of soil directly exerts an important influence upon the behavior of phosphorus. De Datta (1981) reported that increase in tiller was due to application of P.

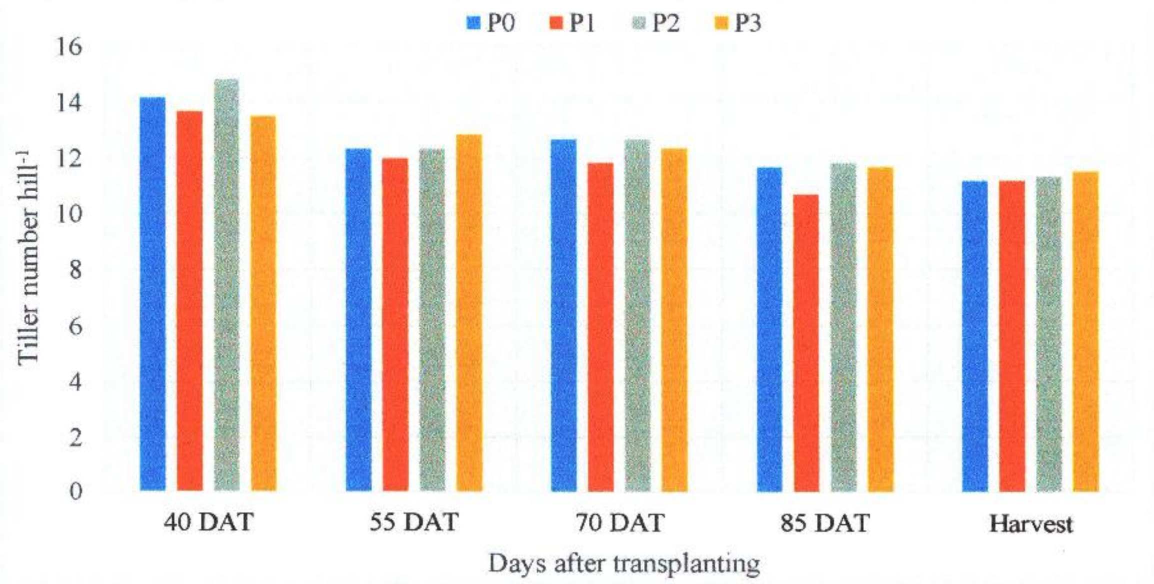

Figure 4: Effect of phosphorus on tiller number hill^{-1} of BR23 rice at different days after transplanting

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.1.2.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus levels showed significant influence on the tiller number in all DAT except at harvest (Table 2 and appendix IV). At 40 DAT, 55 DAT, 70 DAT and 85 DAT the highest tiller was achieved by N_1P_0 (93 kg N ha^{-1} and 0 kg P ha^{-1}) treatment combination and lowest tiller number was achieved by N_0P_0 (control) treatment combination. These treatments were significantly different from each other. At harvest, highest tiller number (12.33) was observed from N_0P_3 (0 kg N ha^{-1}+ 24 kg P ha^{-1}), N_1P_1(93 kg N ha$_{-1}$ + 8 kg P ha^{-1}) and N_1P_2 (93 kg N ha^{-1}+ 16 kg P ha^{-1}) treatment combination. Lowest tiller number (10) was observed from N_0P_1 (0 kg N ha^{-1} and 8 kg P ha^{-1}) treatment combination. In this experiment the total tiller hill^{-1} was found decreased with time. Yoshida (1981) stated that it could happened due to tiller mortality of rice plants after reproductive stage.

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Table 2. Interaction effect of nitrogen and phosphorus on tiller hill^{-1} of BR23 rice at different days after transplanting (DAT)

Treatment combination	Tiller number hill^{-1}				
	40 DAT	55 DAT	70 DAT	85 DAT	Harvest
N_0P_0	9.667 c	10.00 b	10.67 b	9.67 b	10.33
N_0P_1	13.00 abc	11.67 ab	11.00 ab	10.00 b	10.00
N_0P_2	12.33 bc	11.00 ab	11.000	10.33 ab	10.33 b
N_0P3	14.00 abc	12.67 ab	12.67 ab	12.67 ab	12.33
N_1P_0	18.67 a	14.67 a	14.67 a	13.67 a	12.00
N_1P_1	14.33 abc	12.33 ab	12.67 ab	11.33 ab	12.33
N_1P_2	17.33 ab	13.67 ab	14.33 ab	13.33 a	12.33
N_1P_3	13.00 bc	13.00 ab	12.00 ab	10.67 ab	10.67
Level of significance	*	*	*	*	**NS**
CV (%)	**18.35**	**15.30**	**14.94**	**15.73**	**13.37**

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2 = 16 kg P ha^{-1}, P_3 = 24 kg P ha^{-1}; * indicates treatments were significant at 0.05% level; NS= non-significant]

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4.1.3 Total dry matter production

4.1.3.1 Effect of nitrogen

Fresh plant dried to a constant weight is called as dry matter. Total dry matter (TDM) production indicates the potential production of a crop. A high TDM production is the first pre-requisite for high yield. Data on TDM of leaves, leaf sheath + stem and or panicles of plants were measured at 40 DAT, 55 DAT, 70 DAT, and 85 DAT and at harvest. It was showed in Figure 5 and Appendix V that significant variation was found in the total dry matter accumulation at different growth stages. Accumulation of dry matter was very slow at early stage (40 DAT to 70 DAT) and increased progressively over time attaining the highest at harvesting time. However, the rate of increase varied depending on the growth stages. At 40 DAT, 55 DAT, 70 DAT, 85 DAT and at harvest growth stages dry matter production was highest with N_1 (93 kg N ha^{-1}) treatment. And lowest dry matter production was achieved from N_0 (control) treatment. But the differences were

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significant because nitrogen helps in increasing vegetative plant parts. For more applying nitrogen vegetative growth was increased as well as dry matter increased. Geethadevi *et al.*, (2000) concluded that application of 150 kg N ha^{-1} gave highest total dry matter per plant.

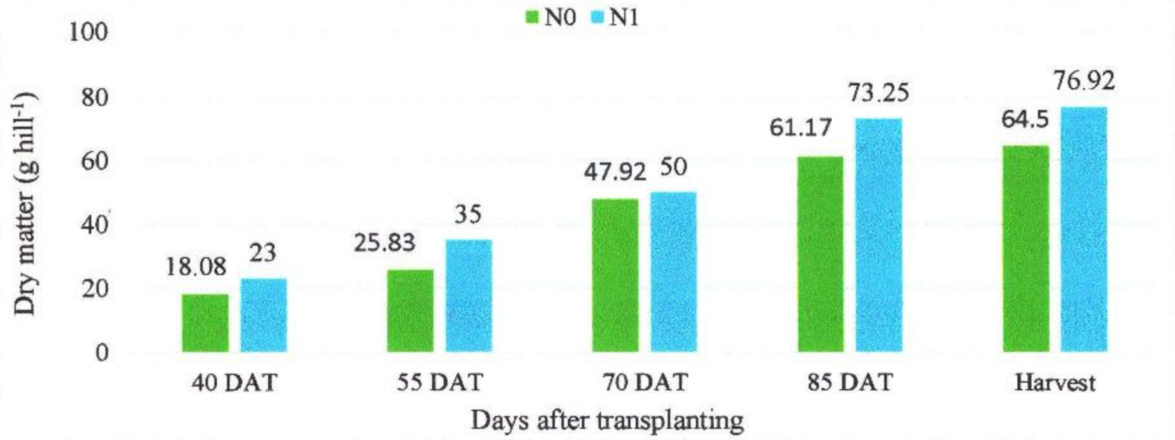

Figure 5: Effect of nitrogen on total dry matter of BR23 rice at different days after transplanting (DAT) [N_0= control treatment, N_1= 93 kg N ha^{-1}]

4.1.3.2 Effect of phosphorus

The level of phosphorus had no significant difference to accumulate the total dry matter in all growth stages of BR23 rice except at 40 DAT (Figure 6 and Appendix V). Accumulation of total dry matter increased progressively over the time attaining the maximum at harvest. The rate of increase, however, varied depending on the growth stages. At 40 DAT, the highest dry matter (22.83 g) was achieved from P_2 (16 kg P ha^{-1}) treatment which was more or less similar to P_3 (24 kg P ha^{-1}) treatment. The lowest dry matter (18.50 g) was achieved from P_0 (control) treatment. At 55 DAT, the highest dry matter production (32.67 g) was found from P_2 (16 kg P ha^{-1}) treatment and the lowest dry matter (28.33 g) was found from P_1 (8 kg P ha^{-1}) treatment. At 70 DAT, the highest dry matter production (51.50 g) was achieved from P_3 (24 kg P ha^{-1}) treatment and the lowest dry matter production (47.67 g) achieved from P_0 (control) treatment. At 85 DAT, the highest dry matter production (72.67 g) was observed from P_3 (24 kg P ha^{-1}) treatment and the lowest dry matter production (64.83 g) was found from P_0 (control) treatment. At harvest, the highest dry matter (75.17 g) was achieved from P_3 (24 kg P ha^{-1}) treatment and the lowest dry matter production (68.83 g) was found from P_0 (control) treatment. Positive influence of

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phosphorus on total dry matter in rice was also reported by Gupta and Bhadra (1980) and Sharkar and Chowdhury (1988).

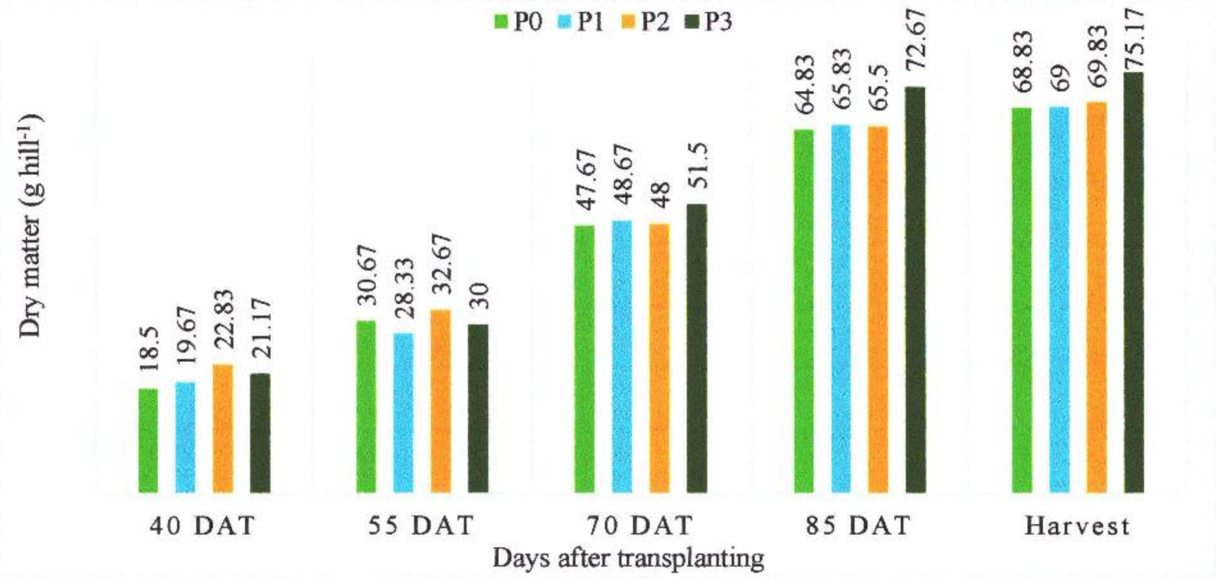

Figure 6: Effect of phosphorus dose on dry matter of BR23 rice at different growth Stages (DAT)

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.1.3.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus had significant difference to accumulate the total dry matter at all growth stages except 70 DAT in BR23 rice (Table 3 and appendix V). Accumulation of total dry matter increased progressively over the time attaining the maximum at harvest. The rate of increase, however, varied depending on the growth stages. At 40 DAT, the highest dry matter production (26.00 g) was found from N_1P_2 (93 kg N ha^{-1}+ 16 kg P ha^{-1}) treatments and the lowest dry matter production (15.00 g) was found from N_0P_0 (control) treatment combination. At 55 DAT, the highest dry matter production (39.00 g) was achieved from N_1P_2 (93 kg N ha^{-1}+ 16 kg P ha^{-1}) treatment combination and the lowest dry matter production (24.67 g) was achieved from both N_0P_0 (control) and N_0P_1 (0 kg N ha^{-1}+ 8 kg P ha^{-1}) treatment combinations. At 70 DAT, the highest dry matter production (56.67 g) was found from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and the lowest dry matter (45.33 g) production was found from N_0P_1(0 kg N ha^{-1}+ 8 kg P ha^{-1}) treatment combination. At these growth stage all the difference was not significant. At 85 DAT, the highest dry matter (77.67 g) was found from N_1P_3 (93 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination. That result was similar

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with N_1P_0 (93 kg N ha^{-1}+ 0 kg P ha^{-1}), N_1P_1 (93 kg N ha^{-1}+8 kg P ha^{-1}) and N_1P_2 (93 kg N ha^{-1}+16 kg P ha^{-1}) treatment combinations. The lowest dry matter (55.00 g) was found from N_0P_0 (control) treatment combination. At harvest, the highest dry matter (80.67 g) was obtained from N_1P_3 (93 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination and the lowest dry matter (59.33 g) was obtained from N_0P_0 (control) treatment combination. Saito *et al.* (2005) reported that application of 90 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave higher total dry matter.

Table 3. Interaction effect of nitrogen and phosphorus on dry matter $hill^{-1}$ of BR23 rice at different days after transplanting (DAT)

Treatment combination	Dry matter $hill^{-1}$ (g)				
	40 DAT	**55 DAT**	**70 DAT**	**85 DAT**	**Harvest**
N_0P_0	15.00 d	24.67 c	49.67	55.00 c	59.33 d
N_0P_1	17.00 cd	24.67 c	45.33	62.00 bc	65.67 bcd
N_0P_2	19.67 bc	26.33 bc	50.33	59.67 bc	63.33 cd
N_0P3	20.67 bc	27.67 bc	46.33	68.00 abc	69.67 abcd
N_1P_0	22.00 bc	36.67 a	45.67	74.67 a	78.33 a
N_1P_1	22.33 b	32.00 ab	52.00	69.67 ab	72.33 abc
N_1P_2	26.00 a	39.00 a	45.67	71.33 ab	76.33 ab
N_1P_3	21.67 bc	32.33 ab	56.67	77.33 a	80.67 a
Level of significance	*	*	NS	*	*
CV (%)	**7.63**	**13.30**	**15.99**	**11.82**	**10.16**

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3 = 24 kg P ha^{-1}; * indicates treatments were significant at 0.05% level; NS= non-significant]

4.1.4 Crop growth rate (CGR)

4.1.4.1 Effect of nitrogen

Effect of nitrogen on crop growth rate was significantly affected at all growth stages (figure 7 and Appendix VI). Maximum CGR was achieved from N_1 treatment (93 kg N ha^{-1}). And lowest CGR was observed from N_0 (control) treatment. Because more nitrogen helps in more vegetative growth of rice plant. Low nitrogen or lack of nitrogen decrease vegetative growth. Leaf cessation may be occurred and that's way photosynthesis was ceased. So, CGR was low with control treatment. Crop growth rate was minimum in the early stages due to the complete absence of vegetation and low percentage of light absorption was lower but with the rapid increase in the rate of plant growth that occurs because the level of developed leaves and thus absorption of solar radiation increases (Beadle, 1987). CGR values increased with the increase in nitrogen dose. This result was in agreement with the findings of Thakur and Patel (1999). Rahman *et al.*,

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(2007) found the highest CGR (15.26 g $m^{-2}d^{-1}$) was produced when 100 kg N ha^{-1} was applied on DAT. The CGR values increased rapidly along with LAI up to 60-90 DAT and there after decreased markedly. CGR values increased with the increase in nitrogen level.

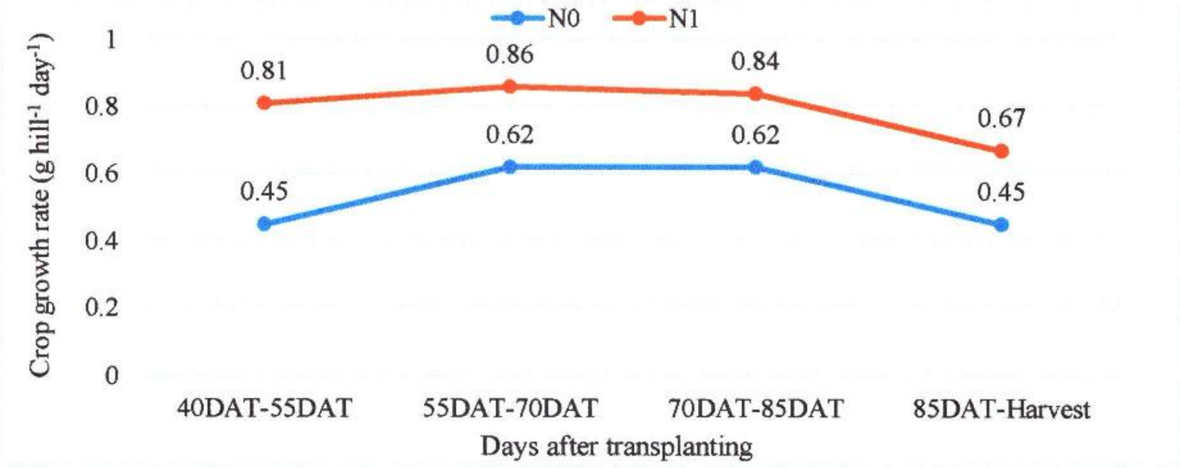

Figure 7: Effect of nitrogen on crop growth rate (CGR) of BR23 rice

[N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}]

4.1.4.2 Effect of phosphorus

Effect of phosphorus on crop growth rate was significantly affected among different phosphorus treatments at all growth stages (figure 8 and appendix VI). During 40 DAT to 55 DAT, 55 DAT to 70 DAT, 70 DAT to 85 DAT and 85 DAT to harvest, the highest crop growth rate was obtained from P_3 (24 kg P ha^{-1}) treatment. It might be due to the progressive increase in dry matter production of crop with the advancement of crop growth stages. This result was supported by Alam *et al.*, (2009), who reported that different levels of phosphorus had significant effect on crop growth rate of rice, irrespective P sources. Plant grown without P fertilizer had the lower CGR values at all the growth stages. The lowest crop growth rate was observed from P_0 (control) treatment. Raghuveer *et al.*, (2014) showed that the maximum CGR was observed with application of 60 kg P_2O_5 ha^{-1} and the lowest in control (without P) at all the growth duration except 90-120 DAT. At 90-120 DAT stage control 0.77 mg cm^{-2} day^{-1} was significantly superior over 20, 40 and 60 kg ha^{-1} phosphorus level.

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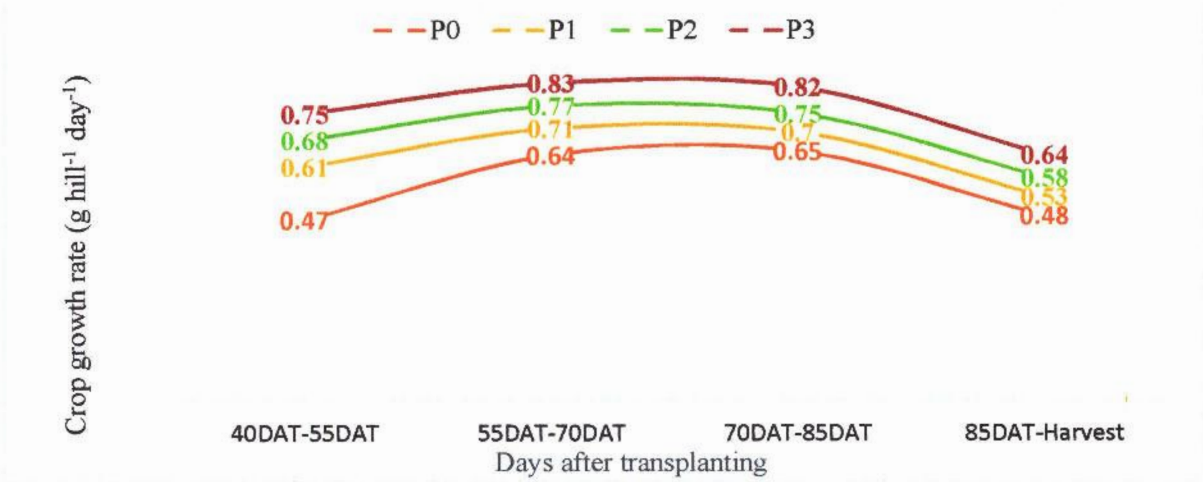

Figure 8: Effect of phosphorus on crop growth rate (CGR) of BR23 rice at different days after transplanting (DAT)

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.1.4.3 Interaction effect of nitrogen and phosphorus

The interaction effect of the treatments had significant effect on the crop growth rate at different growth stages except at 40 DAT to 55 DAT (Table 4 and appendix VI). With increasing phosphorus levels along with added nitrogen, crop growth rate (CGR) was increased and it was peak at the stage between 55 DAT to 85 DAT. The highest CGR was observed in 93 kg nitrogen per hectare (N_1) and 24 kg P ha^{-1} (P_3) treatment combination. As nitrogen helps phosphorus uptake, so ultimately crop growth rate was increased. Minimum of this trait obtained in control levels of nitrogen and phosphorus. In general crop growth rate was increased at faster rate up to 85 DAT and there after decreased up to harvest. At 55 DAT to 70 DAT, highest CGR was obtained from N_1P_3 treatment combination. And the lowest CGR was obtained from N_0P_0 treatment combination. At 70 DAT to 85 DAT, the highest CGR was obtained from N_1P_3 treatment combination. The results reveled that higher phosphorus dose with added nitrogen enhanced CGR but phosphorus had less effect when no nitrogen was added. Higher values of CGR at stages from 55 DAT to 85 DAT might be due to the higher leaf weight ratio in that period. It should be noted that lower values of crop growth rate at the late stages were due to senescence of leaves at the end of the growing season.

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Table 4. Interaction effect of nitrogen and phosphorus on crop growth rate (CGR) g hill^{-1} day^{-1} of BR23 rice at different days after transplanting

Treatments combination	Crop growth rate (g hill^{-1} day^{-1})			
	40DAT-55DAT	**55DAT-70DAT**	**70DAT-85DAT**	**85DAT-Harvest**
N_0P_0	0.31	0.55e	0.54g	0.38h
N_0P_1	0.40	0.58e	0.60f	0.43g
N_0P_2	0.51	0.65d	0.64e	0.47f
N_0P_3	0.58	0.70d	0.70d	0.53e
N_1P_0	0.64	0.74d	0.75d	0.59d
N_1P_1	0.82	0.84c	0.81c	0.64c
N_1P_2	0.86	0.89b	0.86b	0.69b
N_1P_3	0.92	0.96a	0.94a	0.75a
Level of significance	**NS**	*	*	*
CV (%)	**7.50**	**3.65**	**3.04**	**1.09**

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2 = 16 kg P ha^{-1}, P_3 = 24 kg P ha^{-1}; * indicates treatments were significant at 0.05% level; NS= non-significant]

4.1.5 Relative growth rate

4.1.5.1 Effect of nitrogen

Effect of nitrogen on relative growth rate (RGR) was significantly affected at all growth stage (Figure 9 and appendix VII). The highest relative growth rate (RGR) was obtained from N_1 (93 kg N ha^{-1}) and the lowest RGR was obtained from N_0 treatment (control). It indicates that nitrogen addition significantly increased RGR. Nitrogen additions strongly increased unit leaf growth rate but slightly decreased specific leaf area and leaf area ratio, which also results in an overall increase in RGR (Sims *et al.*, 2012). Taub (2002) also found that RGR responded to nitrogen because of increased unit leaf growth rate and leaf area ratio in spite of decreased specific leaf area. Poorter and Nagel (2000) also found similar patterns in a meta-analysis of the literature on trees, seedlings, and herbaceous plants.

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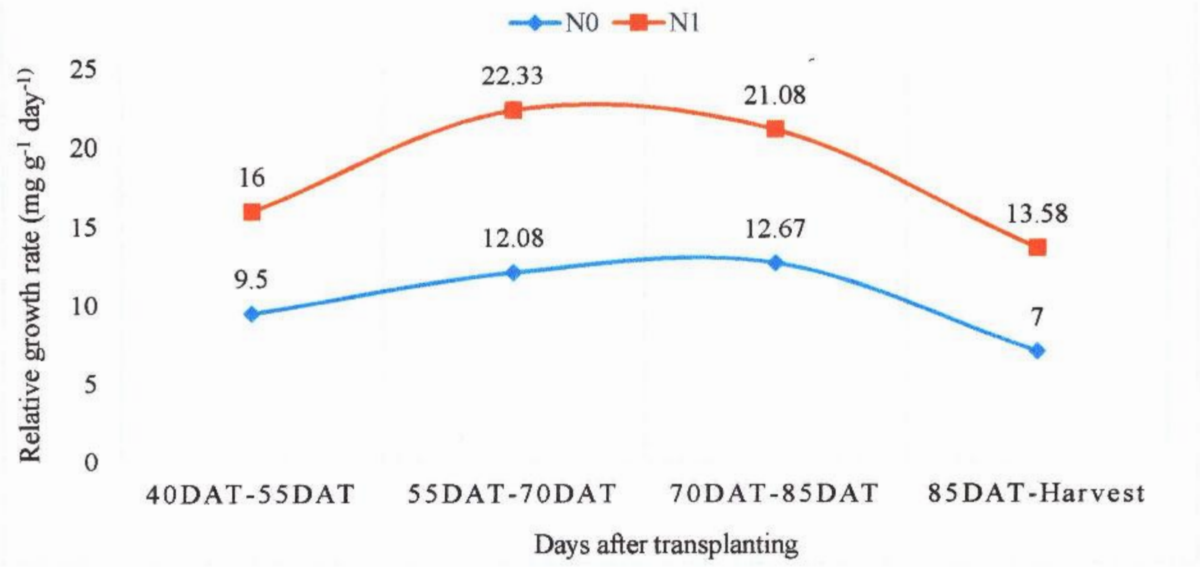

Figure 9: Effect of nitrogen on relative growth rate (RGR) of BR23 rice at different days after transplanting (DAT)

[N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}]

4.1.5.2 Effect of phosphorus

Effect of phosphorus on relative growth rate (RGR) was significantly affected at all growth stage (Figure 10 and appendix VII). The highest RGR was observed from P_3 (24 kg P ha^{-1}) treatment and the lowest RGR was observed from P_0 (control) treatment. A null response can happen when a plant does not take up the available resource and was therefore unable to use it. At 55 DAT to 85 DAT, the highest RGR (19.5 mg g^{-1} day^{-1} and 20.33 mg g^{-1} day^{-1}) was observed from P_3 (16 kg P ha^{-1}) treatment. After 85 DAT, RGR was decreased. Alam *et al.*, (2009) showed in his experiment that RGR at different growth durations was significantly influenced by phosphorus levels. Irrespective of P levels, RGR was more at early stage (25-50 DAT) and showed a decreasing trend with the advancement of plant age. At 25 to 50 DAT the highest RGR was observed with control, where the lowest RGR was observed from application of 96 kg P_2O_5 ha^{-1}. Generally, the highest RGR was observed with 72 and 96 kg P_2O_5 ha^{-1} but the effect was not significantly different. The trend of RGR was partially supported by Fageria and Baligar (1993). Raghuveer *et al.*, (2014) showed that the maximum RGR was observed with application of 60 kg P_2O_5 ha^{-1} and the lowest in control (without P) at all the growth duration except 90-120 DAT. Application of 60 kg P_2O_5 ha^{-1} (22.16 mg g^{-1} day^{-1}) was significantly superior over 40, 20 kg P_2O_5 ha^{-1} and control (19.41, 18.60 and 15.00 mg g^{-1} day^{-1}) at 60-90 DAT, respectively.

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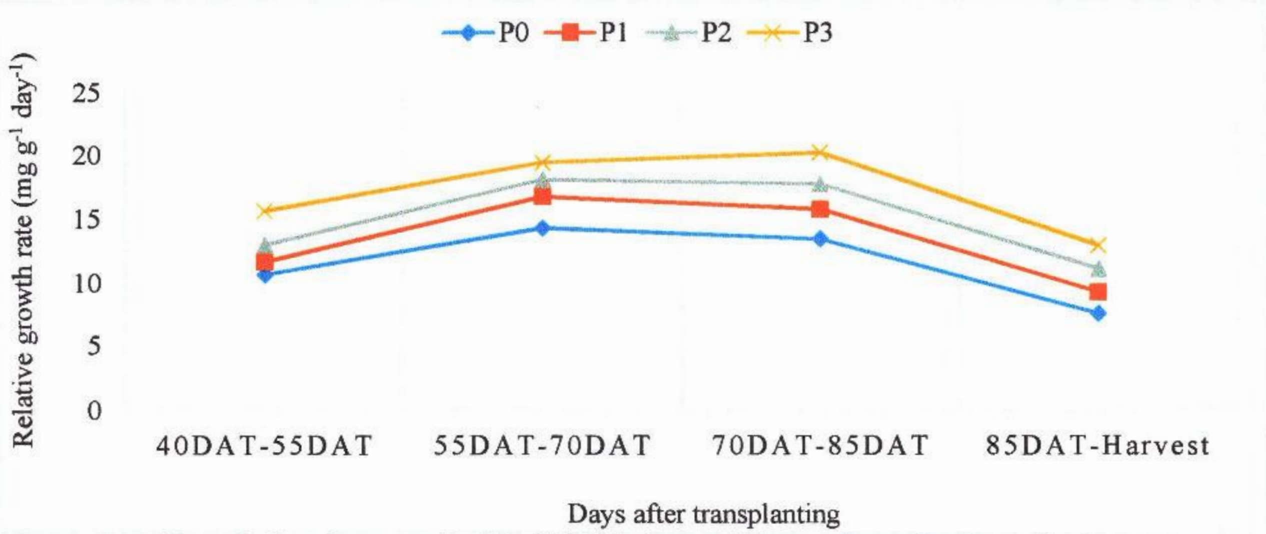

Figure 10: Effect of phosphorus on RGR of BR23 rice at different days after transplanting

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.1.5.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus on relative growth rate (RGR) of BR23 rice variety was significantly different at all the growth stages except 70 DAT to 85 DAT and 85 DAT to harvest (Table 5 and appendix VII). During 40 DAT to 55 DAT, the highest RGR (18.67 mg g^{-1} day^{-1}) was observed from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and lowest RGR (6.67 mg g^{-1} day^{-1}) was observed from N_0P_0 (control) treatment combination. At 55 DAT to 70 DAT and 70 DAT to 85 DAT and 85 DAT to harvest, the highest RGR was achieved from N_1P_3 (93kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and the lowest RGR was found from N_0P_0 (control) treatment combination. Nitrogen additions alone increased biomass, but phosphorus additions alone did not. Phosphorus addition increased biomass only when N was added, indicating a phosphorus limitation after nitrogen limitation is reduced. This interaction between nitrogen and phosphorus availability in wild rice has also been noted by Walker *et al.*, (2010).

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Table 5. Interaction effect of nitrogen and phosphorus on relative growth rate (RGR) mg g^{-1} day^{-1} of BR23 rice at different days after transplanting

Treatments combination	Relative growth rate (mg g^{-1} day^{-1})			
	40DAT-55DAT	**55DAT-70DAT**	**70DAT-85DAT**	**85DAT-Harvest**
N_0P_0	6.67f	8.67g	10.00	4
N_0P_1	8.33e	11.33f	12.33	6.33
N_0P_2	10.33d	13.33e	13.33	8
N_0P_3	12.67c	15.00d	15.00	9.67
N_1P_0	14.67b	20.00c	17.00	11.33
N_1P_1	15.00b	22.33b	19.33	12.33
N_1P_2	15.67b	23.00ab	22.33	14.33
N_1P_3	18.67a	24.00a	25.67	16.33
Level of significance	*	*	**NS**	**NS**
CV (%)	**5.85**	**3.69**	**5.41**	**5.12**

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2 = 16 kg P ha^{-1}, P_3 =24 kg P ha^{-1}; * indicates treatments were significant at 0.05% level; NS= non-significant]

4.1.6 Leaf weight ratio

4.1.6.1 Effect of nitrogen

Effect of nitrogen on leaf weight ratio (LWR) was non-significantly affected at all growth stages. The effect of nitrogen fertilizer contents on leaf weight ratio (LWR) in each treatment was relatively similar (Figure 11). At 40 DAT, 55 DAT, 70 DAT, 85 DAT and at harvest, the higher value of leaf weight ratio was achieved from N_1 (93 kg N ha^{-1}) treatment. Higher value of LWR affected by more nitrogen contents was reported by Gibson *et al*., (2004). Hamidullah *et al*., (2006) obtained highest leaf area increase (5.53) with higher dose of nitrogen. The lowest LWR was recorded at all growth stages from N_0 (0 kg N ha^{-1}) treatment.

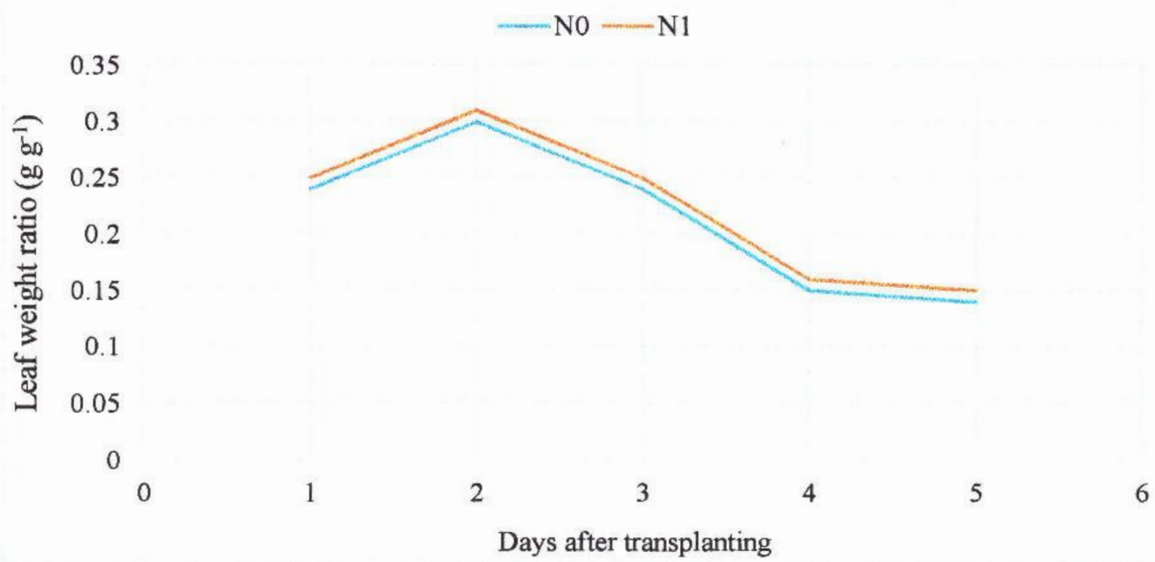

Figure 11: Effect of nitrogen on leaf weight ratio (LWR) of BR23 rice at different days after transplanting [N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}]

4.1.6.2 Effect of phosphorus

Effect of phosphorus on leaf weight ratio (LWR) was non significantly affected at all growth stage except 40 DAT and 70 DAT (Figure 12). However, at all growth stages, the highest leaf weight ratio was observed from P_3 (24 kg P ha^{-1}) treatment and lowest LWR was observed from P_0 (control) treatment. Leaf area ratio was at the peak at 55 DAT and decline there-after. Hamidullah *et al*., (2006) reported that leaf area index was peak at 60 DAT and decline there-after. Phosphorus become active and release faster because of well aerated soil. Phosphorus is an active element in the leaves since it regulates photosynthesis energy storage and its movement through the plant. Transpiration and sugar breakdown or glycolysis also require constant phosphorus levels so that the absorbed sunlight can be converted into usable energy for growth and reproduction while the plant exchanges air with the surrounding environment. The differences were non-significant. It may be due to P-loss was mainly associated with erosion and runoff. Phosphorus is released faster when soil is well aerated (higher oxygen levels) and much slower on saturated wet soils. At these stages, our experimental field was saturated with rain water. So, phosphorus release was slow and its effects on plant growth was not distinct always.

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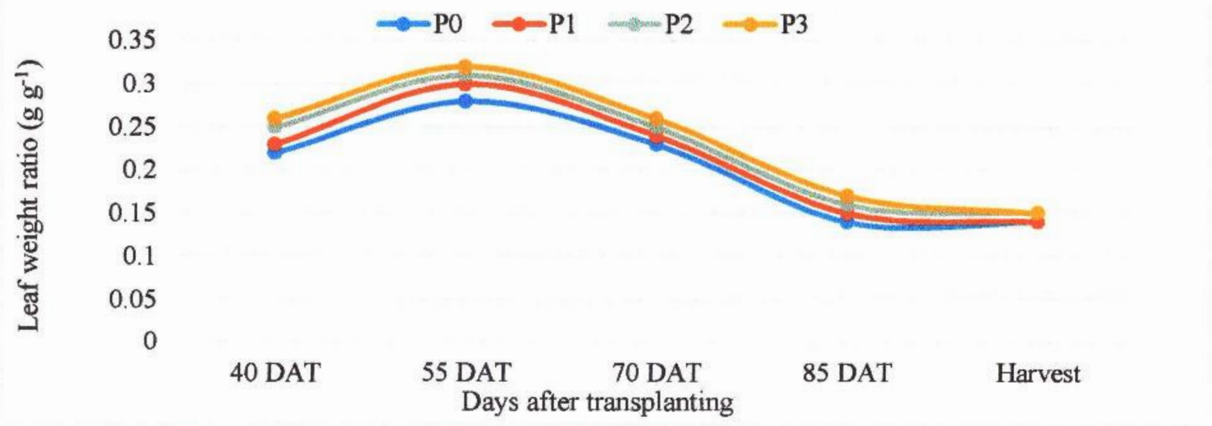

Figure 12: Effect of phosphorus on leaf weight ratio of BR23 rice at different days after transplanting

[P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2 = 16 kg P ha^{-1}, P_3 =24 kg P ha^{-1}]

4.1.6.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus on leaf weight ratio (LWR) of BR23 rice variety was non-significantly affected in all growth stage except 40 DAT and 70 DAT (Table 6). At 40 DAT, 70 DAT, 85 DAT and at harvest, the highest LWR was observed from N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment combination Nitrogen helps phosphorus uptake process. As our experimental soil was riched optimum nitrogen, so, N_0P_0 was performed best. So, ultimately leaf weight ratio was increased. And the lowest LWR (0.21 g g^{-1}) was achieved from N_0P_0 (control) treatment combination at 40 DAT. At 55 DAT, the highest LWR (0.33 g g^{-1}) was observed from N_1P_2 (93 kg N ha^{-1} + 16 kg P ha^{-1}) treatment combination and the lowest LWR was observed from N_0P_0 (control) treatment combination. At 70 DAT, the lowest LWR (0.22 g g^{-1}) was observed from N_0P_2 (0 kg N ha^{-1} + 16 kg P ha^{-1}) treatment combination. It may be due to failure of P uptake process. As temperature affect P uptake process and at these period temperature was high and affected P uptake. At 85 DAT, the lowest LWR (0.14 g g^{-1}) was observed from both N_1P_0 (93 kg N ha^{-1} + control) and N_1P_1 (93 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combinations. Leaf weight ratio was decreased at the end point of plant growth stage near at harvest. At harvest, the lowest LWR (0.12 g g^{-1}) was observed from N_1P_1 (93 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination. At these stage whole plant weight was increased because grain weight was added with whole plant weight and leaf number was decreased as well as leaf weight was decreased.

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Table 6. Interaction effect of nitrogen and phosphorus on leaf weight ratio (LWR) of BR23 rice at different days after transplanting

Treatments combination	Leaf weight ratio ($g\ g^{-1}$)				
	40 DAT	55 DAT	70 DAT	85 DAT	Harvest
N_0P_0	0.27 a	0.28	0.26 a	0.19	0.17
N_0P_1	0.21 c	0.30	0.23 ab	0.15	0.16
N_0P_2	0.26 ab	0.31	0.22 b	0.16	0.14
N_0P_3	0.22 bc	0.31	0.24 ab	0.15	0.13
N_1P_0	0.24 abc	0.29	0.25 ab	0.14	0.14
N_1P_1	0.22 bc	0.32	0.26 ab	0.14	0.12
N_1P_2	0.24 abc	0.33	0.24 ab	0.15	0.15
N_1P_3	0.22 bc	0.30	0.24 ab	0.15	0.15
Level of significance	*	NS	*	NS	NS
CV (%)	9.20	11.45	8.25	18.84	18.12

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1 = 93 kg N ha^{-1}; P_0 = 0 kg P ha^{-1}, P_1 = 8 kg P ha^{-1}, P_2 = 16 kg P ha^{-1}, P_3 =24 kg P ha^{-1}; DAT= Days after transplanting; * indicates treatments were significant at 0.05% level; NS= non-significant]

4.2 Yield contributing characters

4.2.1 Effective tiller $hill^{-1}$

4.2.1.1 Effect of nitrogen

The number of effective tillers $hill^{-1}$ was non-significantly influenced by nitrogen application (Table 7 and appendix VIII). The highest number of effective tillers $hill^{-1}$ (12.92) was obtained in N_1 (93 kg N ha^{-1}) treatment, the number of productive tillers depends on environmental conditions especially nutrient during tiller bud initiation and subsequent developmental stages (Power and Alessi (1978) and Masle (1985). The lowest (10.42) was obtained from N_0 (0 kg N ha^{-1}) treatment. Similar results have been obtained by Singh and Arya (1992) and Jasim *et al.* (1984). Nitrogen also increases the number of tillers as it favors many metabolic processes within the plant system. Adequacy of nitrogen probably favored the cellular activity during panicle formation and development, which led to increased number of effective tillers $hill^{-1}$. Pandey *et al.*, (1991) and Thakur (1993) also reported the similar results from their studies. More number of tillers m^{-2} in experiment might be due to the more availability of nitrogen that played a vital role in cell division. These results are in accordance to the findings of Rajput *et al.*, (1988). The lower effective tiller number occurred due to the failure in competition for nitrogen at lower level and aggravate death of the tillers due to mutual shading (Fageria *et al.*,1997).

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Ahmed *et al.*, (2005) recorded highest number of effective tiller at a moderate rate of N (40 kg ha^{-1}) than higher dose of 60 and 80 kg ha^{-1}.

4.2.1.2 Effect of phosphorus

The number of tillers $hill^{-1}$ was influenced by phosphorus application and it increased significantly with the increase in P dose (Table 8 and appendix VIII). The highest effective tiller number $hill^{-1}$ (13.17) was obtained from P_3 (24 kg P ha^{-1}) treatment and the lowest effective tiller number was obtained from P_1 (8 kg P ha^{-1}) treatment statistically similar to effective tillers which was observed from 0, 8 and 16 kg P ha^{-1}. Plant growth, development of root, tillering, early flowering and performs other functions like metabolic activities, particularly in protein synthesis are highly influenced by phosphorus. Application of phosphorus increased P availability to plant for producing more effective tiller $hill^{-1}$. Alam *et al.*, (2009) reported that 75 kg P_2O_5 ha^{-1} produced higher effective tillers $hill^{-1}$. A similar result was reported by Katyal (1978), Matsua *et al.*, (1995) also reported that it is necessary to apply much P fertilizers to help rice plants to accelerate the P absorption for increased tillering. Matsua *et al.*, (1995) reported that it is necessary to apply much P fertilizers to help rice plants to accelerate the P absorption for increased effective tillering.

4.2.1.3 Interaction effect of nitrogen and phosphorus

The effect of interaction between N and P was found to be significant in respect of number of effective tillers $hill^{-1}$ (Table 9 and appendix VIII). The highest effective tiller (15.67) was achieved from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination. Venkateswarlu and Singh (1980) observed highest number of effective tillers with 120 kg N + 60 kg P_2O_5 + 45 kg K_2O ha^{-1} followed by 80 kg N + 40 kg $P2O_5$ + 30 kg K_2O ha^{-1}. Chaturvedi (2005) stated that yield is greatly influenced by number of tillers per unit area especially fertile tillers. At harvest tillers m^{-2} of rice is increased significantly due to application of nitrogen fertilizer. Yosef Tabar (2012) observed that 150 kg ha^{-1} nitrogen with 90 kg ha^{-1} phosphorus gave maximum (22.25) fertile tillers. Rasheed *et al.*, (2003) reported that the number of effective tillers per hill was increased when NP levels were increased. And the lowest effective tiller number (10.00) was observed from both N_0P_1 (control + 8 kg P ha^{-1}) and N_0P_2 (control + 16 kg P ha^{-1}) treatment combination which was statistically similar with other treatment combination except N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination. The results reveled that effective tiller number was

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affected due to phosphorus dose with no nitrogen and no phosphorus with nitrogen treatments while influenced by phosphorus doses with nitrogen and the highest value was at highest phosphorus dose.

4.2.2 Panicle length

4.2.2.1 Effect of nitrogen

Panicle length was influenced significantly by nitrogen application (Table 7 and appendixVIII). The highest panicle length (27.67 cm) was observed from N_1 (93 kg N ha^{-1}) treatment. And the lowest panicle length (25.83 cm) was observed from N_0 (control) treatment. Nitrogen took part both in panicle formation and elongation and for this reason panicle length increased with adequate N levels. Mondal and Swamy (2003) reported 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. Ahmed *et al.*, (2005) also found that higher N dose produced higher panicle length. Yoseftabar (2013) noticed that panicle length increased with an increase in nitrogen fertilization, maximum panicle length (28.64 cm) was obtained by applying 300 kg N ha^{-1} while minimum was counted when nitrogen was applied @ 100 kg ha^{-1}. Abou-Khalifa (2012) checked some rice varieties under different levels of nitrogen and found the significant effect of nitrogen on panicle length. Nitrogen fertilization at higher rate gave rise to increase panicle length (20.81 cm) while control having no nitrogen application gained minimum panicle length (18.23 cm). Fine rice was evaluated using nitrogen fertilization and seedling density. It was observed that initially panicle length increased with increase in nitrogen and then decreased with further increase.

4.2.2.2 Effect of phosphorus

Phosphorus had significant role in increasing the panicle length of BR23 rice (Table 8 and appendix VIII). The highest panicle length (27.67 cm) was observed from P_3 (24 kg P ha^{-1}) treatment followed by P_2 (16 kg P ha^{-1}) treatment. And the lowest panicle length (25.5 cm) was observed from P_0 (control) treatment. Das and Sinha (2006) reported that 40 kg P_2O_5 ha^{-1} gave the better performance in relation to length of panicle of rice. Similar result was reported for low land rice by Sahar and Burbey (2003).

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4.2.2.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus dose had significant effect on panicle length of BR23 rice (Table 9 and appendixVIII). The highest panicle length (28.33 cm) was achieved from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination which was statistically similar with N_1P_2 (93 kg N ha^{-1} + 16 kg P ha^{-1}) and N_1P_1 (93 kg N ha^{-1}+ 8 kg P ha^{-1})treatment combinations. And the lowest panicle length (24.00cm) was achieved from both N_0P_0 (control) treatment combinations. Asif *et al.*, (2000) reported that NPK levels significantly increase the panicle length when NPK fertilizer applied in 180-90-90 kg ha^{-1}.

4.2.3 Filled grains panicle^{-1}

4.2.3.1 Effect of nitrogen

Filled grains panicle^{-1} is one of the most important yields contributing parameter in case of grain crops. The effect of nitrogen significantly increased the number of filled grains panicle^{-1} (Table 7 and appendix VIII). The highest filled grain (125.83) was observed from N_1 (93 kg N ha^{-1}) treatment and the lowest filled grain (108.5) was observed from N_0 (control) treatment. The variability in number of filled or unfilled grains per panicle is dependent on many factors such as genotypes, cultural techniques and growing environment of the crop (Maloch *et al.*, 2006). Excessive as well as low application of nitrogen fertilizer causes lower number of filled grains and higher number of unfilled grains per panicle of rice. Optimum amount of nitrogen fertilizer on the other hand produces maximum number of filled grains and minimum number of unfilled grains per panicle. These findings were in agreement with the findings of Lawal and Lawal (2002) who reported that adequate supply of nitrogen is essential for grain development of rice and to increase filled grains per panicle. Nitrogen promotes rapid growth and increased spikelet number per each panicle, percentage filled spikelets number per panicle (Fallah, 2012). Hasanuzzaman *et al.*, (2012) reported the significant effect of nitrogen rates on number of filled grains panicle^{-1}. They reported maximum value (154.67) of filled grains when nitrogen was applied as urea super granules @ 75 kg ha^{-1} which was statistically at par with 80, 120 and 160 kg N ha^{-1} and minimum value (126.16) was given by control with no nitrogen application. Metwally *et al.*, (2011) checked the response of hybrid rice to different levels of nitrogen and found that number of filled grains panicle^{-1} increased significantly with increase in nitrogen level up to certain limit and then starts declining with further increase. According to the findings

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of Kandil *et al.*, (2010) maximum number of filled grains panicle^{-1} were obtained at maximum level of nitrogen *i.e.* 192 kg ha^{-1} while minimum value (81.6) was given by control having no nitrogen application.

4.2.3.2 Effect of phosphorus

Filled grains panicle^{-1} was significantly affected by different dose of phosphorus (Table 8 and appendix VIII). The highest filled grain (125.67) was observed from P_3 (24 kg P ha^{-1}) followed by P_2 (16 kg P ha^{-1}) treatment and produced (124.33). The lowest number of filled grains (106.33) was obtained from P_1 (8 kg P ha^{-1}) treatment. Sahar and Burbey (2003) showed that increasing the rate of P significantly affected the grain number panicle^{-1}. Yosef Tabar (2012) stated that the highest total grains panicle^{-1} was recorded for 150 kg ha^{-1} phosphorus fertilizer. Yosefi *et al.*, (2011) also reported that number of grains panicle^{-1} was significantly influenced by phosphorus fertilizer.

4.2.3.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was found significant on filled grains panicle^{-1} (Table 9 and appendix VIII). The highest filled grain per panicle (134.67) was found from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination which was statistically similar with N_1P_2 (93 kg N ha^{-1} + 16 kg P ha^{-1}) and N_1P_0 (93 kg N ha^{-1} + 0 kg P ha^{-1}), N_0P_2 (0 kg N ha^{-1} + 16 kg P ha^{-1}) and N_0P_3 (0 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combinations . In these treatment N was not applied but they were statistically similar. It may be due to nitrogen helps phosphorus uptake process and adequate amount of nitrogen help phosphorus to contribute in grain filling. The lowest number of filled grain (93.33) was found from N_0P_0 (control) treatment combination. Yosef Tabar (2012) found maximum fertile spikelet for 150 kg ha^{-1} nitrogen with 60kg ha^{-1} phosphorus fertilizer. Singh *et al.* (2003) reported 120 kg N ha^{-1} and 26 kg P_2O_5 ha^{-1} produced highest number of filled grains per panicle.

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4.2.4 Unfilled grains panicle^{-1}

4.2.4.1 Effect of nitrogen

Nitrogen had significant influence on the unfilled grains panicle^{-1} (Table 7 and appendix VIII). The highest number of unfilled grains panicle^{-1} (62.33) was found in N_0 treatment (0 kg N ha^{-1}). Minimum unfilled grain per panicle (39.17) was obtained from N_1 (93 kg N ha^{-1}) treatment.

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These result was supported by BRRI (2006) that 0 kg N ha^{-1} produced the higher number of unfilled grains $panicle^{-1}$ compared to 90 and 120 kg N ha^{-1}. Reduction of filled grain observed was probably caused by limiting source and relation between sink and source for yielding higher production of photo assimilate reducing the production of assimilates, that otherwise would be directed to grain filling and increasing the number of unfilled spikelets, consequently reducing spikelet fertility (Tabrizi *et al.*, 2011).

4.2.4.2 Effect of phosphorus

Unfilled grains $panicle^{-1}$ was significantly affected by different phosphorus levels (Table 8 and appendix VIII). The highest unfilled grain per panicle (59.67) was observed from P_0 (control) treatment. Due to lack of phosphorus, the highest number of unfilled grains $panicle^{-1}$ (59.67) was found in control treatment (P_0). Minimum number of unfilled grains per panicle (42.50) was obtained from P_3 (24 kg P ha^{-1}) treatment. The findings are in agreement with those of Fageria and Barosa- Filho (1982). Alam *et al.*, (2009) reported that it was necessary to know the optimum dose of phosphorus fertilizer for maximum yield and to reduce spikelet sterility of rice, they reported that with increasing levels of soil fertility, the number of filled spikelets $panicle^{-1}$ decreased with corresponding increase in unfilled spikelets.

4.2.4.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was significantly affected unfilled grain per panicle (Table 9 and appendix VIII). Maximum unfilled grains per panicle (73.00) was achieved from N_0P_0 (control) treatment combination. N_0P_1 (0 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination produced second highest unfilled grain (67.33) per panicle. N_0P_2 (0 kg N ha^{-1} + 16 kg P ha^{-1}) treatment combination was responsible to produce 56.00 unfilled grain $panicle^{-1}$ which was statistically similar with N_0P_3 (0 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination. It may be due to phosphorus helps minimum grain filling with minimum nitrogen supply, as our experimental soil supplied optimum amount of nitrogen. N_1P_1 (93 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination produced 41.67 unfilled grain per panicle which was statistically similar with N_1P_0 (93 kg N ha^{-1} + 0 kg P ha^{-1}) treatment combination. It may be due to appropriate nitrogen dose with phosphorus helps to uptake these elements and contribute to grain filling in rice consequently reduced unfilled grain number. Minimum number of unfilled grains was observed from both N_1P_2 (93 kg N ha^{-1} + 16 kg P ha^{-1}) and N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment

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combinations. Nitrogen helps in higher production of photo assimilate which would be directed to grain filling and increasing the number of filled grains, consequently reducing spikelet fertility and due to increasing phosphorus doses number of filled grains increased and ultimately unfilled grains was decreased.

4.2.6 1000 grain weight

4.2.6.1 Effect of nitrogen

The weight of 1000 grains were non-significantly influenced by the different doses of nitrogen (Table 7 and appendix VIII). The highest 1000-grain weight (41.08 g) was recorded from N_1 (93 kg N ha^{-1}) treatment and the lowest 1000-grain weight (38.30 g) was recorded from N_0 (control) treatment. The result was in agreement with the findings of Ibrahiem *et al.*, (2004) that with the increasing levels of nitrogen, no significant effect was observed on 1000 grain weight. Islam *et al.*, (2008) reported weight of 1000 grain weight was not significantly influenced by N level as it is mostly governed by genetic makeup of the variety.

4.2.6.2 Effect of phosphorus

1000-grain weight of BR23 rice varied significantly due to phosphorus application (Table 8 and appendix VIII). The highest 1000-grain weight (46.65 g) was observed from P_3 (24 kg P ha^{-1}) treatment. P_2 (16 kg P ha^{-1}) showed second highest 1000-grain weight and it was 42.58 g. Minimum 1000-grain weight (30.33 g) was observed from P_0 (control) treatment. Shah (2002) reported application of 30 kg ha^{-1} P gave highest 1000 grain weight. Alam *et al.*, (2009) found that application of 72 kg P_2O_5 ha^{-1} gave the highest 1000 grain weight. Yosef Tabar (2012) stated that 90 kg ha^{-1} phosphorus fertilizer gave the maximum 1000 grains weight.

4.2.6.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus had significant effect on 1000-grain weight (Table 9 and appendix VIII). The highest 1000-grain weight (49.53 g) was observed from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination followed by N_1P_2 (93 kg N ha^{-1} + 16 kg P ha^{-1}) treatment combination that was statistically similar with N_0P_3 (0 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment. Minimum 1000-grain weight (31.32 g) was observed from N_0P_0 (control) treatment combination. Saito *et al.*, (2005) conducted an experiment and reported that application of 90 kg

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N ha^{-1} with 50 kg P_2O_5 ha^{-1} produced highest thousand grains weight. Yosef Tabar (2012) found that the highest 1000 grains weight with 150 kg N ha^{-1} nitrogen with 90 kg P ha^{-1}.

Table 7. Effect of nitrogen on yield contributing characters of BR23 rice

Treatments combination	Yield contributing characters				
	Effective tiller (no) $hill^{-1}$	Panicle length (cm)	Filled grain per panicle (no)	Unfilled grain per panicle (no)	1000-grain weight (g)
N_0	10.42	25.83b	108.50 b	62.33a	38.30
N_1	12.92	27.67a	125.83 a	39.17b	41.08
Level of significance	NS	*	*	*	NS
CV(%)	16.04	2.02	5.62	9.79	5.23

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}; * indicates significant at 0.05% level; NS=non-significance]

Table 8. Effect of phosphorus on yield contributing character of BR23 rice

Treatment combination	Yield contributing characters				
P_0	11.33b	25.5c	112.33bc	59.67a	30.33d
P_1	11.00b	26.67b	106.33c	54.50b	39.20c
P_2	11.17b	27.17ab	124.33ab	46.33c	42.58b
P_3	13.17a	27.67a	125.67a	42.50d	46.65a
Level of significance	*	*	*	*	*
CV(%)	10.30	2.45	8.33	5.52	3.87

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}; * indicates significant at 0.05% level]

Table 9. Interaction effect of nitrogen and phosphorus on yield contributing character of BR23 rice

Treatments combination	Yield contributing characters				
	Effective tiller (no) $hill^{-1}$	Panicle length (cm)	Filled grain $panicle^{-1}$ (no)	Unfilled grain $panicle^{-1}$ (no)	1000-grain weight (g)
N_0P_0	11.00b	24.00e	93.33c	73.00a	31.32e
N_0P_1	10.00b	26.00d	104.00bc	67.33b	37.62d
N_0P_2	10.00b	26.33cd	120.00ab	56.00c	40.49d
N_0P_3	10.67b	27.00b-d	116.67ab	53.00cd	43.78bc
N_1P_0	11.67b	27.00b-d	131.33a	46.33de	29.34e
N_1P_1	12.00b	27.33a-c	108.67bc	41.67e	40.77cd
N_1P_2	12.33b	28.00ab	128.67a	36.67f	44.67b
N_1P_3	15.67a	28.33a	134.67a	32.00 f	49.53a
LS	*	*	*	*	*
CV (%)	10.30	2.45	8.33	5.52	3.87

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[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}; P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1};* indicates significant at 0.05% level; NS=non-significance]

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of nitrogen

Grain yield was non-significantly influenced by different levels of nitrogen (Figure 13 and appendix IX). The highest grain yield (5.56 t ha^{-1}) was achieved from N_1 (93 kg N ha^{-1}) treatment. Increased grain yield by high rates of applied nitrogen may be due to the favorable growth with higher nutrient uptake, more translocation of carbohydrates towards the sink which increased yield attributes and resulted in producing higher grain yield. And the lowest grain yield (5.13 t ha^{-1}) was achieved from N_0 (0 kg N ha^{-1}) treatment. There was no significant difference was present. Application of nitrogen fertilizer @ 93 kg N ha^{-1} in the experimental field in the present experiment produced the highest number of effective tillers hill^{-1}, filled grains panicle^{-1} which ultimately gave higher grain yield. Singh *et al.*, (2005) stated that each increment dose of nitrogen significantly increased grain yield. BRRI (2006) reported that cultivation of hybrid rice in *boro* required 120 kg N ha^{-1}. In line with this, improvements in yield and its components under the acceptable increasing N rates were reported by Sticksel *et al.*, (2000).

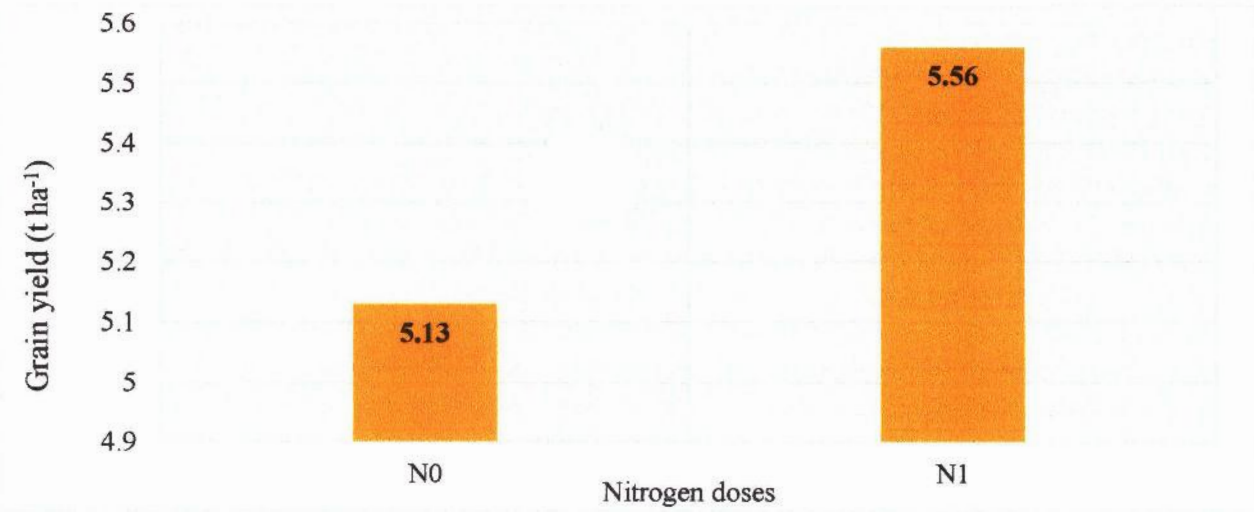

Figure 13: Effect of nitrogen on grain yield of BR23 rice [N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}]

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4.3.1.2 Effect of phosphorus

The effect of phosphorus on grain yield ha^{-1} was significantly affected by different dose of phosphorus (Figure 14 and appendix IX). The highest grain yield (5.63 t ha^{-1}) was observed from P_2 (16 kg P ha^{-1}) treatment which was statistically similar with P_1 (8 kg P ha^{-1}) and P_3 (24 kg P ha^{-1}) treatment. The lowest grain yield (4.79 t ha^{-1}) was observed from P_0 (control) treatment. Shah (2002) reported similar response of P on grain yield. Islam *et al.*, (2010) reported that grain yield was significantly increased by 10 kg ha^{-1} P but it did not differed by the application of 20 and 30 kg P ha^{-1}. They also reported that phosphorus rate did not influence grain yield irrespective of varieties in T. *aman* season.

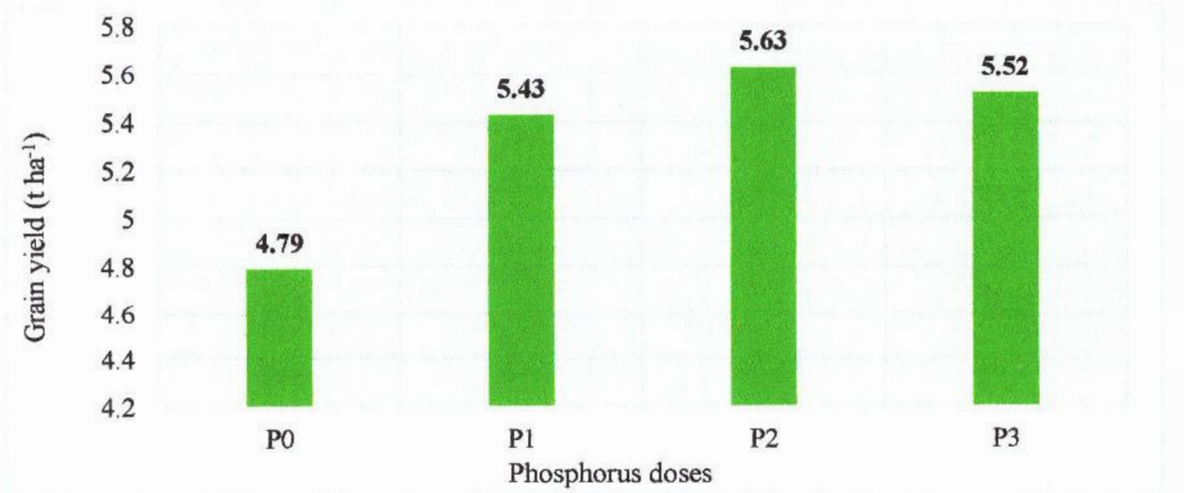

Figure 14: Effect of phosphorus doses on grain yield of BR23 rice

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.3.1.3 Interaction effect of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus exerted significant influence on the grain yield (Table 10). The highest grain yield (5.73 t ha^{-1}) was observed from N_1P_3 (93 kg N ha^{-1}+24 kg P ha^{-1}) treatment combination which was statistically similar with all the treatment combinations except at control. Phosphorus contribute remarkably on the grain development as a result 1000-grain weight and grain yield were reduced in the treatments without phosphorus (N_0P_0 and N_1P_0) compared to P added treatment combinations. The minimum grain yield (4.42 t ha^{-1}) was recorded from N_0P_0 (control) treatment. Irfan *et al.*, (2016) showed that the treatment where N

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and P were integrated at the rate of 120 and 90 kg ha^{-1} exhibited the highest paddy yield (4785 kg ha^{-1}) which was 56% more over control.

4.3.2 Straw yield

4.3.2.1 Effect of nitrogen

Straw yield was significantly affected due to the application of nitrogen (Figure 15 and appendix IX). The highest straw yield (6.67 t ha^{-1}) was observed rom N_1 (93 kg N ha^{-1}) treatment and the lowest straw yield (4.93 t ha^{-1}) was observed from N_0 (control) treatment. Significant differences may be occurred due to more nitrogen increased vegetative growth and finally increased straw yield. BRRI (2009) reported application of 150 kg N ha^{-1} gave the highest yield. Awan *et al.*, (2011) observed application of 156 kg N ha^{-1} gave highest straw yield. Mondal and Swamy (2003) reported that N (120 kg ha^{-1}) applied as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest straw yield. Islam *et al.*, (2008) found that straw yield significantly influenced by nitrogen levels. This result was in an agreement with the findings of Dhane *et al.*, (1989) who reported that straw yield increases with increasing nitrogen level. Enhancing straw yield with corresponding addition of N was due to the increased vegetative growth which was the most important function attributed to N (Ma *et al.*, 2004).

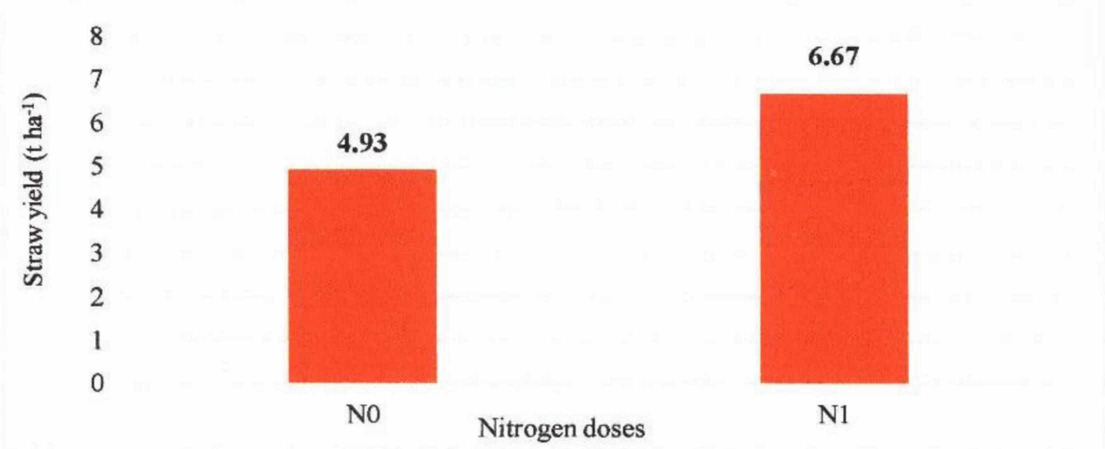

Figure 15: Effect of nitrogen on straw yield of BR23 rice

[N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}]

4.3.2.2 Effect of phosphorus

The effect of phosphorus on straw yield was non-significantly affected by different doses of phosphorus (Figure 16 and appendix IX). The highest straw yield (5.96 t ha^{-1}) was recorded from

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both P_2 (16 kg P ha^{-1}) and P_3 (24 kg P ha^{-1}) treatments. The lowest straw yield (5.63 t ha^{-1}) was observed from P_1 (8 kg P ha^{-1}) treatment. Alam *et al.*, (2009) also found that application of 48 kg P_2O_5 ha^{-1} and 72 kg P_2O_5 ha^{-1} gave higher straw yield. Gebrekidan and Seyoum (2006) reported that harvest index of rice was significantly increased by the application of 13.2 kg P ha^{-1} accordingly harvest index of the rice crop was negatively and significantly correlated with straw yield.

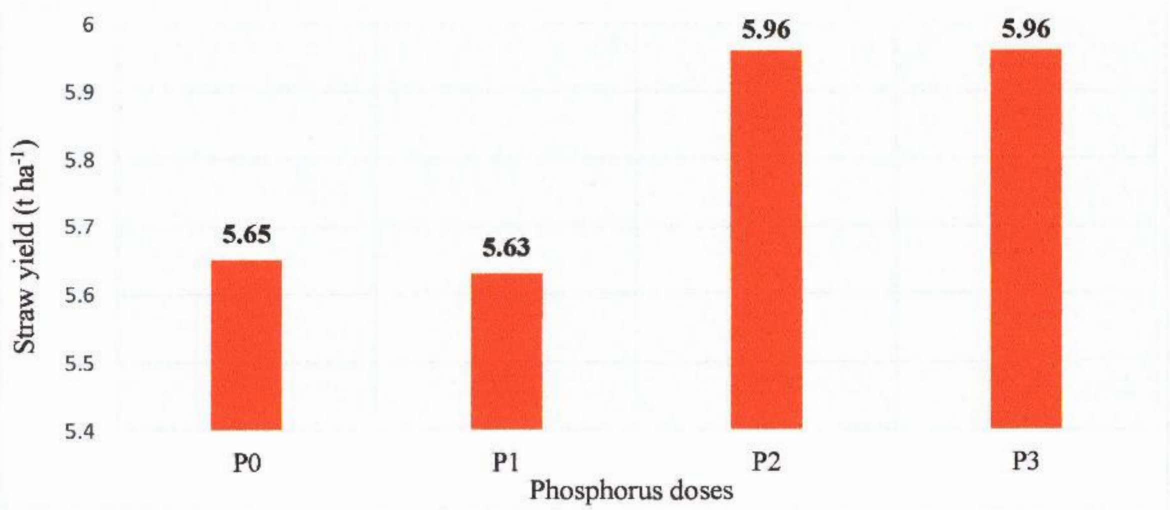

Figure 16: Effect of phosphorus on straw yield of BR23 rice

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.3.2.3 Interaction effect of nitrogen and phosphorus

The straw yield was strongly influenced with the addition of N and P into various ratios. Interaction effect of nitrogen and phosphorus was observed significant on straw yield (Table 10). Straw yield increased with the successive addition of P at each N level. The highest straw yield (6.84 t ha^{-1}) was observed from N_1P_0 (93 kg N ha^{-1} + 0 kg P ha^{-1}) treatment combination which was statistically similar with N_1P_1 (93 kg N ha^{-1} + 8 kg P ha^{-1}), N_1P_2 (93 kg N ha^{-1}+ 16 kg P ha^{-1}), N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combinations. Nitrogen helps phosphorus uptake and improved plant vegetative growth. So, straw yield was increased. Second highest straw yield (5.22 t ha^{-1}) was observed from N_0P_3 (0 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination which was statistically similar with N_0P_2 (0 kg N ha^{-1} + 16 kg P ha^{-1}) and N_0P_1 (0 kg N ha^{-1} +8 kg P ha^{-1}) treatment combinations. It may be due to minimum amount of nitrogen. Phosphorus alone plays a minimum role in plant growth without nitrogen. The lowest straw yield (4.47 t ha^{-1}) was

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recorded from N_0P_0 (control) treatment combination. These result was statistically similar with N_0P_1 (0 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination. Irfan *et al*., (2016) showed that the least straw yield (4265 kg ha^{-1}) was observed in control plots, while the highest straw yield (9723 kg ha^{-1}) was recorded in plots receiving 150 kg N + 75 kg P_2O_5 ha^{-1}, showing an increase of 56% over control. Brink *et al*., (2001) has also reported an additive effect of P on plant growth when combined with N in balance proportion.

4.3.3 Biological yield

4.3.3.1 Effect of nitrogen

Biological yield was significantly affected by the nitrogen doses showed in figure 17 and appendix IX. The highest biological yield (12.22 t ha^{-1}) was recorded from N_1 treatment. And the lowest biological yield (10.07 t ha^{-1}) was recorded from N_0 (control) treatment. More nitrogen increased both grain yield and straw yield and finally increased biological yield. Vegetative growth was influenced due to the higher dose of urea and for the reason the grain and straw yield was also increased with the increased dose of nitrogenous fertilizer. Singh and Lallu (2005) stated that each increment dose of N significantly increased grain and straw yields (biological yield) over its preceding dose. The result agreed with the findings of Ahmed *et al.*, (2005) who observed the effect of nitrogen dose on biological yield (t ha^{-1}) of rice.

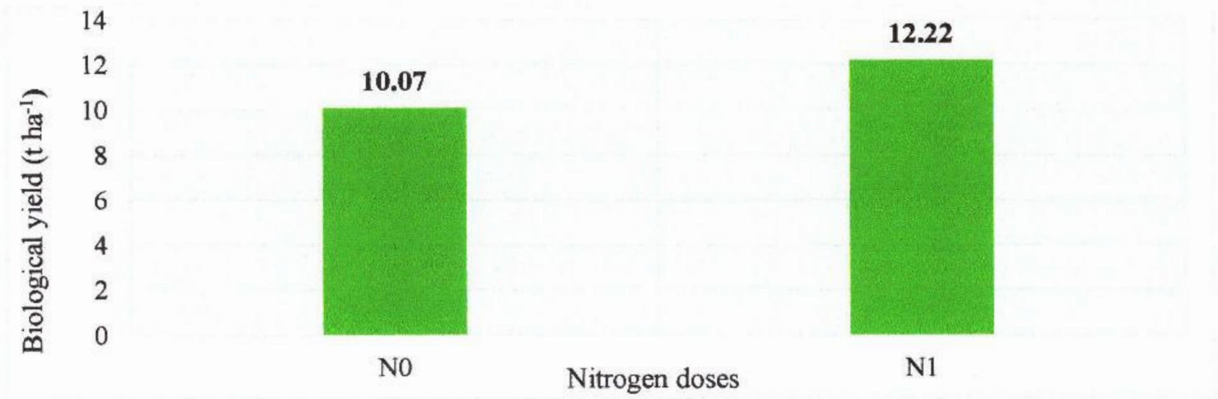

Figure 17: Effect of nitrogen on biological yield of BR23 rice

[N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}]

4.3.3.2 Effect of Phosphorus

Biological yield was non-significantly affected by different doses of phosphorus (Figure 18 and appendix IX). The highest biological yield (11.58 t ha^{-1}) was recorded from P_2 (16 kg P ha^{-1})

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treatment which was statistically similar with P_3 (24 kg P ha^{-1}) treatment. The second highest biological yield (11.06 t ha^{-1}) was observed from P_1 (8 kg P ha^{-1}) treatment. The lowest biological yield (10.45 t ha^{-1}) was recorded from P_0 (control) treatment. Uddin *et al.*, (2014) found that maximum biological yield obtained from 40 kg P ha^{-1}. Yosef Tabar (2013) also stated that 90 kg P ha-1 gave the highest biological yield.

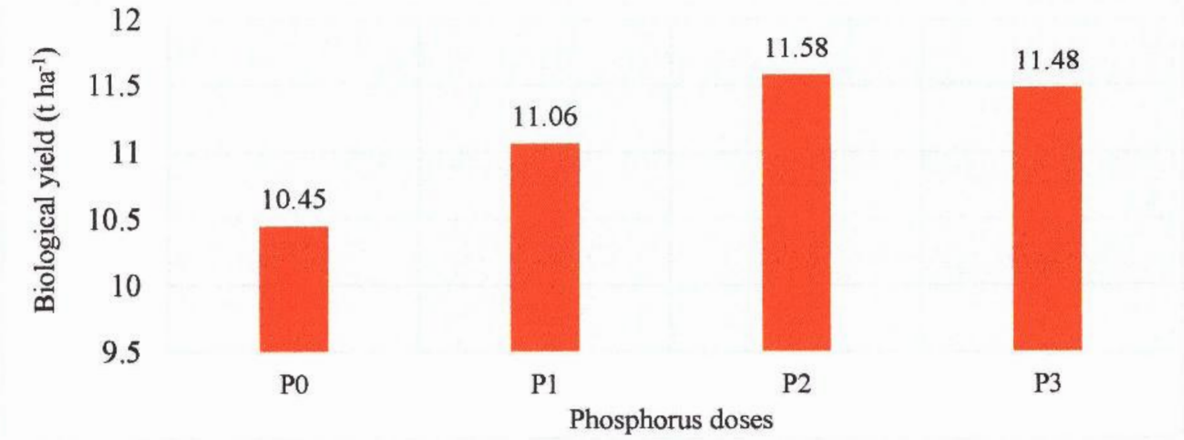

Figure 18: Effect of phosphorus on biological yield of BR23 rice

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.3.3.3 Interaction effect of nitrogen and phosphorus

Interaction effect of nitrogen and phosphorus was observed significant on biological yield (Table 10 and appendix IX). The highest biological yield (12.42 t ha^{-1}) was recorded from N_1P_3 (93 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination which was statistically similar with N_1P_2 (93 kg N ha^{-1}+ 16 kg P ha^{-1}), N_1P_1 (93 kg N ha^{-1}+ 8 kg P ha^{-1}) and N_1P_0 (93 kg N ha^{-1}+ 0 kg P ha^{-1}) treatment combinations. Nitrogen and phosphorus have a positive relation. So, phosphorus with nitrogen played a role in increasing plant growth. More nitrogen and phosphorus increased more biological yield. The second highest biological yield (10.80 t ha^{-1}) was recorded from N_0P_2 (0 kg N ha^{-1}+16 kg p ha^{-1}) treatment combination which was identical with N_0P_3 (0 kg N ha^{-1}+24 kg P ha^{-1}) treatment combination but statistically different from N_0P_1 (0 kg N ha^{-1}+ 8 kg P ha-1) treatment combination. The lowest biological yield (8.88 t ha^{-1}) was recorded from N_0P_0 (control) treatment combination. More N produced more straw yield and grain yield so ultimately biological yield was increased.

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4.3.4 Harvest index

4.3.4.1 Effect of nitrogen

Harvest index is the ratio between grain yield and biological yield. Effect of nitrogen doses showed significant variation on harvest index (Figure 19 and appendix IX). The highest harvest index (50.86%) was recorded from N_1 (93 kg N ha^{-1}) treatment. And the lowest harvest index (45.43%) was recorded from N_0 (control) treatment. Awan *et al.*, (2011) reported highest harvest index was found with 156 kg N ha^{-1}. Ehsanullah *et al.*, (2012) reported highest harvest index (38.32%) when nitrogen was applied @ 100 kg ha^{-1} to Basmati rice. Pramanik and Bera (2013) reported significant effect of nitrogen on harvest index, maximum harvest index (47.07%) was observed when nitrogen was applied @ 150 kg ha^{-1} while minimum (42.60%) was obtained in case of control having no nitrogen application.

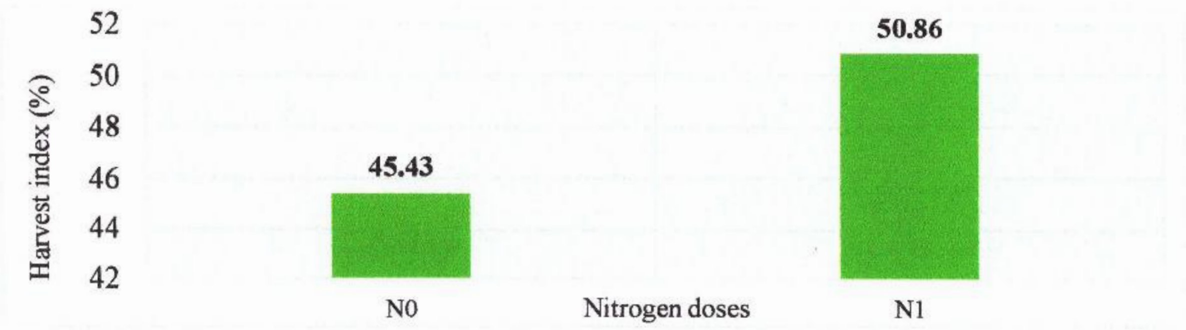

Figure 19: Effect of nitrogen on harvest index of BR23 rice [N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}]

4.3.4.2 Effect of phosphorus

There was no significant effect of phosphorus was found on the harvest index (Figure 20 and appendix IX). Maximum harvest index (49.26%) was obtained from P_1 (8 kg P ha^{-1}) treatment. The lowest harvest index (46.29%) was recorded from P_0 (control) treatment. Yoseftabar (2013) showed that maximum harvest index was (47.92) observed for 90 kg ha^{-1} phosphorus fertilizer and minimum of that was (47.79) obtained for(control) 0 kg ha^{-1} phosphorus fertilizer. Alam et *al.*, (2009) reported that no significant effect of phosphorus was found on the harvest index of *boro* rice. Application of 13.2 kg P ha^{-1} significantly ($p<0.01$) increased harvest index of rice. Accordingly harvest index of the rice crop was negatively and significantly correlated with plant height, panicle length, number of panicle m^{-2}, number of spikelets $panicle^{-1}$ and straw yield (Gebrekidan and Seyoum, 2006). The harvest index increased initially with increasing rates of

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applied P and decreased finally with further increase in application rates of P fertilizer (Alam *et al.*, 2009).

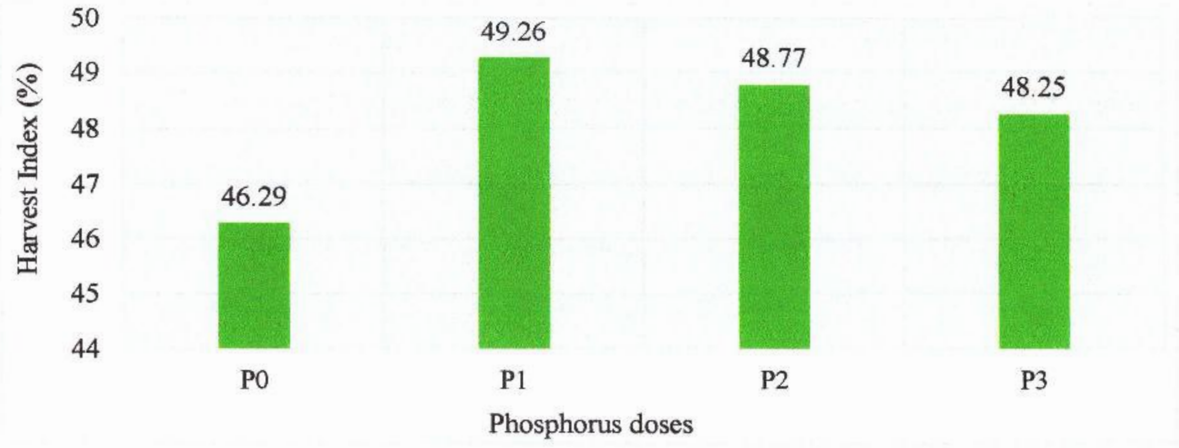

Figure 20: Effect of Phosphors on harvest index of BR23 rice

[P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}]

4.3.4.3 Interaction of nitrogen and phosphorus

The interaction effect of nitrogen and phosphorus had significant effect on harvest index on BR23 rice (Table 9). Among the treatment combination, N_0P_1 produced the highest harvest index (52.17%). The lowest value of harvest index (43.12%) was obtained from N_1P_0 treatment combination.

Table 10. Interaction effect of nitrogen and phosphorus on yield parameters of BR23 rice

Treatments combination	Yield parameters			
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0P_0	4.42b	4.47c	8.88d	49.47ab
N_0P_1	5.24a	4.79bc	10.03c	52.17a
N_0P_2	5.56a	5.24b	10.80b	51.47ab
N_0P_3	5.32a	5.22b	10.54bc	50.32ab
N_1P_0	5.18ab	6.84a	12.01a	43.12c
N_1P_1	5.62a	6.46a	12.08a	46.35bc
N_1P_2	5.69a	6.67a	12.36a	46.06bc
N_1P_3	5.73a	6.70a	12.42a	46.17bc
Level of significance	*	*	*	*
CV (%)	2.59	5.19	3.62	4.96

[In a column, figures with similar letter (s) do not differ significantly, whereas, figures with different letter (s) differ significantly; N_0 = 0 kg N ha^{-1}, N_1= 93 kg N ha^{-1}; P_0= 0 kg P ha^{-1}, P_1= 8 kg P ha^{-1}, P_2= 16 kg P ha^{-1}, P_3= 24 kg P ha^{-1}; * indicates significant at 5% level]

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CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Professor Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna, during August, 2018 to December, 2018 with a view to examine the effect of phosphorus with added nitrogen dose on growth and yield of *aman* rice variety BR23. The experimental treatments included two doses of nitrogen N_0 (0 kg N ha^{-1}), N_1 (93 kg N ha^{-1}) and four levels of phosphorus P_0 (0 kg P ha^{-1}), P_1 (8 kg P ha^{-1}), P_2 (16 kg P ha^{-1}), P_3 (24 kg P ha^{-1}). The experiment was laid out in a split plot design with three replications having nitrogen in the main plots and phosphorus in the sub-plots. There were 24 treatments combinations. The size of unit plot was 6 m^2.

Urea was applied in three equal splits at basal dose, 45 DAT and before panicle initiation. On the other hand, phosphorus was applied at basal dose. Number of 2 or 3 Seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills and 50 cm distance between plot to plot. Intercultural operations such as gap filling, weeding, water management and pest management were done as when necessary. Maturity of crop was determined when 90% of the grains become golden yellow in color. Randomly five hills were selected to taken yield and yield contributing characters data. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 14 %. Straw was also sun dried properly.

The data on crop growth characters like plant height, tiller number $hill^{-1}$, dry matter, crop growth rate, relative growth rate, leaf weight ratio etc. were recorded at 40, 55, 70 and 85 DAT and at harvest. The yield contributing characters like effective tiller number $hill^{-1}$, panicle length, filled grain per panicle, unfilled grain per panicle and 1000-grain weight were recorded after harvest. Finally, grain yield, straw yield, biological yield and harvest index were recorded after harvest and converted the data into ton ha^{-1}. The data were analyzed by using 'Statistix 10' software. The mean differences among the treatments were compared by Duncan's New Multiple Range Test (DMRT).

Nitrogen dose showed non-significant variation at different days after transplanting on plant height. Plant height increased progressively up to maturity. At harvest highest plant height was observed from N_1 (93 kg N ha^{-1}) treatment at all growth stages. Phosphorus had significant

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variation in plant height only at 40 DAT. The highest plant height was observed from P_3 (24 kg P ha^{-1}) treatment at all growth stages. At 40, 55, 70 and 85 DAT highest plant height was observed from N_1P_1 (93 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination. At harvest, the highest plant height was observed from N_0P_3 (0 kg N ha^{-1}+ 24 kg P ha^{-1}) treatment combination. The lowest plant height was observed from N_0, P_0 treatment and N_0P_0 treatment combination.

Tiller number $hill^{-1}$ increased with age and was highest at 40 DAT and there after decline. At 40 DAT, 55 DAT, 70 DAT and at harvest, tiller number $hill^{-1}$ was not affected significantly due to nitrogen application. The highest tiller number $hill^{-1}$ was observed from 93 kg N ha^{-1} (N_1) and the lowest tiller number was obtained from control treatment (N_0) at all growth stages. At 40, 70 and 85 DAT, the highest tiller number $hill^{-1}$ was recorded from P_2 (16 kg P ha^{-1}) treatment and the lowest tiller number was recorded from P_1 (16 kg P ha^{-1}) treatment. At 55 DAT and at harvest, the highest tiller number $hill^{-1}$ was recorded from P_3 (24 kg P ha^{-1}) treatment. Nitrogen and phosphorus interaction significantly affected tiller number $hill^{-1}$ at all growth stages except at harvest stage. At harvest, the highest tiller number $hill^{-1}$ was recorded from N_1P_0 (93 kg N ha^{-1}+ 0 kg P ha^{-1}) treatment combination and minimum tiller number $hill^{-1}$ was recorded from N_0P_0 (control) treatment combination.

Accumulation of dry matter increased progressively over time attaining the highest at harvesting time. Application of N_1 (93 kg N ha^{-1}) produced highest dry matter and the lowest dry matter was obtained from control treatment. Phosphorus had no significant variation on accumulation of total dry matter except at 40 DAT. At 40 and 55 DAT, the highest dry matter production was recorded from P_2 (16 kg P ha^{-1}) treatment. At 70, 85 DAT and at harvest, the highest dry matter was recorded from P_3 (24 kg P ha^{-1}) treatment. The lowest dry matter was recorded from P_0 (0 kg P ha^{-1}) treatment at all stages. At 40 and 55 DAT, the highest dry matter was recorded from N_1P_2 (93kg N ha^{-1} + 16 kg P ha^{-1}) treatment combination and at 70, 85 DAT and at harvest, the highest dry matter was recorded from N_1P_3 (93 kg N ha^{-1}+24 kg P ha^{-1}) treatment combination. And the lowest dry matter was recorded from N_0P_0 (control) treatment combination.

Highest crop growth rate (CGR) and relative growth rate (RGR) were observed from N_1 (93 kg N ha^{-1}) treatment and N_0 (0 kg N ha^{-1}) treatment showed lowest CGR and RGR at all growth stages. The highest CGR and RGR were recorded from P_3 (24 kg P ha^{-1}) treatment and the lowest CGR and RGR were observed from P_0 (0 kg P ha^{-1}) treatment. The highest CGR and RGR were

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observed from N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and the lowest CGR and RGR were obtained from N_0P_0 (control) treatment combination.

At all growth stages, the highest LWR was recorded from N_1 (93 kg N ha^{-1}) treatment and P_3 (24 kg P ha^{-1}) treatment and the lowest LWR was recorded from N_0 (0 kg N ha^{-1}) and P_0 (0 kg P ha^{-1}) treatment. N_0P_0 (control) treatment combination showed highest LWR at all growth stages except at 55 DAT. At 55 DAT, the highest LWR was recorded N_1P_1 (93 kg N ha^{-1}+8 kg P ha^{-1}) treatment combination.

Nitrogen and phosphorus had positive role in increasing the effective tiller number $hill^{-1}$ and panicle length. Application of N @ 93 kg ha^{-1} recorded the highest effective tiller number $hill^{-1}$ and panicle length and the lowest by control. The highest effective tiller number $hill^{-1}$ and panicle length were recorded from P_3 (24 kg P ha^{-1}) treatment. Treatment combination N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) showed the highest effective tiller number $hill^{-1}$ and panicle length. N_0P_0 (control) showed the lowest effective tiller number $hill^{-1}$ and panicle length.

Highest filled grain $panicle^{-1}$ and lowest unfilled grain $panicle^{-1}$ were recorded from N_1 (93 kg N ha^{-1}) treatment, P_3 (24 kg P ha^{-1}) treatment and N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and the lowest filled grain $panicle^{-1}$ and highest unfilled grain $panicle^{-1}$ were recorded from N_0 (0 kg N ha^{-1}) treatment, P_0 (0 kg P ha^{-1}) treatment and N_0P_0 (control) treatment combination.

1000-grain weight was highest at N_1 (93 kg N ha^{-1}) treatment, P_3 (24 kg P ha^{-1}) treatment and N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination and lowest at N_0 (0 kg N ha^{-1}) treatment, P_0 (0 kg P ha^{-1}) treatment and N_0P_0 (control) treatment combination.

Highest grain yield was recorded from N_1 (93 kg N ha^{-1}) treatment, P_2 (16 kg P ha^{-1}) treatment and N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination. And lowest grain yield was recorded from N_0 (0 kg N ha^{-1}) treatment, P_0 (0 kg P ha^{-1}) treatment and N_0P_0 (control) treatment combination.

Highest straw yield and biological yield were observed from N_1 (93 kg N ha^{-1}) treatment, P_2 (16 kg P ha^{-1}) treatment and N_1P_3 (93 kg N ha^{-1} + 24 kg P ha^{-1}) treatment combination. And lowest straw yield was achieved from N_0 (0 kg N ha^{-1}) treatment, P_1 (8 kg P ha^{-1}) treatment and N_0P_0

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(control) treatment combination. Lowest biological yield was recorded from N_0 (0 kg N ha^{-1}), P_0 (0 kg P ha^{-1}) treatment and N_0P_0 (control) treatment combination.

Highest harvest index was recorded from N_1 (93 kg N ha^{-1}), P_1 (8 kg P ha^{-1}) treatment and N_0P_1 (0 kg N ha^{-1} + 8 kg P ha^{-1}) treatment combination. Lowest harvest index was recorded from N_0 (0 kg N ha^{-1}), P_0 (0 kg P ha^{-1}) treatment and N_1P_0 (93 kg N ha^{-1}+ 0 kg P ha^{-1}) treatment combination.

It could be concluded that application of nitrogen and phosphorus is necessary for raising yield of BR23 rice. Application of 93 kg N ha^{-1} produced the highest grain yield (5.56 t ha^{-1}). Application of 16 kg P ha^{-1} produced the highest grain yield (5.63 t ha^{-1}). Present results suggest that application of 24 kg P ha^{-1} along with 93 kg N ha^{-1} would be needed for obtaining higher growth and yield for BR23 rice. Phosphorus doses had significant effect on CGR, RGR, yield contributing characters and yield of *aman* rice variety BR23. Addition of nitrogen showed a positive impact on plant height, total dry matter, CGR, RGR, filled grain panicle^{-1}, biological yield and harvest index but grain yield did not vary significantly. Phosphorus had an effective role on grain development as a result 1000-grain weight and grain yield were less in treatments without P (N_0P_0 and N_1P_0) compared to other treatment combinations with P.

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CHAPTER VI

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Appendices

Appendix I. Temperature and rainfall data, 2018, Khulna

Date	Minimum Temperature	Maximum Temperature	Rainfall (mm)
July	26.7	32.9	264
August	26.9	33.4	107
September	26.7	34.2	106
October	23.6	32.6	53
November	19.3	30.7	1
December	13.7	25.8	3

Appendix II. Chemical properties of the initial soil

Name of the parameters	Value
Nitrogen	0.35 %
Phosphorus	11.20 ppm
Potassium	0.43 meq 100^{-1} g soil
Sulpher	61.90 ppm
Zinc	1.25 ppm
pH	7.5
EC	4.6 dsm^{-1}
Organic Matter (OM)	2.03 %

Appendix III. Means square values for plant height (cm) of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting				
		40 DAT	55DAT	70DAT	85DAT	At Harvest
Replication	2	231.17	498.29	716.29	393.04	413.29
Nitrogen (N)	1	504.17^{NS}	661.50^{NS}	513.38^{NS}	266.67^{NS}	28.17^{NS}
Error (a)	2	106.17	56.63	42.87	72.04	33.04
Phosphorus (P)	3	61.44^{*}	25.11^{NS}	21.15^{NS}	19.00^{NS}	46.44^{NS}
N x P	3	36.5^{NS}	39.28^{*}	26.82^{*}	17.67^{NS}	76.61^{*}
Error (b)	12	31.89	30.40	36.36	26.20	27.61

[*Significant at 5% level; NS=Non-Significant]

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Appendix IV. Means square values for tiller number hill^{-1} of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting				
		40 DAT	55DAT	70DAT	85DAT	At Harvest
Replication	2	0.791	2.000	0.125	1.292	1.167
Nitrogen (N)	1	77.041^{NS}	26.041^{NS}	26.041^{NS}	15.041*	7.041^{NS}
Error (a)	2	9.041	4.167	3.041	0.541	1.167
Phosphorus (P)	3	2.152^{NS}	0.708^{NS}	0.930^{NS}	1.708^{NS}	0.152^{NS}
N x P	3	28.708*	6.041*	6.486*	10.375*	5.152^{NS}
Error (b)	12	6.638	3.583	3.416	3.250	2.278

[*Significant at 5% level; NS=Non-Significant]

Appendix V. Means square values for dry matter production hill^{-1} (g hill^{-1}) of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting				
		40 DAT	55DAT	70DAT	85DAT	At Harvest
Replication	2	20.04	48.67	225.79	17.79	11.16
Nitrogen (N)	1	145.04*	504.17*	26.04^{NS}	876.04*	925.04*
Error (a)	2	7.542	2.17	8.79	1.29	4.67
Phosphorus (P)	3	21.15*	19.27^{NS}	18.26^{NS}	80.48^{NS}	54.15 ^{NS}
N x P	3	10.93*	21.94*	85.81^{NS}	42.37*	39.37*
Error (b)	12	2.45	16.36	61.29	63.09	51.63

[*Significant at 5% level; NS=Non-Significant]

Appendix VI. Means square values for crop growth rate (CGR) (g hill^{-1} day^{-1}) of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting			
		40DAT-55DAT	55DAT-70DAT	70DAT-85DAT	85DAT-Harvest
Replication	2	0.015	0.09270	0.02847	0.02558
Nitrogen (N)	1	0.78844*	0.34560*	0.29040*	0.27520*
Error (a)	2	0.02536	0.00579	0.00125	0.00053
Phosphorus (P)	3	0.08318*	0.03808*	0.03069*	0.02833*
N x P	3	0.00225^{NS}	0.00130*	0.00030*	0.00002*
Error (b)	12	0.00225	0.00073	0.00050	0.00004

[*Significant at 5% level; NS=Non-Significant]

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Appendix VII. Means square values for relative growth rate (RGR) (mg g^{-1} day^{-1}) of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting			
		40DAT-55DAT	55DAT-70DAT	70DAT-85DAT	85DAT-Harvest
Replication	2	94.50	40.042	52.625	50.167
Nitrogen (N)	1	253.500*	630.375*	425.042*	260.042*
Error (a)	2	0.500	0.875	9.042	3.167
Phosphorus (P)	3	28.167*	29.153*	50.708*	31.819*
N x P	3	1.944*	1.819*	4.708^{NS}	0.486^{NS}
Error (b)	12	0.556	0.403	0.833	0.278

[*Significant at 5% level; NS=Non-Significant]

Appendix VIII. Means square values for yield contributing characters of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting				
		Effective tiller(no) $hill^{-1}$	Panicle length(cm)	Filled grains $panicle^{-1}$ (No)	Unfilled grains $panicle^{-1}$ (No.)	1000 grains weight (g)
Replication	2	1.1667	3.1250	1654.54	40.50	115.296
Nitrogen (N)	1	37.500^{NS}	20.1667*	1802.67*	3220.17*	46.259^{NS}
Error (a)	2	3.5000	0.2917	43.29	24.67	4.303
Phosphorus (P)	3	6.1111*	5.1667*	528.67*	362.28*	289.348*
N x P	3	4.9444*	0.9444*	331.56*	18.94*	16.828*
Error (b)	12	1.4444	0.4306	95.36	7.86	2.364

[*Significant at 5% level; NS=Non-Significant]

Appendix IX. Means square values for yield parameters of BR23 rice at different days after transplanting

Source of variation	DF	Means square values at different days after transplanting			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.33032	0.2251	0.8639	5.813
Nitrogen (N)	1	1.07104^{NS}	18.0613*	27.9288*	177.235*
Error (a)	2	0.19005	0.0800	0.2263	6.856
Phosphorus (P)	3	0.83380*	0.2033^{NS}	1.5908*	10.116^{NS}
N x P	3	0.10074*	0.2857*	0.6987*	1.322*
Error (b)	12	0.11235	0.0908	0.1630	5.695

[*Significant at 5% level; NS=Non-Significant]

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