EFFECT OF DIFFERENT DOSES OF PHOSPHORUS AND POTASSIUM ON GROWTH AND YIELD OF BRRI HYBRID DHAN2

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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF DIFFERENT DOSES OF PHOSPHORUS AND POTASSIUM ON GROWTH AND YIELD OF BRRI HYBRID DHAN2''

This document, which was submitted to the Faculty of Agriculture at Sher-e-Bangla Agricultural University in Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, represents the findings of a piece of legitimate research that **MD. TAREKUL HAQUE**, **Registration No. 19-10255**, carried out under my direction. No part of the thesis has been submitted for any other degree or diploma.

I also confirm that any assistance or information obtained throughout the course of this inquiry has been properly recognized.

Dated:
December,2021
Dhaka, Bangladesh

Prof. Dr. Nasima Akhter
Supervisor

DEDICATED TO

My Parents and Respected Research Supervisor

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The Author

EFFECT OF DIFFERENT DOSES OF PHOSPHORUS AND POTASSIUM ON GROWTH AND YIELD OF BRRI HYBRID DHAN2

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ABSTRACT

The field experiment was carried out at the central research farm of the Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2019 to June, 2020 in boro season with a view to effect of phosphorus and potassium on growth and yield of BRRI Hybrid dhan2. The experiment consisted of two factors. Factor A: Different levels of phosphorous as P_0= 0 kg P ha^{-1} ,P_1=30 kg P ha^{-1}, P_2=45 kg P ha^{-1}, P_3=60 kg P ha^{-1} and Factor B: Different levels of potassium as K_0= 0 kg K ha^{-1}, K_1=30 kg K ha^{-1}, K_2=45 kg K ha^{-1}, K_3=60 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design with three replications. Four levels of both nutrients i.e. phosphorous and potassium, total 16 treatments were tested in this experiment. In the study. N, P, K, S and Zn were applied in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate respectively. The collected data were statistically analyzed. The result revealed that there was a significant difference among the treatments. However, the application of 45 kg P ha^{-1} and 60 kg K ha^{-1} together resulted in the maximum number of tillers hill^{-1} (24.33) and leaf area index (7.44), and with the combined treatment of P_2K_3 (45 kg P+60 Kg K ha^{-1}) also produced the height plant height (101.33 cm). The highest grain yield 5.29 t ha^{-1} was recorded from the treatment combination was P_3K_2 (60 kg P+45 Kg K ha^{-1}). The highest biological yield (13.26 t ha^{-1}) was noticed from the treatment combination was P_3K_2 (60 kg P+45 Kg K ha^{-1}). So, the hybrid rice variety "BRRI Hybrid dhan2" with application of 60 kg P ha^{-1} and 45 kg K ha^{-1} considerably more grain than the other treatment combinations. Comparatively, a control treatment where no phosphorus and potassium applications were made during the research period reported a minimum rice yield of 2.79 t ha^{-1}.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
DAT	=	Days after transplanting
DF	=	Degree of freedom
DMRT	=	Duncan' Multiple Range Test
et al.	=	and others
FAO	=	Food and Agricultural Organization
GDP	=	Gross domestic product
HI	=	Harvest Index
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LAI	=	Leaf area index
ns	=	Non significant
%	=	Percentage
CV %	=	Coefficient of Variance percentage
P	=	Phosphorus
K	=	Potassium
TDM	=	Total dry matter
Kg ha^{-1}	=	Kilogram per hectare

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is most commonly farmed in tropical and sub-tropical region (Singh *et al*., 2012). Over three billion people worldwide eat it as their primary source of nutrition (Jahan *et al.*, 2017). Globally, rice is grown on 514.76 million metric tons (FAO, 2021), though its production and consumption is concentrated in Asia, where more than ninety percent of all rice is consumed. Rice alone constitutes 97% of the food grain production in Bangladesh (BBS, 2012). It dominates over all other crops and covers 75% of the total cropped area (DAE, 2020). With 38.4 million tons produced in 2021, Bangladesh ranks third globally for the fourth straight year (Food Outlook FAO, 2022). Among three rice seasons, boro rice covers about 48.97% of total rice area and contributes to 38.14% of total rice production in the country (BBS, 2012). Bangladesh ranks 4th in rice production and ranks 6th in per hectare production of rice (Sarkar *et al*., 2016). About two millions of people are added every year which will be thirty million over the next twenty years and thus, to meet up the food demand for this over population. Rice production has to be increased at least 60% by 2020 to meet up food requirement of the increasing population (Masum, 2009). Thus, the population by the year 2030 will swell progressively to 223 million which will demand more than 48 million tons of cereal crops (Julfiquar *et al*., 2008). In Bangladesh, rice covers an area of about 11,420,725 ha and total production is about 34,710,417 metric tons (BBS, 2019). According to FAO (2014) the average yield of rice of Bangladesh is about 2.92 t ha^{-1} which is very low compared to other rice growing countries like Korea (6.30 t ha^{-1}),China (6.30 t ha^{-1}) and Japan (6.60 t ha^{-1}). The introduction of hybrid rice is a crucial step in increasing rice yields. The yield potential of hybrid rice is between fifteen and twenty percent or more than the inbrid rice with the application of almost same amount of agricultural inputs (Husain *et al*., 2000). But the low productivity of rice in Bangladesh is attributed by several factors including balance nutrition. Balanced nutrition especially application of phosphorus and potassium to the rice crop is one of the important inputs that can enhance productivity to a great extent. Rapid adoption of improved cultivars as a result of cropland intensification has increased yield while also significantly increasing nutrient output. Where there has been an imbalance between outputs and inputs, this has led to declining soil fertility and an increase in the incidence of deficiencies of specific plant nutrients, such as phosphorus and potassium.

Phosphorus contributes to the structural stability, crop quality, seed generation, and other processes essential for healthy plant growth. Additionally, phosphorus fosters root development, increases flowering, and is crucial for DNA synthesis. In addition to being a major plant macronutrient, phosphorus also enables the conversion of solar energy into useful materials. Adequate phosphorus nutrition enhances many aspects of plant physiology including the elementary process of photosynthesis, nitrogen fixation, flowering, fruiting and maturation. Without a proper supply of phosphorus, plants cannot produce their optimum yield (Murtaza *et al*., 2014). Phosphorus decreases spikelet sterility while simultaneously increasing yield. It is an essential component of the organic compound obtain called the energy currency of living cell. Available P is present in the soil as an anion (PO_4^{3-}, HPO_4^{2-} or H_2PO^{4-}) such as nitrate or sulfate, but it is not as readily leached from the soil as other anions. Phosphorus combines very easily with other elements such as iron (ferric phosphates or ferrous phosphates), aluminum (aluminum phosphates) and calcium (calcium phosphates) in the soil. In these P compounds, a large portion of the P is not immediately accessible for plant consumption. Phosphorus availability for plant uptake increases when the soil is flooded, increasing the quantity of P in solution. When the soil is flooded, ferric phosphate is converted to ferrous phosphate, which is more soluble in water. Plants rarely absorb more than twenty percent of the total fertilizer P applied (Friesen *et al.* 1997). Phosphorus is most available for plant uptake when soil pH is between 6.5 and 7.5. Reduced soil conditions under lowland rice typically enhance the P availability to rice. Phosphorus fertilizer can be applied to fields either in the fall, immediately prior to planting or pre-flood. Fall applications of phosphorus fertilizer to phosphorus deficient soils are generally discouraged because the phosphorus may become fixed into forms that are not available for plant uptake.

Other mechanisms that support the growth and production of boro rice also depend on potassium. Potassium is repeatedly referred to as the "quality element" since it contributes to many of the qualities we identify with quality, including size, color, shape and even flavor, among others. Besides the main benefits of potassium fertilizer management in plant growth and yield, K nutrition also helps to improve plant overall health by reducing the severity of nutritional and pests and diseases. A study to determine the effects of K rates on the incidence of stemborer (majrapoka) and rice yield was conducted by Sarwar (2012). Potassium deficient plants grow slowly and produce fewer yields. To continued increase crop yield per unit area, proper use of inorganic fertilizers are essential. Inorganic fertilizers supply necessary amount of nutrients when it is needed. Inorganic fertilizers like Urea, TSP, SSP, MOP, Zinc Sulphate, Gypsum etc.

Many farmers are using very low and others are using very high level of phosphorus and potassium in hybrid rice production. After only a brief time, phosphorus is in fixation with the soil complex, making more than two-thirds unavailable (Sahrawat *et al.* 2001).

Thus, the present experiment was undertaken with the following objectives:

i. To find out the effect of using phosphorus and potassium on growth and yield of BRRI Hybrid dhan2.
ii. To determine the optimum doses of phosphorus and potassium for BRRI Hybrid dhan2.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Numerous studies have been conducted on how different fertilizers and manures affect crops, particularly rice, in Bangladesh and other nations that cultivate rice. In Bangladesh, cultivated land is declining day by day but our demand of foods is increasing rapidly. To meet the demand, soil health maintain is necessary. A good soil is that which contain all of necessary nutrients in adequate amount. If the soil is not good, then crops shows some deficiencies symptoms. Applying some inorganic fertilizer is required to recover this. Due to the fast release of inorganic fertilizer, plants receive the right nutrients on schedule. The outcome is that rice grows and develops properly. However, a brief survey of some domestic and international works is provided here.

Effect of fertilizers on grain and straw yield of rice:

Haque and Biswas (1990) reported that the grain yield of rice significantly increased due to application of sulphur and the yield increased was boosted up to 56% and 82% over control when sulphur was added with N and NPK treatment respectfully.

Singh *et al.* (1990) observed that hog manure; Phosphorus and potassium fertilizer played a significant role in achieving high stable yield of crops. They further reported that hog manuring coupled with N, P and K application was a good combination, in the same time it can increase N and P utilization efficiency by 6 to 18% and 1 to 10% respectively.

Mondal *et al.* (1992) conducted a missing element trail to investigate the nutrient requirements for BR11 rice in sonatala silt loam soil at Bangladesh Agricultural University farm in T. aman season, 1990. They observed the significant response of crop to N, P, K, S, Zn and B. further they noted that unlike these elements, Cu and Mo did not have positive effect on rice yield.

Patnaik and Sathe (1993) reported that increase of grain yield with the application of Sulphur as Gypsum and K as MOP were relatively less than that with N. The highest grain yield was obtained with the application of 150 kg N+ 60 kg K_2O + 60Kg S.

Islam and Bhuiya (1997) studied the effect of N and P on the growth, yield and nutrient uptake of deep watered rice. It was observed that due to using N and P fertilization significantly increased the number of fertile tiller m^{-2} and also that of grain $panicle^{-1}$, which resulted in significant increase in grain yield. The application of 60kg N ha^{-1} alone gave 44% yield increase over control.

According to Donovan et al. (1998), rice farmers in the Sahel spend roughly 20% of their overall production expenditures on mineral fertilizers.

Mian and Moslehuddin (1999) reported from their long term fertilization trial at Bangladesh Agricultural University (BAU) farm from 1978-95 that grain yield of rice increased due to N, P and S application but the rate of increased varied in different season. Reduction of residual S remarkably decrease the yield in Aman season. The N, P, K, S and Zn treatment maintained its superiority both in T. aman and Aus rice.

According to studies by Rasool et al. (2007), when nutrients are given in the right amounts, nutrient absorption and translocation to sink are enhanced, which leads to balanced plant growth and development and boosts crop yield.

M.A. Kamal (2016) observed that application of 162-120-72 kg NPK/ha resulted in maximum increase in number of productive tillers, spikelet per panicle, 1000 grain weight, grain yield as well as harvest index.

According to Djomo Sime. H et al. (2017), low land rice varieties were more likely to contract rice blast than upland varieties, and both the incidence and severity of the illness increased during the vegetative growth of the various kinds of rice. Fertilizer N-P-K (20-10-10) at the dose 200 kg ha^{-1} makes the plant less susceptible to the blast at all its growth phases.

Phosphorus

Phosphorus is an essential element required for energy storage and transfer within the plant. At maturity, a high-yielding rice crop contains 60 to 80 lbs P_2O_5 $acre^{-1}$, with about 70 percent of the P contained in the rice panicles. Phosphorus is a major component in ATP, that provides “energy” to the plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material (DNA, RNA). In addition, P has been observed to increase root growth and influence early maturity, straw strength, crop quality and disease resistance. Plant absorbed P in the form of $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}. Numerous aspects of plant physiology, such as the basic process of photosynthesis, nitrogen fixation, flowering, fruiting, and maturity, are improved by adequate phosphorus nutrition. It is an essential component of the organic compound obtain called the energy currency of living cell (ATP) (Brady and Weil). Considerable numbers of works Have been done on the effects of phosphorus on rice in different parts of the world. Some of them are cited below:-

Ranjha *et al*. (1993) conducted a field trial in 1991 where P was applied at the rate of 0, 20, 40, 60, 80 and 100 kg P_2O_5 ha^{-1} alone with 150kg N ha^{-1}, 100kg K_2O and 12 kg $ZnSO_4$ ha^{-1}. They observed that growth parameters like number of tiller per hill, grain and straw yield and 1000 grain weight increased significantly with increasing rate of P application.

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 per kg soil to rice and wheat respectively. Recommend basal doses of N and K were also applied. Grain and straw yields and productive tillers of rice and wheat increased significantly with P application.

Mahajan *el 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}.

Subba Rao *et al.* (1995) reported that phosphorus when applied @ 50 mg P kg^{-1} soil as SSP increased the grain and straw yields significantly.

A field trial using rice cv. Sarju-52 was undertaken by Rao and Shukla in 1997 that was grown with given 13, 26 or 39 kg P ha^{-1} as ammonium polyphosphate, urea nitric phosphate or diammonium phosphate, in combination with 15, 30 or 45 kg $ZnSO_4$ ha^{-1}. They stated that grain yield in both years increased with increasing P rate also with 30 kg $ZnSO_4$ ha^{-1}. Yield was highest when P was applied as applied as ammonium polyphasphate.

Morgan (1997) also showed that excess amount of P application may causes environmental pollution problems by losing P into water.

Kumar and Singh (2001) reported that the significance response of rice to P was observed only up to 26.2 kg P ha^{-1} and application of P in all seasons recorded maximum rice equivalent yield (79.6 q ha^{-1}) which was at part with treatment receiving P in both year rabi (70.8 q ha^{-1}) and treatment receiving p in first year kharif and rabi (70.8 q ha^{-1}).

Using phosphorus fertilizer on rice, Zubaida and Munir (2002) tested the results. They found that phosphorus application by P-starter (20 kg SP36 ha^{-1}) is more economical and more benefit over phosphorus application of 100 kg SP36 ha^{-1} and reduce fertilizer application 80 kg SP36 ha^{-1} and yielded 4.236 and 4.320 t ha^{-1} of paddy rice, respectively.

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}) relevant to lowland rice yield and P absorption. 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}. Following harvest, the amount of available P in soil samples significantly increased with increasing P and Zn application rates.

Singh *et al.* (2003) conducted a field experiment under rain fed condition in Jharkhand, India during to establish the relationships between plant P and grain yield of upland rice cv. Kalinga III grown on red upland soils. He reported that rice yield varied significantly due to P fertilizer.

Dongarwar *et al.* (2003) conducted an experiment in Bhandara, Maharashtra, India during Kharif 2000-2001 to investigate the requirement of phosphorus for rice production. They observed that there was a significant increase in grain yield with successive increase in P fertilizer. The highest grain yield (53.05 q ha^{-1}) was obtained with the application of 75 kg P ha^{-1}.

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

A field experiment was done by 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.

Krishna kumar *et al.* (2005) noticed that application of 150:75:50 kg N:P_2O_5:K_2O ha^{-1} recorded the highest grain yield (7.060 kg ha^{-1}) of hybrid rice up to 135% over the no fertilizer application (3.015 kg ha^{-1}) plot. This treatment had the higher total Phosphorus and K uptake. Application of 150:50:0 kg N: P_2O_5: K_2O ha^{-1} gave the highest straw yield (122% of hybrid rice over the unfertilized treatment).

Islam M.A. *et al.* (2008) was conducted an experiment under submerge condition with a level of P were 100, 200, 500 and 800 kg P_2O_5. 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} DW at high P application (800 kg).

Alam *et al.* (2009) reported 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}).

According to Panhawar *et al.* (2011), phosphorus has a significant impact on how plants grow and develop their roots, tillers, early flowers, and complete other tasks including metabolic activities, notably protein synthesis.

Massawe and Jerome Mrema (2017) noticed that phosphorus was applied at the rate of 0, 20,40and 60 kg ha^{-1} MPR and TSP along with 60 kg N ha^{-1} as urea. The yield components between 0-60kg P ha^{-1} were 23.47- 64.97, 23.47-66.17 and 23.47-60.03cm plant height, 12-22, 12-19,12-22 no of tiller $plant^{-1}$, 1.5-8.63, 1.5-9.23, 1.5-10.43 ton ha^{-1} grain yields, 3.97-15.70, 3.97-17.03, 3.97-15.77 ton ha^{-1} straw yield for MPR, TSP respectively. P fertilizer application increase rice yield as the level of P increased from 0-60 kg P ha^{-1}.

Potassium

Potassium involves in essential functions such as osmoregulation, enzyme activation, regulation of cellular cation and anion balance, regulation of transpiration by stomata, and the transport of assimilates. In addition to the normal function, optimum K nutrition increases the number of spikelet per panicle, percentage of filled grains, and 1000 grain-weight in rice. It also gives a strength to the rice plant and helps stand firm against strong winds by improving rigidity of pseudo stems and stalks. This is important to reduce lodging. Considerable number of works has been done on the effects of K on rice in different parts of the world. Some of them are cited below.

Razzaque *et al (*1990) performed a field experiment in two soil series (Lokdeo and Ghatail) in Mymensingh and the results indicated significant positive influence of potassium on rice in both the soil series. The highest straw yield was recorded with 83 kg K ha^{-1}.

Chowdhury and Bodiuzzaman (1992) reported that the application of 0, 50, 100 and 150 kg K_20 and 60 kg S ha^{-1} to rice gave grain yields of 4.5, 4.8 and 4.9 t ha^{-1}, respectively.

Thakur *et al.* (1993) performed a field experiment at Rajendra Agricultural University Farm, Pusa (Bihar) to find out the effect of application of potash on wetland rice. The results indicated that with an increase in the potassium level up to 66 kg ha^{-1} there was an increase in number of total tillers m^{-2}.

Vijayalakshmi and Mathan (1994) observed that direct application of 25 kg K_20 increased grain yield significantly. They also found that grain yield was not increased by further K application.

Smith *et al.* (1994) reported that soil solution pH is dependent on mineral weathering and mineral weathering increase pH by releasing Ca, Mg and K.

Mahajan *el 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}.

Roy *et al.* (1995) carried out a field trial using 0-51 kg K ha^{-1} as muriate of potash and observed that rice grain yield increased with the rate of K application.

Subbarao *et al.* (1995) reported that phosphorus when applied @ 50 mg P kg^{-1} soil as SSP increased the grain and straw yields significantly.

Sarker *et al.* (1995) conducted a field experiment at the experimental farm of Calcutta University, Barvipur on Gangetic Alluvial soils during the kharif (wet) seasons of 1991 and 1992, where application of 100 kg N + 75 kg K_20 ha^{-1} in three equal splits at transplanting, active tillering and panicle initiation stages proved most effective in increasing yield attributes and grain yield of high yielding rice.

Sharma and Baruch (1997) conducted a field experiment in Assam, India, with rice cv. Krisna. The rice was given 25, 50, 75 or 100 kg K ha^{-1} as basal or 2 or 3 splits. Split application of K increased grain yield compared to a single basal dose.

Nelson (1978) revealeded that potassium has a positive role in plant growth under saline conditions, because this element plays an essential role in stomata movement, photosynthesis and regulation of osmotic pressure for plant.

Devendra *et al.* (1999) found that application of potassium enhanced the grain and straw production. However, the effect was limited to the application of 30 mg K20 in both grain and straw. Combined application of 60 mg N along with 30 mg K_20 proved most effective in increasing grain and straw yield of rice.

Doberman and Fairhurst (2000) showed that K deficient plants are susceptible to plant diseases such as bacterial leaf blight, sheath blight, brown spots, and seed spots.

A.M. Ranjha *et al.* (2001) showed that potassium was applied @ 0, 100, 200, 300, 400 and 500 mg kg^{-1} soil each from MOP and SOP along with basal dose of N + P @ 150 and 100 kg ha^{-1}. Plant height, number of tillers pot^{-1}, paddy yield, 1000-grain weight and straw yield remained unaffected by both the sources of potassium.

Lia *et al.* (2001) showed that K fertilizer helped reducing severity of rice bronzing as K tissue levels increased together with plant biomass.

Dongarwar *et al.* (2003) conducted an experiment in Bhandara, Maharashtra, India during Kharif 2000-2001 to investigate the requirement of phosphorus for rice production. They observed that there was a significant increase in grain yield with successive increase in P fertilizer. The highest grain yield (53.05 q ha^{-1}) was obtained with the application of 75 kg P ha^{-1}

Meena *et al.* (2003) conducted a field experiment at the Indian Agricultural Research Institute, New Delhi, India to study the productivity and economics of rice (*Oryza* *sativa* L.) as influenced by K application. The experiment was laid out in split plot design with 2 levels of potassium, viz., 62.5 and 125 kg K ha^{-1}. Significantly higher total number of tillers, dry matter accumulation, grain yield and straw yield were recorded with the application of 62.5 kg K ha^{-1} when applied in 2 equal splits (half at transplanting + half at maximum tillering.

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

Rao et al. (2004) reported that increase in P & K doses from 100 to 125 % improved grain yield significantly however, further incremental doses of P & K beyond 125 % did not result in significant yield improvement. Increased grain yield associated with added fertilizer levels might be due to the cumulative effect of increased translocation of photo synthases to sink resulting in enhanced level of yield components.

Singh *et al.* (2006) reported that application of potassium increased the grain and straw yield of rice.

Yadav *et al.* (2006) reported that K application increased K content and uptake by rice.

Ali *et al*. (2007) showed that foliar application of K_2SO_4 at different concentrations significantly influenced the yield components. Foliar application with 6.0% K_2SO_4 significantly out yielded than rest of the treatments that was statistically at par with soil application of K_2SO_4 @ 50 kg K_2O ha^{-1}. Maximum paddy yield (3.84 ton/ha) was obtained with this treatment. foliar application of K_2SO_4 at 6.0 % concentration (equivalent to 48 kg K_2SO_4 ha^{-1}) and soil application of K_2SO_4 @ 50 kg K_2O ha^{-1} to rice crop produce almost equal yields.

Bahmaniar *et al.* (2007) observed that higher yield of rice can be obtained from higher dose of K over the present recommended rate.

According to Fairhurst *et al.* (2007), the rule of thumb 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).

P.K. Saha *et al.* (2009) reported that the application of K fertilizer either alone or in combination with rice straw positively influenced the plant height in both Boro and T. Aman season, while no beneficial effect of K fertilization was observed on panicle production in any season.

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.

Sangeetha *et al*. (2010) observed that recommended dose of NPK (75-50-50 kg ha-1) produced highest milling recovery, percent head rice, grain length, grain breadth and volume expansion ratio.

Bhiah *et al.* (2010) in a greenhouse experiment concluded that potassium application significantly increased the number of tillers in all varieties.

Bahmanyar and Soodaee (2010) reported that panicle length, plant height, number of tiller, number of grain per panicle, hollow grain percentage, grain and biological yield were significantly affected by N and K fertilization.

Sharma *et al.* (2012) found that increasing phosphorus levels up to 45 kg P ha^{-1} significantly increased growth parameters (plant height, flag leaf area, dry matter accumulation), yield components (number of panicles m^{-2} and number of grains panicle^{-1}) and grain and straw yields.

Yosef Tabar (2013) showed that plant height, stem height, total fertile tillers and rice grain yield significantly increased with increasing phosphorus fertilizer rates up to 90 kg ha^{-1}.

Zian N. *et al.* (2016) reported that as the potassium rate increased from $80 > 120 > 160$ kg K_2O ha^{-1}, the transpiration rate was observed to be increased and also increased nutrient uptake and reduced water stress that help to repair damage tissue. He also showed that application of potassium would minimize the effects on rice growth and physiology under cyclic water stress.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the influence of phosphorus and potassium on growth and yield of BRRI Hybrid dhan2. Materials used and methods followed during the course of study have been mentioned in this chapter under the heads and sub-heads as follows.

3.1 Description of the experimental site

3.1.1 Experimental period

The research was conducted from November 2019 to June 2020.

3.1.2 Experimental location

The present experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 23.077′ N latitude and 90.035′ E longitude with an elevation of 8.2 meter from sea level.

Experimental location presented in Appendix I.

3.1.3 Weather situation

The experimental site was located in a sub-tropical environment, which has three different seasons, with the winter season lasting from November to February. The pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). The maximum temperature during the crop growth period ranged from 15°C to 35°C with an average of 28.5°C during 2019-2020, while the minimum temperature ranges was from 10°C to 24°C with an average 17.33° C. The mean relative humidity ranged from 57 percent to 74 percent. The total rainfall received during the crop growth period was 245 mm received in 18 rainy days. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.1.4 Soil

The soil of the experimental field belonged to ‘The Modhupur Tract’, AEZ-28 (FAO,1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct yellowish brown mottles. The experimental area was well irrigated with proper drainage system and the land situated above flood level. The soil was sandy loam with 15% organic matter, 26% sand, 45% silt and 31% clay. The soil is slightly acidic in reaction with low organic matter with low organic matter content.

The experimental area was above flood level and proper sunshine having available irrigation and drainage system during the experimental period. The experimental plot was high land having Potential of Hydrogen 5.6. The Details morphological, physical and chemical properties of the experimental field soil are presented in Appendix III.

3.2 Experimental details

3.2.1 Planting materials

Rice variety, BRRI hybrid dhan2 (II) was used as the test crops in this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Levels of P (4 levels) as

i. P_0: 0 kg P ha^{-1} (control)

ii. P_1: 30 kg P ha^{-1}

iii. P_2: 45 kg P ha^{-1}

iv. P_3: 60 kg P ha^{-1}

Factor B: Levels of K (4 levels) as

i. K_0: 0 kg K ha^{-1} (control)

ii. K_1: 30 kg K ha^{-1}

iii. K_2: 45 kg K ha^{-1}

iv. K_3: 60 kg K ha^{-1}

There were total 16 (4×4) combination as a whole *viz.*, P_0K_0,P_0K_1,P_0k_2,P_0K_3,P_1K_0,P_1K_1,P_1K_2,P_1K_3,P_2K_0,P_2K_1,P_2k_2,P_2K_3,P_3K_0,P_3K_1, P_3K_2 and P_3K_3.

3.2.3 Experimental design and layout

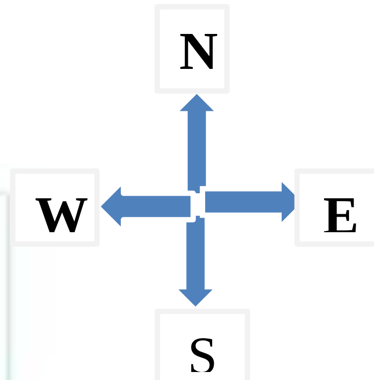
Three replications of the two factors experiment were set up using a randomized complete block design (RCBD). Each replication represents a block and each block sub-divided into sixteen unit plots. The treatments were randomly distributed to the unit plots in each block. Total numbers of unit plots were 48 (forty-eight).

The size of the each unit plot was 4.0m x 2.5m. Plot to plot distance was 0.25m and block to block distance was 0.50. The layout of the experiment has been shown in the figure 3.1.

Figure 1: Layout of the experiment plot.

R_1	R_2	R_3
P_0K_2	P_3K_1	P_2K_3
P_3K_0	P_0K_3	P_0K_2
P_3K_1	P_2K_2	P_1K_1
P_3K_3	P_0K_0	P_3K_0
P_1K_3	P_1K_0	P_0K_1
P_0K_0	P_3K_2	P_1K_3
P_2K_2	M_2K_1	P_3K_0
P_1K_1	P_1K_3	P_3K_0
P_2K_3	P_1K_0	P_3K_0
P_1K_0	P_2K_2	P_2K_3
P_0K_3	P_3K_3	P_3K_1
P_1K_2	P_0K_1	P_1K_2
P_2K_0	P_3K_2	P_0K_3
P_3K_2	P_2K_1	P_1K_1
M_0K_1	P_1K_3	P_2K_2
P_3K_1	P_0K_0	P_0K_0

Legend



Plot Length: 4 m

Plot Breath: 2.5 m

Unit plot area = 4.0 x 2.5 m^2

Plot to plot distance: 0.25 cm

Block to block distance: 0.5 m

Table 1. Two factors consist of sixteen (4*4=16) treatments combination. There are as follows:

Treatments	Description	
	Phosphorus	Potassium
P_0K_0	Control (No phosphorus)	Control (No potassium)
P_0K_1	Control	30 kg k/ha
P_0K_2	Control	45 kg k/ha
P_0K_3	Control	60 kg k/ha
P_1K_0	30 kg P/ha	Control
P_1K_1	30 kg P/ha	30 kg k/ha
P_1K_2	30 kg P/ha	45 kg k/ha
P_1K_3	30 kg P/ha	60 kg k/ha
P_2K_0	45 kg P/ha	Control
P_2K_1	45 kg P/ha	30 kg k/ha
P_2K_2	45 kg P/ha	45 kg k/ha
P_2K_3	45 kg P/ha	60 kg k/ha
P_3K_0	60 kg P/ha	Control
P_3K_1	60 kg P/ha	30 kg k/ha
P_3K_2	60 kg P/ha	45 kg k/ha
P_3K_3	60 kg P/ha	60 kg k/ha

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds of BRRI Hybrid dhan2 (II) were collected from BRRI (Bangladesh Rice Research Institute) from Gazipur just 20 days ahead of the sowing of seeds in seed bed. To collect seedlings, clean seeds were soaked for twenty four hours in a pail of water. The seeds were then removed from the water and stored in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in the seed bed in 72 hours.

3.3.2 Raising of seedlings

Puddling, repeated ploughing, and laddering were used to prepare the bed. The sprouted seeds were sown on beds as uniformly as possible at 18th November, 2019. When necessary, a gentle irrigation was applied to the bed. The nursery bed did not have any fertilizer.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 15th December, 2019 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design at 23th December, 2019. Organic and inorganic manures as indicated 3.3.4 were mixed with the soil of each unit plots. The fertilizers N, P, K, S, Zn and B in the form of Urea, Triple superphosphate (TSP), muriate of potash (MOP), Gypsum, Zinc sulfate and Borax, respectively were applied @ 120, 60, 60, 16 and 10 kg ha^{-1} (BRRI, 2016). P and K were applied as per treatment. The entire amount of TSP, MOP, gypsum, zinc sulfate and borax were applied during final preparation. At the early and maximal tiller and panicle start stages, urea was supplied in three equal installments as top dressing.

3.3.4 Transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 21 December, 2019 through well paddled plot with spacing of 20 x 15 cm. One healthy seed was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.5 Intercultural operations

To ensure the crop's regular development, intercultural activities were carried out. When necessary, precautions for plant preservation were taken. The following intercultural operations were done.

3.3.6.1 Irrigation and drainage

In the early stages to establishment of the seedlings irrigation was provided to maintain a constant level of standing water up to 6 cm and then maintained the amount drying and wetting system throughout the entire vegetative phase. There was no water stress during the reproductive and ripening phases. After fifteen days prior to harvest, the plot had completely dried out.

3.3.6.2 Weeding

To maintain the plots free of weeds, weeding was done, which eventually resulted in greater seedling growth and development. At 20 DAT and 40 DAT (days after transplanting), mechanical methods were used to gently eradicate the weeds.

3.3.6.3 Insect and pest control

The plot received a carbofuran application at 15 DAT. Leaf roller (*Chaphalocrosis medinalis*) was found and used Malathion @1.12 L ha^{-1} at 25 DAT using sprayer but no diseases infection was observed in the field.

3.4 Harvesting, threshing and cleaning

The crop was harvested full maturity based on variety when eighty percent of the grains were turned into straw color. The harvested crop was bundled separately properly tagged and brought to threshing floor. The grains were dried, cleaned and weighed for plot. The weight was adjusted to twelve percent moisture content. Yields of rice grain and straw were recorded from each plot.

3.5 Collecting Data

Biometrical data were recorded on growth, development, yield attributes and yield. Different parameters were recorded at different well defined physiological stages viz., tillering. panicle initiation (PT) stage, anthesis and maturity. These stages are critical stages for growth and development as well as realization of final output.

Tillering

Starting at the plant's base and sprouting from the inside of seedling leaves on the main stalk are tillers. Tiller (or shoot) development normally starts as rice hits the 3–4 leaf stage, beginning the tillering stages (35 days). Tillers are supplementary shoots that grow from the primary shoot.

Panicle Initiation (PI)

Panicle initiation (60 days) is the first stage in the reproductive phase of growth. It is determined when the panicle primordial initiate the production of a panicle in the uppermost node of the culm. At this point, the developing panicle is microscopic in size inside the stem and is not visible to the naked eye.

Anthesis or flowering stage

The flowering stage (85 days) completes with the emergence of the first anthers from the uppermost spikelet on each panicle.

Maturity

When the endosperm turns firm and opaque, the grain is said to be mature or ripe. As the grains mature, nitrogen is transported from the leaves to the seed, causing the plant's leaves to become yellow. The full maturity stage (110 DAT) is reached when more than ninety percent of the grains in the panicles have ripened.

3.5.A Growth parameter

3.5.A.1 Plant height

The height of plant was measured in centimeter (cm) from the ground level to the tip of the plant at the afore-mentioned four stages. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot, plot. The weight was adjusted to 12% moisture content. Yields of rice grain and straw were recorded from each plot.

3.5.A.2 Panicle hill^{-1}

Panicle per hill was recorded from 5 hills and the means were calculated. Tiller with at least one leaf was counted. It included both effective and non effective tiller.

3.5.A.3 Dry matter hill^{-1}

At harvest time, five hills from each unit plot were uprooted, oven-dried for 72 hours at 70 degrees, and weighed to determine the total dry matter accumulation.

3.5.A.4 Leaves hill^{-1}

The number of tillers hill^{-1} was counted at first at afore-mentioned four stages. Only those tillers having three or more leaves were used for counting.

3.5.B Sampling

Data pertaining to dry matter accumulation and LAI were taken through destructive sampling method. Five sample hills were uprooted from each plot at different stages and roots were removed. Hills were selected from third rows during sampling to minimize the border or side effect.

3.5.C. Leaf area index

Then uprooted plant hills were partitioned into green leaf, dead leaf, stem (culm + leaf sheath) and panicles. Leaf area was measured manually measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981) just after removal of leaves to avoid rolling and shrinkage, and were transformed into leaf area index (LAI).

$$LAI = (\text{Area of leaf coverage per plant})/(\text{Area of soil covered per plant})$$

3.5.D. Dry matter accumulation

The segmented plant samples were kept in separated envelopes and were oven dried at 70°C for 72 hours. After drying, weight of each component was determined with a digital balance and the means were calculated. Finally total dry matter (TDM) at different stages was calculated adding the weight of different plant parts.

3.5.F. Yield data

3.5.F.1 Effective tillers (panicles) hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers during harvesting. The panicle which had at least one grain were considered as effective tiller.

3.5.F.2 Non-Effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the number of non-panicle bearing tillers during harvesting. Data on non-effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.F.3 Panicle length

Panicle length was measured from the rachis's base node to the tip of each panicle. The length of each panicle from five different hills was measured, the means were computed, and the average length in cm was reported.

3.5.F.4 Filled grains panicle

The total numbers of filled grains were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.F.5 Unfilled grains panicle^{-1}

The total number of empty grains panicle^{-1} was gathered at random from 5 plants in a plot that had no grain in the spikelet, and the average number of unfilled grains panicle^{-1} was recorded.

3.5.F.6 Total grains panicle^{-1}

Grains were separated from panicles and grain number per panicle was counted manually. Presence of food materials in the spikelet was considered as grain and total number of grains present on each panicle was counted and the means were calculated. It includes both filled and unfilled grains per panicle.

3.5.F.7 Weight of 1000-grains

1000 clean dried grains from the seed stock of each plot were counted separately and weighted by an electric balance and adjusted at fourteen percent (14%) moisture level. The moisture content was also measured with an electric moisture meter taking ten to twelve (10-12) grain from the sample. Grain moisture content was adjusted by using the following formula:

Grain weight (at 14% moisture content)

$$= \frac{(100 - \text{sample MC}) \times (1000\ \text{grain weight at sample MC})}{100 - 12}$$

3.6.A. Grain yield

Grain obtained from whole plot basis were threshed and grains were dried well and weighed. The weights were adjusted at 12% moisture level. Dry weight of grains of each plot was converted to kg ha^{-1}. Grain yield was measured using triple balance and converted the yield into 14% field moisture content (FMC) by using the following formula:

Yield (at 12% moisture content)= $\frac{10\,(100-\text{FMC})}{100-12} \times \frac{\text{Plot yielding}}{\text{Plot area (m}^2)}$

3.6.B. Straw yield

Total straw yield of the harvest area of each plot was determined. Sample straw of each plot was dried in oven at 70˚ C for 72 hours and converted the sample into total straw yield. The weights were adjusted at 12% moisture levels.

3.6.C. Biological yield

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

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1})+ straw yield (t ha^{-1})

After recording data from five plant samples, the sample yield was included with the respective plot yield and finally converted in hectare yield.

3.6.D. Harvest index

The harvest index was computed as the ratio of economic yield (grain yield) to the biological yield (grain yield + straw yield). The harvest index (%) was calculated by the following empirical formula given below :

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7. Statistical analysis:

The data was statistically evaluated using the Statistix 10 computer software tool. The mean for all treatments was computed and F-test was used to do analysis of variance for each of the characters. Finally, at a significance level of 0.05 percent, the difference between treatments was analyzed using the Least Significant Difference (LSD) test.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

At the experimental farm of SAU, Dhaka, the effects of various phosphorus and potassium nutrient dosages on the yield contributing characteristic and yield of BRRI hybrid dhan2 (II) were investigated. Results obtained were discussed under appropriate sub heads with suitable tables and graphs presented in proper format. The data on growth, yield and yield attributing characters of BRRI Hybrid dhan2 (II) are shown in figures two to nine and tables two to nine. Yield and yield attributing characters include plant height, tillers hill^{-1}, leaf area index, dry matter accumulation, panicles hill^{-1}, dry-matter translocation into shoot, panicle length, filled grains panicle^{-1}, total weight of 1000-grains, grain yield, straw yield, and biological yield and harvest index.

4.1 Plant height

Plant height is one of the important growth and development indicators; Data analysis revealed that both nutrients (phosphorus and potassium) had a substantial impact on rice plant height at different days after transplanting (DAT). However, the magnitude varied according on the level and increased with growth up until anthesis, after which it slowed down significantly (Figure 2). Application of phosphorus at 30 kg ha^{-1} produced significantly taller plants over no application of phosphorus (P_0) at 35 DAT. Application of phosphorus at 45 kg ha^{-1} demonstrated advantage over P_0 and P_1 treatments at all DAT but produces at level with maximum amount of phosphorus application, i.e. 45 kg ha^{-1}. At maturity, plots treated with phosphorus at 45 kg ha^{-1} produced the tallest (97.08 cm) plant. These results are in partial agreement with those of Morgan in 1997 who has reported that application of NPK significantly affected plant height.

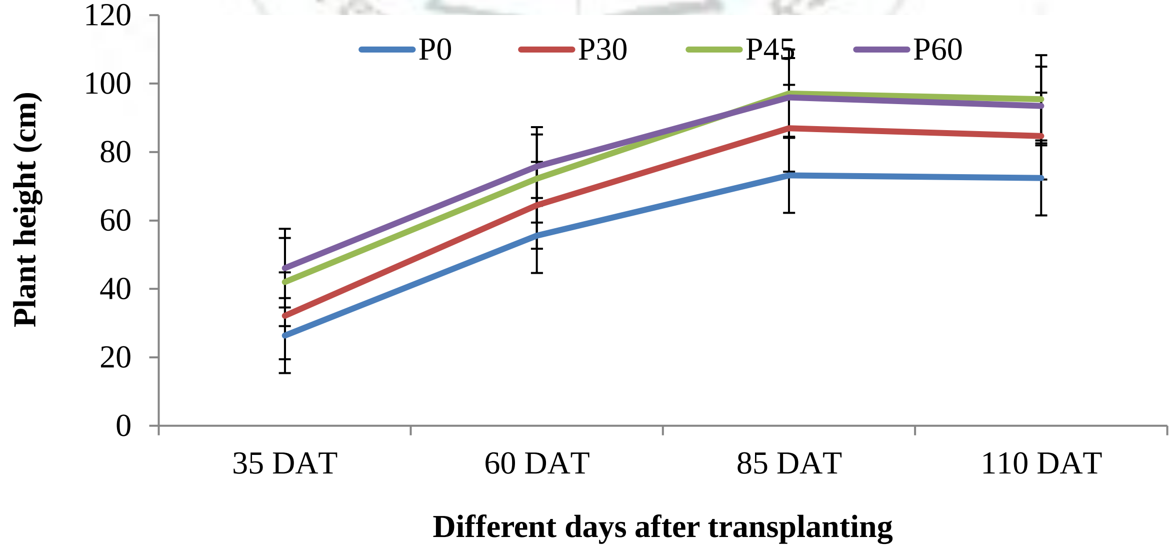


Figure 2. Effect of phosphorus on plant height at different days after transplanting.

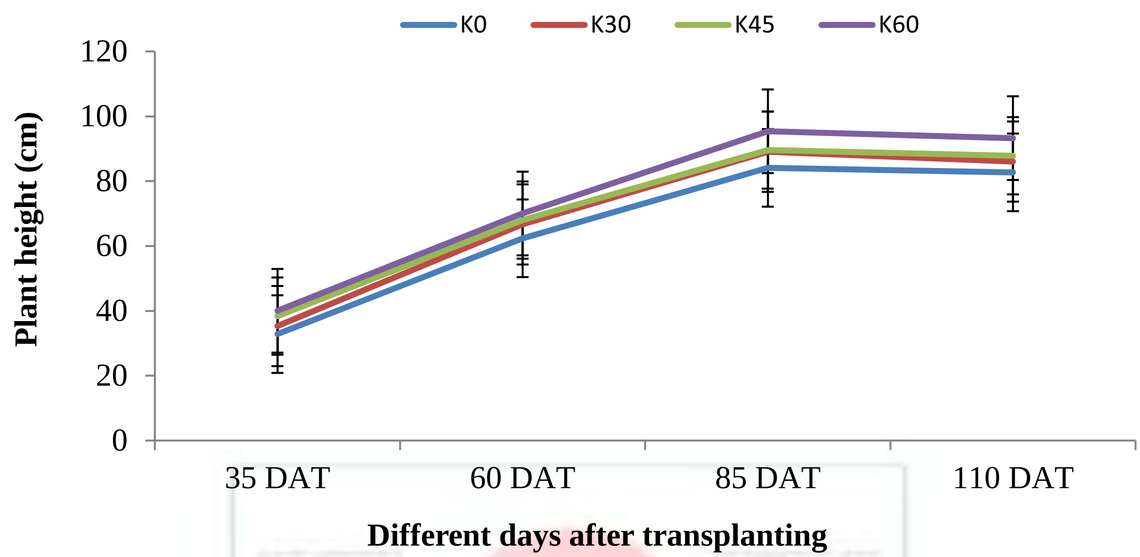


Figure 3. Effect of potassium on plant height at different days after transplanting.

Similar type of response was also noticed in case of potassium application. Application of K at 60 kg ha^{-1} recorded significantly higher plant height over no application of K, however it produces with K applied at 60 kg ha^{-1} (K_3 treatment) during entire life cycle (Fig. 3). Maximum (95.38 cm) plant height at maturity was recorded with application of 60 kg ha^{-1} (K_3 treatment), whereas corresponding minimum (62.83 cm) plant height was recorded with no application of K_0. The interaction effective of phosphorus and potassium was significant on the plant height. Table 2 shows that the highest (101.33) plant height was obtained by P_2K_3 treatment (45 kg P ha^{-1}+60 kg K ha^{-1}) and the lowest figure was noticed in control treatment (P_0K_0).

Table 2: Interaction effect of different levels of phosphorus and potassium on plant height.

Treatment	Plant height

	35 DAT	60 DAT	85 DAT	110 DAT
P_0K_0	23.08i	50.92j	67.67i	68.17k
P_0K_1	25.42hi	54.17i	72.33h	72.17j
P_0K_2	27.42gh	56.00hi	75.00gh	74.17ij
P_0K_3	29.50fg	57.33h	77.67g	75.17i
P_1K_0	28.92fg	61.75g	85.17f	82.17h
P_1K_1	31.08ef	63.33fg	86.08ef	83.08h
P_1K_2	33.75de	65.25ef	87.50def	85.92g
P_1K_3	34.75d	67.33e	89.00de	87.42fg
P_2K_0	35.42d	63.92fg	90.08d	90.58de
P_2K_1	40.42c	73.17cd	98.00b	95.67bc
P_2K_2	43.83b	74.50bcd	98.92ab	96.33b
P_2K_3	48.33a	77.42a	101.33a	99.08a
P_3K_0	43.92b	72.92d	93.50c	89.92ef
P_3K_1	44.33b	75.92abc	95.92bc	93.25cd
P_3K_2	47.50a	76.25ab	96.50bc	94.92bc
P_3K_3	48.50a	78.00a	97.92b	95.67bc
$LSD_{(0.05)}$	2.85	2.75	3.23	2.72
CV%	3.56	3.15	3.19	2.88

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation .

4.2 Number of tillers

Phosphorus levels had significant influence on number of tillers as recorded at 35,60, 85 and at 110 DAT (Table 2). As the phosphorus levels was increased from 0 kg P ha^{-1} to 60 kg P ha^{-1}, the number of tillers increased significantly and recorded maximum (total tillers $hill^{-1}$) at 85 DAT. However, at 35 DAS phosphorus level failed to brings significant variations in number of tillers. This may be due to mutual competition among the plants for light, nutrients and other growth input resulting in slower increases of tillers. The highest total tillers $hill^{-1}$ at 85 DAT might be due to higher availability of nutrient which facilitated proper synchronized tillering. These results are in close accordance to those of Yosef Tabar (2012); Alam *et al.*, (2015) and Puteh *et al.,* (2014). The maximum (21.75) tillers was obtained with 60 kg P ha^{-1} (P_3 treatment) at 85 DAT.

This might be due to the fact that the number of tillers at this level of phosphorus was so high that even after mortality, it remained significantly higher than that of other levels of phosphorus and this consequently led to more number of panicle bearing tillers and panicle at this type of phosphorus management. Similar findings also reported by Devi and Sumathi (2013).

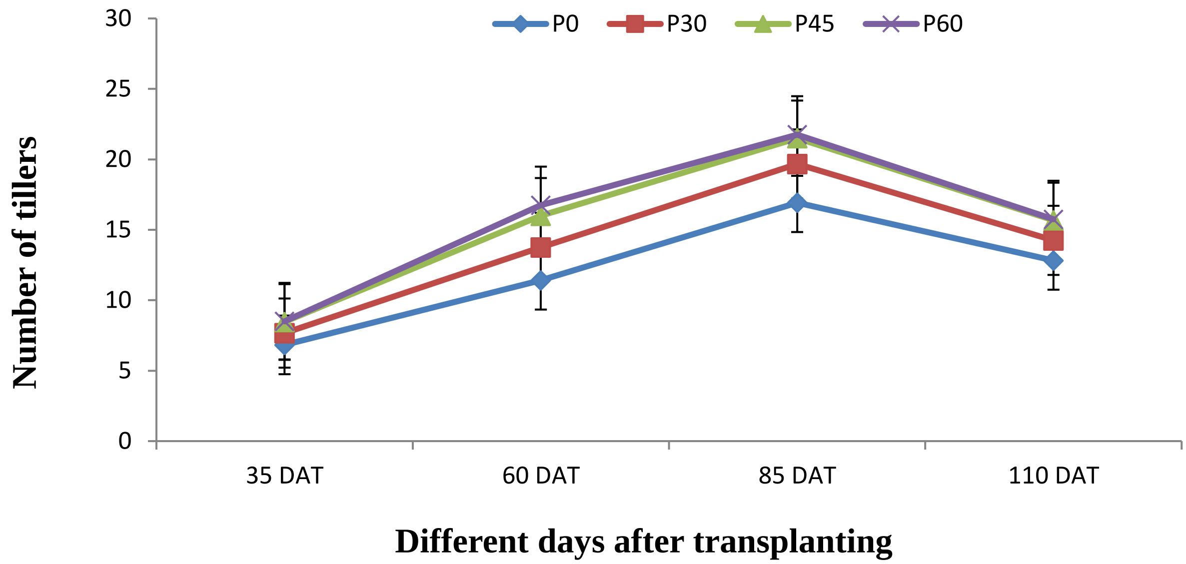


Figure 4. Effect of phosphorus on number of tillers at different days after transplanting.

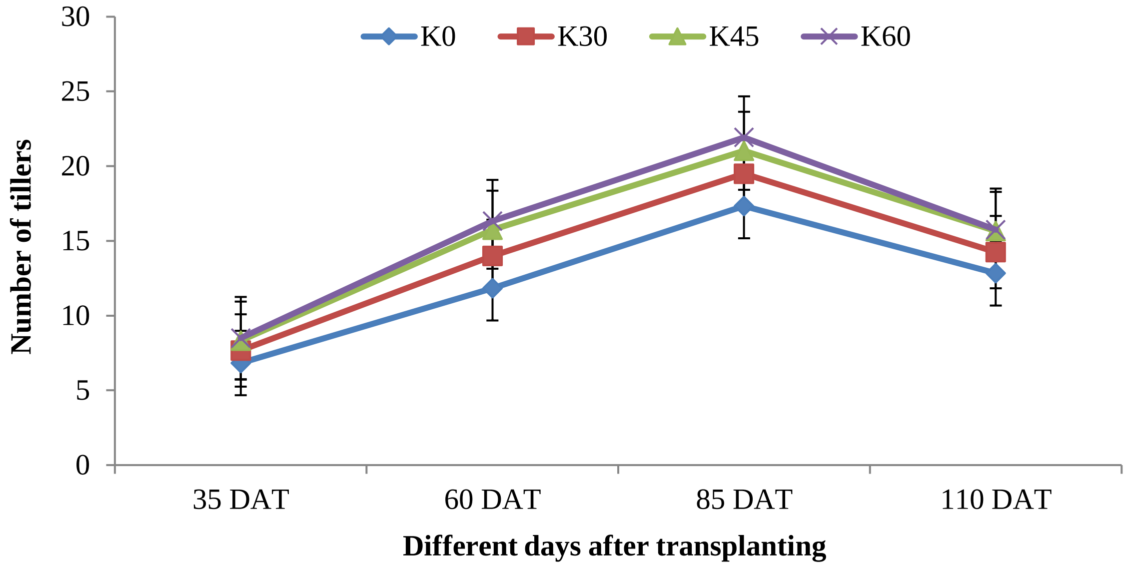


Figure 5. Effect of potassium on number of tillers at different days after transplanting.

Table 3: Interaction effect of different levels of phosphorus and potassium on number of tillers per hill.

Treatment	Number of tillers			
	35 DAT	60 DAT	85 DAT	110 DAT
P_0K_0	6.33g	10.67h	15.00h	12.00i
P_0K_1	6.67fg	11.33gh	16.67g	12.67ghi
P_0K_2	7.33def	12.33fg	18.67ef	13.67efg
P_0K_3	7.33def	13.00f	19.00ef	13.67 efg
P_1K_0	6.67fg	11.00h	16.33gh	12.33hi
P_1K_1	7.67cde	13.33f	19.67de	14.00ef
P_1K_2	8.00bcd	15.33de	21.00cd	15.33cd
P_1K_3	8.33bc	16.33cd	21.33cd	15.67bcd
P_2K_0	7.00efg	11.67gh	17.67fg	13.33fgh
P_2K_1	8.00bcd	14.67e	20.67cd	14.67de
P_2K_2	8.67b	17.33bc	22.00bc	16.33abc
P_2K_3	9.67a	19.33a	24.00a	17.00a
P_3K_0	7.33def	12.33fg	18.67ef	13.67efg
P_3K_1	8.33bc	15.67de	21.67bc	15.67bcd
P_3K_2	9.67a	19.00a	24.33a	17.33a
P_3K_3	8.67b	18.33ab	23.00ab	16.67ab
$LSD_{(0.05)}$	0.84	1.08	1.47	1.07
CV%	6.42	4.48	4.43	4.38

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. . P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

The number of tillers per hill^{-1} was significantly influence by potassium application (Figure 5). The maximum (21.92) tillers were observed with 60 kg ha^{-1} potassium (K_3 treatment) at 85 DAT. These may be due to contribution of potassium in plant growth. The similar kind of result was recorded by Muamba and Ambara (2013) and Saeed *et al.*, (2011). The interaction effective of phosphorus and potassium was significant on number of tillers per hill . Table 3 shows that the numbers of tillers (24.33) was obtained by P_3K_2 treatment (60 kg P ha^{-1}+45 kg K ha^{-1}) and the lowest figure was noticed in control treatment (P_0K_0).

4.1.3 Leaf Area Index (LAI)

Leaf area index (LAI) or the surface area of green leaves produced by rice plants unit area^{-1} of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. LAI was significantly affected by phosphorus treatments observed at 35, 60, 85, 110 DAT and at harvest. Maximum (6.51) LAI was found at 85 DAT due to the effect of 60 kg P ha^{-1} which was followed by P_3 treatment (60 kg P ha^{-1}). However, after 110 DAT, LAI declined due to senescence of leaves with the progress to maturity. Thus, Phosphorus application influences leaf area index (LAI) significantly. LAI increases with advancement of growth stage till the anthesis. Marked reduction in LAI was noticed at maturity for rice plant at different fertilizer level. Similar result was reported by Rahman *et al*., 2008 and Singh *et al*., 2011.

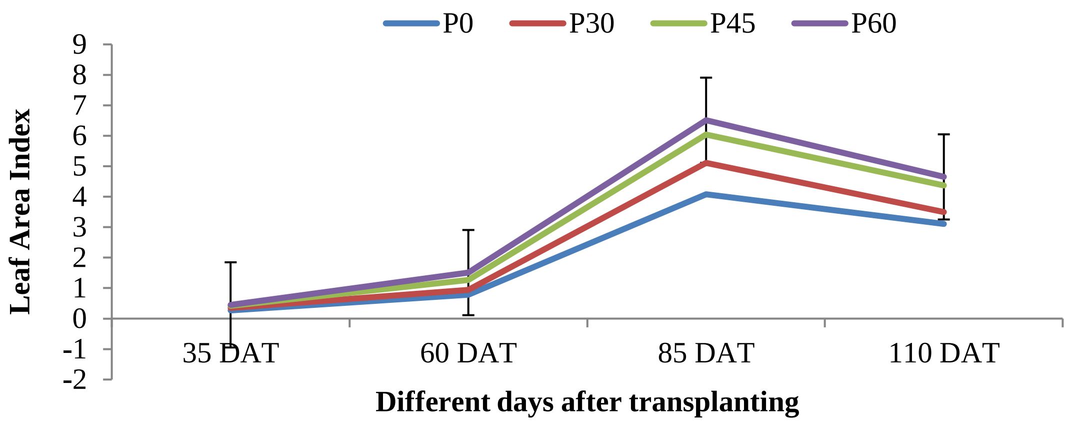


Figure 6. Effect of phosphorus on leaf area index at different days after transplanting.

Plots received 60 kg phosphorus and produced significantly higher LAI over no application and produced at par with other tested levels of phosphorus in most of the stages. P deficiency in rice is referred to as a "hidden hunger" is characterized by an abnormal bluish green color of the foliage with small leaf, relatively few tillers, and decreased root mass probably may be the main reason to decrease the LAI in rice. Pellerin *et al.* (2000) reported that P deficiency in the control plots (P not applied) had negative effects on LAI and its subsequent effect on PAR absorption, C-nutrition. Marked response of applied potassium on LAI was also noticed and it was more pronounce than phosphorus treatments in general.

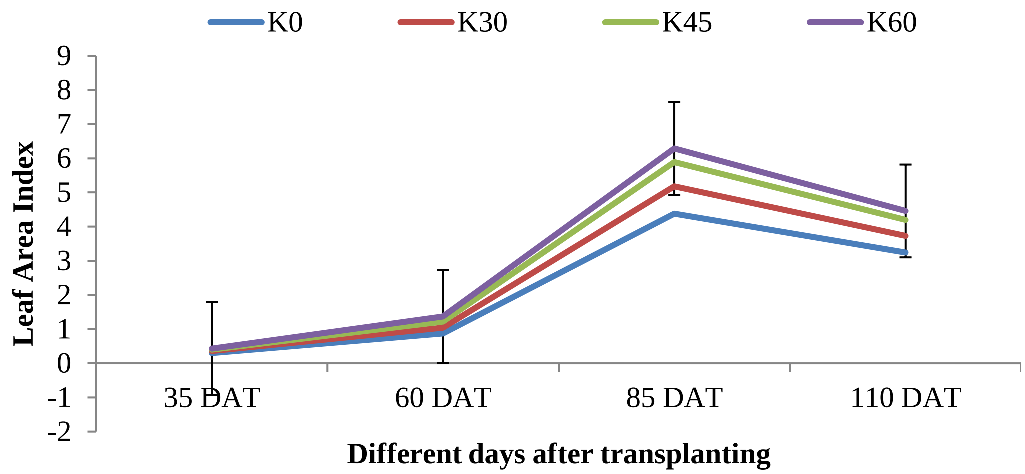


Figure 7. Effect of potassium on leaf area index at different days after transplanting.

In case of potassium application highest (6.29) LAI was obtained with potassium at 60 kg ha^{-1} and minimum (4.38) with no application of potassium (K_0) at anthesis. However lower LAI was notice during 35 days after transplanting. There was no statistically variation in the value of LAI as was observed at 35 DAT but significant at others due to the interaction of phosphorus and potassium. At 35 DAT maximum (0.52) LAI was observed with P_2K_3 (45 kg P ha^{-1}+ 60 kg K ha^{-1}) and minimum was with P_0K_0. At 60 DAT maximum (1.78) LAI was observed with P_2K_3 (45 kg P ha^{-1} and 60 kg K ha^{-1}) which was statistically similar with P_3K_2 (60 kg P ha^{-1} and 45 kg K ha^{-1}) and minimum was with P_0K_0. At 85 DAT maximum (7.44) LAI was observed with P_2K_3 (45 kg P ha^{-1} and 60 kg K ha^{-1}) which was all time higher.

Table 4: Interaction effect of different levels of phosphorus and potassium on leaf area index (LAI) at different days after transplanting.

Treatment	Leaf area index			
	35 DAT	60 DAT	85 DAT	110 DAT
P_0K_0	0.23j	0.67j	3.88j	2.85g
P_0K_1	0.26ij	0.73ij	3.98ij	2.95g
P_0K_2	0.28i	0.82gh	4.13i	3.24f

P_0K_3	0.31gh	0.88fg	4.34h	3.40f
P_1K_0	0.29hi	0.78hi	4.03ij	2.967g
P_1K_1	0.34efg	0.89f	4.86g	3.31f
P_1K_2	0.37de	1.00e	5.37f	3.66e
P_1K_3	0.40cd	1.11d	6.16d	4.07d
P_2K_0	0.34fg	0.92f	4.39h	3.39f
P_2K_1	0.39d	1.11d	5.62e	4.34c
P_2K_2	0.43c	1.28c	6.72c	4.52c
P_2K_3	0.52a	1.78a	7.44a	5.24ab
P_3K_0	0.35ef	1.10d	5.21f	3.74e
P_3K_1	0.43c	1.45b	6.28d	4.34c
P_3K_2	0.52a	1.76a	7.33ab	5.38a
P_3K_3	0.48b	1.73a	7.20b	5.13b
$LSD_{(0.05)}$	0.04	0.06	0.19	0.24
CV%	5.82	3.37	3.04	3.74

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

4.4 Total dry matter

Dry matter is the material that was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. Total dry matter of roots, leaves, leaf sheath + stem and or panicles of plants data were measured at 35, 60, 85 and 110 DAT. It was evident from Figure 8 that significant variation was found in the total dry matter accumulation at different days after transplanting. Accumulation of dry matter was very slow at early stage (35 DAT to 60 DAT) and increased progressively over time attaining the highest at harvesting time. The rate of increase varied depending on the growth stages. At 35 DAT, higher (0.40 g) total dry matter was found with P_3 (60 kg P ha^{-1}) which was statistically similar (0.35 g, 0.29 g) with P_1 (30 kg P ha^{-1}) , P_2 (45 kg P ha^{-1}) and lowest (0.14 g) with P_0 (0.0 kg P ha^{-1}).

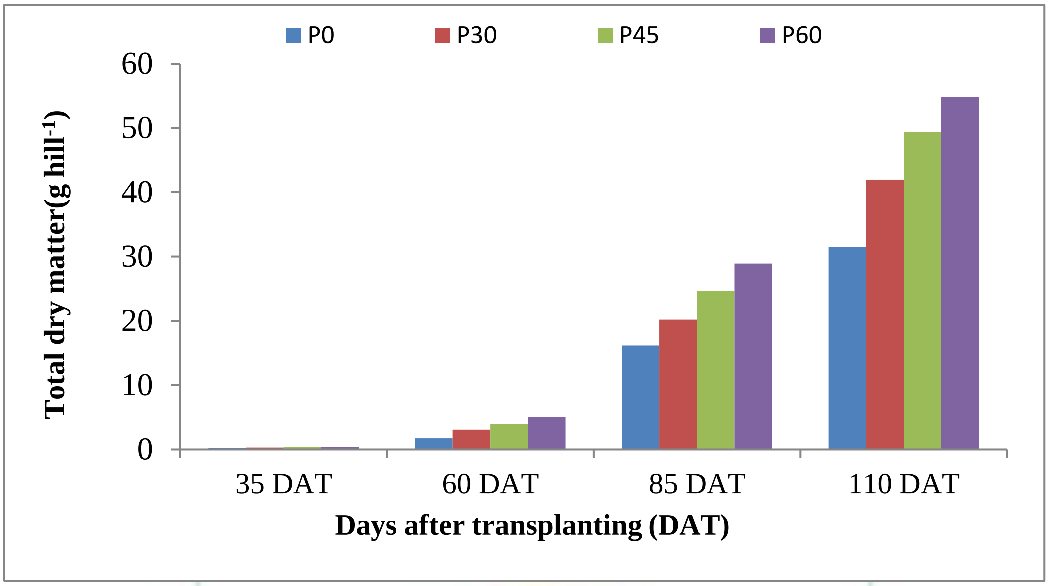


Figure 8. Effect of phosphorus on total dry matter at different days after transplanting.

At 60 DAT, maximum (5.07 g) total dry matter was obtained with P_3 (60 kg P ha^{-1}) and minimum (1.73 g) with control P_0 (no phosphorus). The trend was also found at 85 DAT and 110 DAT. At 85 DAT the highest total dry matter (28.94 g) was obtained with P_{60} (60 kg P ha^{-1}) and lowest (16.16) with P_0 (control treatment). At 110 DAT higher (54.83 g) total dry matter was found with P_3 (60 kg P ha^{-1}) and lowest (31.44 g) with P_0 treatment which was 74.4% lower than P_3 treatment. Positive influence of phosphorus on total dry matter in rice was also reported by Gupta and Bhadra (1980) and Sharkar and Chowdhury (1988**).**

The level of potassium has no significant difference to accumulate the total dry matter. It was evident from Figure 9 that significant dry matter increased progressively over the time attaining the maximum at harvest. The rate of increase, however, varied depending on the growth stages.

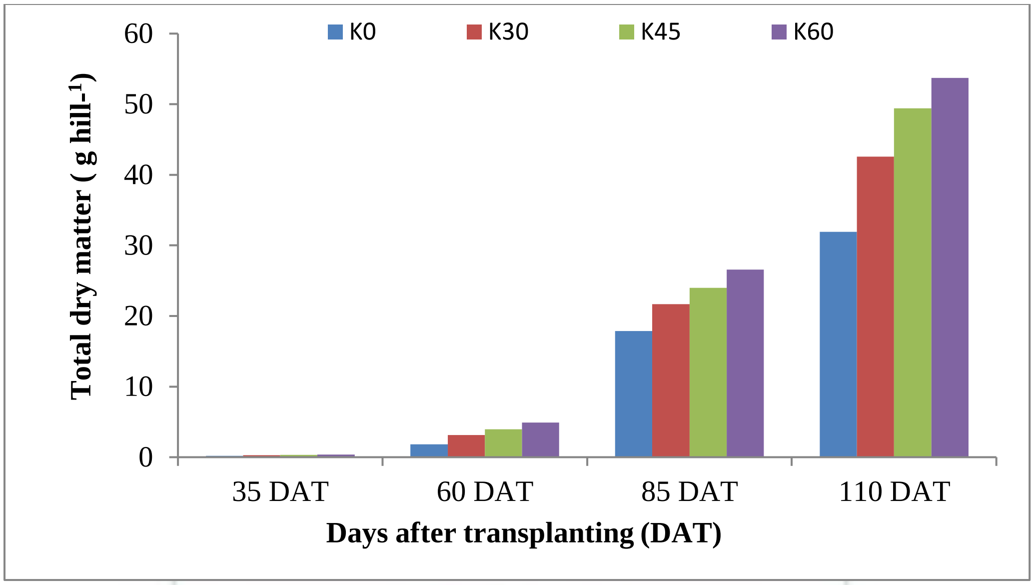


Figure 9. Effect of potassium on total dry matter at different days after transplanting.

At 35 DAT, higher total dry matter (0.38 g) was found with K_3 (60 kg K ha^{-1}) which was statistically similar (0.29 g, 0.35 g) with K_1 (30 kg K ha^{-1}) , K_2 (45 kg K ha^{-1}) and lowest (0.21 g) with K_0 (0.0 kg K ha^{-1}). At 60 DAT, maximum (4.89 g) total dry matter was obtained with K_3 (60 kg K ha^{-1}) and minimum (1.82 g) with control K_0(no potassium). The trend was also found at 85 DAT and 110 DAT. At 85 DAT the highest (26.56 g) total dry matter was obtained with K_3 (60 kg K ha^{-1}) and lowest (17.86 g) with K_0(control treatment). At 110 DAT higher (53.71 g) total dry matter was found with K_3 (60 kg P ha^{-1}) and lowest (31.90 g) with P_0 treatment which was 68.37% lower than P_3 treatment.

The interaction effect of phosphorus and potassium has significant difference to accumulate the total dry matter (Table 5). Accumulation of total dry matter increased progressively over the time attaining the maximum at 110 DAT. The rate of increase, however, varied depending on the growth stages**.** At 30 DAT, maximum (0.51 g) total dry matter was obtained with the treatment combination of P_3K_2 (60 kg P ha^{-1} and 45 kg K ha^{-1}) which was statistically similar with P_2K_3 (45 kg P ha^{-1} and 60 kg K ha^{-1}) and minimum (0.15 g) with P_0K_0 treatment. At 60 DAT, highest (6.13 g) total dry matter was observed with P_3K_2 (60 kg P ha^{-1} and 45 kg K ha^{-1}) and lowest (1.22 g) with P_0K_0. At 85 DAT, the highest (32.83 g) total dry matter was found with with P_2K_3 (45 kg P ha^{-1} and 60 kg K ha^{-1}) and lowest (14.33 g) with P_0K_0 which was 129.1% lower than P_2K_3..At 110 DAT, highest total dry matter (64.13 g) was observed with P_3K_2 (60 kg P ha^{-1} and 45 kg K ha^{-1}) and lowest (24.57 g) with P_0K_0 which was 161.01% lower than P_2K_3..

Table 5: Interaction effect of different levels of phosphorus and potassium on dry matter accumulation at various days after transplanting.

Treatment	Total dry matter			
	35 DAT	60 DAT	85 DAT	110 DAT
P_0K_0	0.15j	1.22k	14.33h	24.57h
P_0K_1	0.18ij	1.43jk	15.19h	28.88g
P_0K_2	0.20i	1.83h	16.78gh	33.71f
P_0K_3	0.25gh	2.43g	18.34fg	38.60de
P_1K_0	0.19ij	1.53ij	15.73gh	29.33g
P_1K_1	0.28efg	2.47g	20.14ef	40.50d
P_1K_2	0.32de	3.42e	20.93ef	46.18c
P_1K_3	0.36cd	4.90c	24.11cd	51.75b
P_2K_0	0.22hi	1.77hi	18.39fg	34.99ef
P_2K_1	0.32def	3.34e	21.96de	46.14c
P_2K_2	0.37c	4.41d	25.60c	53.60b
P_2K_3	0.50a	6.13a	32.83a	62.78a
P_3K_0	0.27fg	2.75f	22.96cde	38.71d
P_3K_1	0.39bc	5.29b	29.34b	54.78b
P_3K_2	0.51a	6.13a	32.50a	64.13a
P_3K_3	0.42b	6.11a	30.95ab	61.72a
Lsd $_{(0.05)}$	0.05	0.27	2.86	3.62
CV%	8.98	4.64	7.63	4.89

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. . P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

4.5. Yield Components

4.5.1. Panicle hill^{-1}

Panicles hill^{-1} differed significantly due to different levels of phosphorus application (table 6). The highest (12.49) number of panicles hill^{-1} was observed with P_3 treatment that is when the crop was fertilized with 60 kg P ha^{-1} and the lowest (8.27) was obtained in control. It can be concluded from the above results that increase in P levels caused considerable increase in number of panicles hill^{-1}. The results corroborate the findings of Verma *et al*. (1991). Chowdhury *et al.* (1995) also reported that number of panicles of rice was increased due to P applications. Crop grown with K_3 treatment (60 kg K ha^{-1}) produced the highest panicles hill^{-1} (11.36) and the control treatment (K_0) produced the lowest (9.12) panicles hill^{-1} . But the result is insignificant statistically. The interaction effective of phosphorous and potassium was significant on the panicles hill^{-1}. Table 8 shows that the highest (14.44) panicles hill^{-1} was obtained by P_3k_2 treatment (60 kg P ha^{-1} +45 kg K ha^{-1}) and the lowest figure was noticed at control treatment (P_0K_0).

4.5.2 Panicle length

Panicle length was significantly affected by different levels of phosphorus applications (table 6). The highest (24.56 cm) panicle length was found at 60 kg P ha^{-1} and the lowest (18.11) was at control. Different levels of K produced a significant variation in panicle length. Table 7 shows that the highest (22.89 cm) panicle length was observed with 60 K kg ha^{-1} and the lowest (19.63 cm) was obtained in control treatment.

The interaction effect of P and K levels showed significant influenced on the panicle length (Table 8). The highest (26.52) panicles hill^{-1} was obtained by P_3k_2 treatment (60 kg P ha^{-1} +45 kg K ha^{-1}) produced statistically similar panicle length of rice. The lowest

(17.07 cm) value was found from the control. Above findings focused that interaction of P and K has a pronounced influence on panicle length.

Table 6. Effect of different Levels of phosphorus on yield components..

Treatment	Panicle $hill^{-1}$	Panicle length	Filled grains $panicle^{-1}$	Weight of 1000-grains (g)
P_0	8.27d	18.11d	84.19d	17.86d
P_{30}	9.92c	20.57c	89.92c	19.52c
P_{45}	11.67b	22.95b	96.94b	21.31b
P_{60}	12.49a	24.56a	105.83a	21.92a
$Lsd_{(0.05)}$	0.31	0.26	2.14	0.37
CV (%)	3.74	4.39	6.18	3.92

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, CV= Coefficient variation.

Table 7. Effect of different Levels of potassium on yield components..

Treatment	Panicle $hill^{-1}$	Panicle length	Filled grains $panicle^{-1}$	Weight of 1000-grains (g)
K_0	9.12c	19.63d	87.99c	18.79d
K_{30}	10.61b	21.21c	93.83b	19.87c
K_{45}	11.19a	22.46b	97.03a	20.73b

K_{60}	11.36a	22.89a	98.03a	21.2a
$Lsd_{(0.05)}$	0.36	0.29	2.01	0.33
CV (%)	3.84	4.51	5.29	4.62

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

Table 8: Interaction effect of different levels of phosphorus and potassium on yield yield components.

Treatment	Panicle $hill^{-1}$	Panicle length cm	Filled grains $panicle^{-1}$	Weight of 1000-grains (g)
P_0K_0	7.44 i	17.07 k	79.00 j	17.13 j
P_0K_1	8.33 h	17.81 j	82.89 ij	17.61 i
P_0K_2	8.66 h	18.28 j	86.22 ghi	18.06 h
P_0K_3	8.66 h	19.28 i	88.67 fgh	18.62 g
P_1K_0	8.78 gh	18.94 i	85.89 hi	17.77 hi
P_1K_1	9.33 fg	20.30 h	89.56 efgh	18.90 g
P_1K_2	9.89 ef	21.01 g	93.78 de	20.04 e
P_1K_3	11.67 d	22.03 ef	90.45 efg	21.35 c
P_2K_0	10.33 e	20.66 gh	91.67 def	19.65 f
P_2K_1	12.00 cd	22.43 e	95.44 d	20.86 d
P_2K_2	11.78 d	24.03 d	99.78 c	21.93 b
P_2K_3	12.56 bc	24.66 c	100.89 c	22.82 a
P_3K_0	10.22 e	21.83 f	95.44 d	20.62 d
P_3K_1	12.78 b	24.31 cd	107.45 b	22.11 b
P_3K_2	14.44 a	26.523 a	112.34 a	22.89 a
P_3K_3	12.56 bc	25.570 b	108.11 ab	22.03 b

Lsd $_{(0.05)}$	0.62	0.53	4.27	0.37
CV	3.50	3.46	2.72	3.09

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

4.5.3 Filled grains Panicle^{-1}

Table 6 shows that the highest (105.83) number of filled grains panicle^{-1} was observed with 60 kg P ha^{-1} and the lowest (84.19) was observed with 0 kg P ha^{-1}. Potassium brought about a significant variation in relation to number of filled grains panicle^{-1} (Table 7). It was noticed that the highest (98.03) number of filled grains panicle^{-1} was obtained by 60 kg K ha^{-1}. The control treatment (K_0) gave the lowest (87.99) number of filled grains panicle^{-1} There was significant variation in number of filled grains panicle^{-1} due to P and K interaction (Table 8). The highest (112.34) number of filled grains panicle^{-1} was achieved with 60 kg P ha^{-1} + 45 kg K ha^{-1} (P_3K_2)and the lowest (79.00) was with control treatment (P_0K_0).

4.5.4 Thousand grain weight

Data in the Table 6 shows that 1000-grain weight was significantly influenced by phosphorous application. The highest (21.92 g) 1000-grain weight was found by 60 kg P ha^{-1} and the lowest (17.86g) was with 0 kg P ha^{-1}. Present results are in agreement with that of Islam *et al*., (1978). 1000-grain weight was significantly influenced by K application (Table 6). The highest 1000-grain weight (21.20 g) was obtained by 60 kg K ha^{-1} and the lowest one (18.79 g) at control treatment (K_0). Data in the Table 8 the interaction effects of P and K was significant of 1000 grain weight .The highest (22.89) 1000 grain weight obtained at (60 kg P ha^{-1} + 45 kg K ha^{-1} (P_3K_2) and the lowest (17.13 g) was found at control treatment (P_0K_0).

4.6 Yield

4.6.1 Grain yield

Grain yield showed a significant variation for different phosphorus levels (Table 9). among the treatments P_3 (60 kg P ha^{-1}) produced significantly highest (4.75 t ha^{-1}) grain yield and the lowest (2.95 t ha^{-1}) was found from the control. Higher grain yield at 60 kg P ha^{-1} might have resulted from the cumulative favorable effect of number of effective tillers hil^{-1} and filled grain $panicle^{-1}$. The result obtained is in consonance with the findings of Adhikari *et al.*, (2018). Grain yield was influenced significantly due to K application. The highest (4.40 t ha^{-1}) grain yield was observed at K_3 treatment (60 kg K ha^{-1}) and the lowest yield (3.35 t ha^{-1}) was recorded in control treatment (Table 10). The interaction effect of P and K was significantly influenced grain yield (Table 11). The highest (5.29 t ha^{-1}) grain yield was recorded in P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) and the lowest (2.79 t ha^{-1}) was found from control. It was clear from above result that P in conjunction with K produces higher grain yield. Similar opinion was put forward by Alam *et al.*, (2015) and Ahmed *et al.*, (1991) who reported that P in combination of K produced higher seed yield.

Table 9. Effect of different Levels of phosphorus on yield components.

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	HI (%)
P_0	2.95 d	5.41 d	8.37 d	35.27 c
P_{30}	3.62 c	6.04 c	9.68 c	37.34 b
P_{45}	4.56 b	7.23 b	11.79 b	38.60 a
P_{60}	4.75 a	7.45 a	12.20 a	38.85 a
$Lsd_{(0.05)}$	**0.09**	**0.13**	**0.20**	**0.38**
CV (%)	3.76	2.33	3.29	4.21

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, CV= Coefficient variation.

Table 10. Effect of different Levels of potassium on yield components.

Treatment	Grain yield	Straw yield	Biological yield	HI

	$(t\ ha^{-1})$	$(t\ ha^{-1})$	$(t\ ha^{-1})$	(%)
K_0	3.35 d	5.80 c	9.15 d	36.49 d
K_{30}	3.89 c	6.52 b	10.42 c	37.16 c
K_{45}	4.23 b	6.86 a	11.10 b	37.87 b
K_{60}	4.40 a	6.96 a	11.36 a	38.53 a
$Lsd_{(0.05)}$	**0.07**	**0.13**	**0.23**	**0.34**
CV (%)	3.24	3.29	3.41	5.16

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

4.6.2 Straw yield

Different levels of P on straw yield also showed the same trend as did the grain yield (Table 9). The production of higher (7.45 t ha^{-1}) straw yield in 60 kg P ha^{-1} might be due to the fact that P tends primarily to encourage vegetative growth. The findings for these characters agree with the result result were found by Sharma and Singh in 1997. Table 10 shows that straw yield was significantly influenced by K application .The highest straw yield (6.96 t ha^{-1}) was observed at K_3 treatment (60 kg K ha^{-1}) and the lowest straw yield (5.80 t ha^{-1}) was observed at control treatment control (K_0). The interaction effect of P and K in relation to straw yield was found to be the same trend as obtained by grain yield (Table 11). From this discussion , it is clear that P_3K_2 (60 kg P ha^{-1} + 45 kg K ha^{-1}) had the best performance (7.97 t ha^{-1}) for straw yield .

4.6.3 Biological yield

Biological yield showed a significant variation for different P levels (Table 9). Among the treatment P_3 (60 kg P ha^{-1}) produced the highest (12.20 t ha^{-1}) biological yield and the lowest (8.37 t ha^{-1}) was found from the control. Higher grain yield at P_3 treatment (60 kg P ha^{-1}) might have resulted from the cumulative favorable effect of number of effective tillers hill $^{-1}$, filled grains panicle^{-1}. The result obtained in this regard is at par with the findings of Chowdhury *et al*., (1995), Mandal and Halder, (1998). Biological yield was also influenced significantly due to K application (Table 10). The highest (11.36 t ha^{-1}) biological yield was observed at K_3 treatment (60 kg K ha^{-1}) and the lowest (9.15 t ha^{-1}) was recorded in control treatment. Table 11 shows that the interaction of P and K was also significant in regards to biological yield. The highest (13.26 t ha^{-1}) biological yield was recorded in P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) and lowest (8.0 t ha^{-1}) was found from control.

4.6.4. Harvest index

Harvest index was not significantly influenced by P applications. The lowest (35.27 %) harvest index was observed 0 kg P ha^{-1} and the highest (38.85 %) was observed with P_3 treatment (60 kg P ha^{-1}). Potassium had no significant effect in relation to harvest index (Table 10). It was noticed that the lowest harvest index (36.49 %) was obtained by 0 kg K ha^{-1} and the highest value (38.53 %) was obtained by control treatment (K_0). Statistically significant variation was observed in terms of harvest index due to combined effect of P and K application (Table 11). The highest (40.22 %) harvest index was recorded from the treatment combination, P_2K_3 whereas the lowest (34.82%) harvest index was observed from the treatment combination, P_0K_0.

Table 11: Interaction effect of different levels of phosphorus and potassium on yield and yield components.

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	HI (%)
P_0K_0	2.79 k	5.21 i	8.0 k	34.82 j
P_0K_1	2.92 k	5.36 hi	8.28 jk	35.25 ij
P_0K_2	2.96 jk	5.48 h	8.44 ij	35.05 j
P_0K_3	3.14 i	5.60 h	8.75 i	35.94 hi

P_1K_0	3.10 ij	5.49 h	8.59 ij	36.08 h
P_1K_1	3.39 h	5.91 g	9.29 h	36.44 gh
P_1K_2	3.76 g	6.20 ef	10.02 g	37.73 ef
P_1K_3	4.23 e	6.58 d	10.81 f	39.13 b
P_2K_0	3.56 h	6.05 fg	9.61 h	37.06 fg
P_2K_1	4.50 d	7.24 c	11.74 e	38.32 cde
P_2K_2	4.92 bc	7.77 ab	12.69 cd	38.79 bc
P_2K_3	5.25 a	7.84 a	13.09 ab	40.22 a
P_3K_0	3.95 f	6.45 de	10.40 g	38.01 de
P_3K_1	4.77 c	7.58 b	12.35 d	38.62 bcd
P_3K_2	5.29 a	7.97 a	13.26 a	39.91 a
P_3K_3	4.96 b	7.81 ab	12.77 bc	38.84 bc
Lsd $_{(0.05)}$	0.18	0.25	0.40	0.75
CV (%)	3.76	2.33	3.29	4.21

Within a column, values followed by the same letter (s) are not significantly different at 5% level of probability as per LSD test. P_0 = 0 kg P ha^{-1}, P_1 = 30 kg P ha^{-1}, P_2 = 45 kg P ha^{-1}, P_3 = 60 kg P ha^{-1}, K_0 = 0 kg K ha^{-1}, K_1 = 30 kg K ha^{-1}, K_2 = 45 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, CV= Coefficient variation.

CHAPTER V

SUMMARY AND CONCLUSION

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An experiment was run at the Sher-e-Bangla Agricultural University (SAU) experimental farm from November, 2019 to June, 2020 to see how phosphorus and potassium impacted the growth and yield performance of BRRI Hybrid dhan2. The experiment comprised of two factor *viz.* (1) Factor A: Levels of P - i. P_0: 0 kg P ha^{-1} (control), ii. P_1: 30 kg P ha^{-1}, iii. P_2: 45 kg P ha^{-1}, iv. P_3: 60 kg P ha^{-1} and (2) Factor B: Levels of K- i. K_0: 0 kg K ha^{-1}(control), ii. K_1: 30 kg K ha^{-1}, iii. K_2: 45 kg K ha^{-1}, iv. K_3: 60 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and the total number of unit plots were 48. The size of unit plot was 4.0m× 2.5m. The treatments of the experiment were assigned at random into each replication according to the experimental design. Seedlings were sown in seedbed and age of transplanted seedling was 30 days. Line to line distance was maintained 25 cm and hill to hill distance was 15 cm. Two seedlings $hill^{-1}$ were used in each hill.

Plant height, number of tillers $hill^{-1}$, leaf area index, dry matter $hill^{-1}$, panicle $hill^{-1}$, panicle length, filled grains, unfilled grains, 1000 grain weight, grain yield, straw yield, biological yield, and harvest index data were gathered. Data on growth, yield, and yield-contributing characteristics of experimental materials showed significant diversity. Significant variation was recorded for data on growth, yield and yield contributing parameters of experimental materials. 15 cm between hills and 25 cm between lines separated the seedlings during transplantation. When necessary, cross-cultural tasks like weeding, gap filling, water management, and pest control were carried out. 90% of the grains' golden yellow hue was used as a measure of crop maturity. Each plot's data was often collected in the center to prevent the border effect. Each plot's harvested crop was packed separately, properly identified, and taken to the threshing floor. The grains were cleaned and allowed to sun dry until they had a 12% moisture content. Furthermore, straw was carefully sun-dried.

At 35, 60, 85, and 110 DAT in the field, data on crop growth characteristics, such as plant height, the number of tillers $hill^{-1}$, and the leaf area index, were collected. After harvest, data on yield and yield-contributing characteristics, such as panicle length, the number of grains $panicle^{-1}$, the percentage of filled and unfilled grains, 1000-grain weight, grain yield and straw yield were collected. The difference in phosphorus and potassium levels was found to cause a significant variation in plant height at different plant ages. Up until maturity, plant height increased gradually.

Between 35, 60, and 110 DAT, plant height peaked at 85 DAT. Phosphorus plots treated at 45 kg ha^{-1} generated the tallest plants at 85 DAT (97.08 cm). When potassium was applied, a similar type of response was also seen. Application of potassium at K_2 treatment (45 kg ha^{-1}) recorded significantly higher plant height (95.38 cm) over no application of potassium. However, in the interaction effect of phosphorous and potassium, the maximum plant height (101.33 cm) at maturity was recorded with application of P_2K_3 treatment (45 kg P ha^{-1} + 60 kg K ha^{-1}), whereas the corresponding minimum (67.67 cm) plant height was recorded with control treatment P_0K_0.

The number of tillers considerably rose from 0 kg P ha^{-1} to 60 kg P ha^{-1} as the phosphorus levels were raised, reaching a maximum at 85 DAT and then declining. The maximum number of tillers was possibly present at 85 DAT as a result of better nutrient availability that allowed for synchronized tillering. With 60 kg P ha^{-1}, the highest (21.75) number of tillers was attained per hill (P_3 treatment). Application of potassium had a big effects on how many tillers were on each hill. With 60 kg K ha^{-1}, the greatest (21.92) tillers were noted (K_3 treatment). In the interaction effect of phosphorous and potassium, the maximum (24.33) number of tillers per hill at 85 DAT was recorded with application of P_3K_2 treatment (60 kg P ha^{-1}+45 kg K ha^{-1}), whereas the corresponding minimum (15.00) number of tillers per hill was recorded with control treatment P_0K_0.

Application of phosphorous at 60 kg ha^{-1} produced highest (6.51) LAI at anthesis. In case of potassium application highest (6.29) LAI was obtained with potassium at 60 kg ha^{-1} and minimum (4.38) with no application of potassium (K_0) at anthesis. However lower LAI was notice during 35 days after transplanting. The treatment (K_3) consisting of potassium at 60 kg ha^{-1} produced significantly higher (0.43) LAI over no application of potassium. The highest (7.44) leaf area index was recorded at 85 DAT with application of the P_2K_3 treatment (45 kg P ha^{-1}+60 kg K ha^{-1}), whereas the corresponding minimum leaf area index (3.88) was obtained with the control treatment P_0K_0.

Between 35, 60, and 85 DAT, dry matter production peaked at 110 DAT. Phosphorus plots treated at 60 kg ha^{-1} generated the highest (54.83 g) dry matter production at 110 DAT. When potassium was applied, a similar type of response was also seen. Application of potassium at K_3 treatment (60 kg Kha^{-1}) recorded significantly highest (53.71 g) dry matter production over no application of potassium. However, in the interaction effect of phosphorous and potassium, the maximum (64.13 g) dry matter production was recorded with application of P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}), whereas the corresponding minimum (24.57 g) dry matter production was recorded with control treatment P_0K_0.

The highest (12.49) number of panicle hill^{-1} was observed with P_3 treatment that is when the crop was fertilized with 60 kg P ha^{-1} and the lowest (8.27) was obtained in control. Crop grown with K_3 treatment (60 kg K ha^{-1}) produced the highest (11.36) panicles hill^{-1} and the lowest was control treatment (K_0) produced the lowest (9.19) panicles hill^{-1}. In the interaction effect the highest panicles hill^{-1} (14.44) was obtained by P_3K_2 treatment (60 kg P ha^{-1}+45 kg K ha^{-1}) and the lowest (7.44) figure was noticed at control treatment (P_0K_0).

The highest (24.56 cm) panicle length was found at 60 kg P ha^{-1} and the lowest (18.11) was at control. Different levels of K produced a significant variation in panicle length. The highest (22.89 cm) panicle length was observed with 60 kg K ha^{-1} and the lowest (18.11 cm) was obtained in control treatment. In the interaction of phosphorous and potassium the highest (26.52 cm) panicle length was attained in P_3K_2 treatment (60 kg P +45 kg K ha^{-1}). The lowest (17.07 cm) value was found from the control P_0K_0 treatment.

The highest (105.83) number of filled grains panicle^{-1} was observed with 60 kg P ha^{-1} and the lowest (84.19) was observed in control. The highest (98.03) number of filled grains panicle^{-1} was obtained by 60 kg K ha^{-1}. The control treatment (K_0) gave the lowest (87.99) number of filled grains panicle^{-1}. In the interaction effect the highest (112.34) number of filled grains panicle^{-1} was achieved with 60 kg P ha^{-1} + 45 kg K ha^{-1} and the lowest (79.00) was with control treatment (P_0K_0).

The highest (21.92 g) 1000-grain weight was found by 60 kg P ha^{-1} and the lowest (17.86g) was with 0 kg P ha^{-1}. The highest (21.20 g) 1000-grain weight was obtained by 60 kg K ha^{-1} and the lowest (18.79 g) one at control treatment (K_0). The highest (22.89 g)

1000 grain weight obtained at P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) and the lowest (17.13 g) was found at control treatment P_0K_0.

The highest (4.75 t ha^{-1}) grain yield was found by 60 kg P ha^{-1} and the lowest (2.95 t ha^{-1}) was found from the control. The highest (4.40 t ha^{-1}) grain yield was observed at K_3 treatment (60 kg K ha^{-1}) and the lowest yield (3.35 t ha^{-1}) was recorded in control treatment. In the interaction effect the highest (5.29 t ha^{-1}) grain yield was recorded in $P_{60}K_{45}$ treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) and the lowest (2.79 t ha^{-1}) was found from control P_0K_0.

In comparison to the control, 60 kg P ha^{-1} produced the highest (4.75 t ha^{-1}) grain yield and the lowest (2.95 t ha^{-1}). The control treatment's grain yield was the lowest (3.35 t ha^{-1}), whereas the K_3 treatment's grain yield (4.40 t ha^{-1}) was the highest (60 kg K ha^{-1}). The $P_{60}K_{45}$ treatment (60 kg P ha^{-1}+45 kg K ha^{-1}) recorded the maximum (5.29 t ha^{-1}) grain yield whereas the control P_0K_0 was found to have the lowest (2.79 t ha^{-1}).

The production of higher (7.45 t ha^{-1}) straw yield in 60 kg P ha^{-1} might be due to the fact that P tends primarily to encourage vegetative growth. The highest (6.96 t ha^{-1}) straw yield was observed at 60 kg K ha^{-1} and the lowest

(5.80 t ha^{-1}) straw yield was observed at control treatment (K_0). The interaction effect of P and K in relation to straw yield was found to be the same trend as obtained by grain yield. In the interaction effect the highest (7.97 t ha^{-1}) straw yield was recorded in P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) and the lowest (5.21 t ha^{-1}) was found from control P_0K_0.

The fact that P tends to primarily promote vegetative growth may account for the increased straw yield (7.45 t ha^{-1}) produced with 60 kg P ha^{-1}. The 60 kg K ha^{-1} treatment produced the maximum (6.96 t ha^{-1}) straw yield whereas the control treatment produced the lowest (5.80 t ha^{-1}) straw yield. It was discovered that the interaction impact of P and K in regard to straw yield followed the same general pattern as grain yield. The interaction effect showed that P_3K_2 treatment (60 kg P ha^{-1} + 45 kg K ha^{-1}) had the maximum (7.97 t ha^{-1}) straw yield, whereas control (P_0K_0) had the lowest (5.21 t ha^{-1}).

Phosphorus plots treated at 60 kg P ha^{-1} generated the highest (12.20 t ha^{-1}) biological yield and the lowest (8.37 t ha^{-1}) was found from the control. When potassium was applied, a similar type of response was also seen. Application of potassium at K_3

treatment (60 kg K ha^{-1}) recorded significantly higher (11.36 t ha^{-1}) biological yield over no application of potassium. The interaction of P and K was also significant in regards to biological yield. The highest (13.26 t ha^{-1}) biological yield was recorded in P_3K_2 (60 kg P ha^{-1} + 45 kg K ha^{-1}) and lowest (8.27 t ha^{-1}) was found from control (P_3K_2) treatment.

The lowest (35.27 %) harvest index was observed 0 kg P ha^{-1} and the highest (38.85 %) was observed with 60 kg P ha^{-1}. The highest (40.22%) harvest index was recorded from the treatment combination, P_2K_3 (45 kg P ha^{-1} + 60 kg K ha $^{-1}$) whereas the lowest (34.82%) harvest index was observed from the control treatment, P_0K_0.

Conclusions

- Different doses of fertilizer had a great effect on growth and yield parameter of BRRI Hybrid dhan2.
- Plant height, number of tillers $hill^{-1}$, leaf area index, dry matter $hill^{-1}$, panicle $hill^{-1}$, panicle length, filled grains, unfilled grains, 1000 grain weight, grain yield, straw yield, biological yield, and harvest index data were affected by the application of different phosphorus and potassium fertilizer doses.
- Treatment combination of P_2K_3 (60 kg P ha^{-1} and 45 kg K ha^{-1}) is suitable for getting higher yield from BRRI Hybrid dhan2 in boro season.

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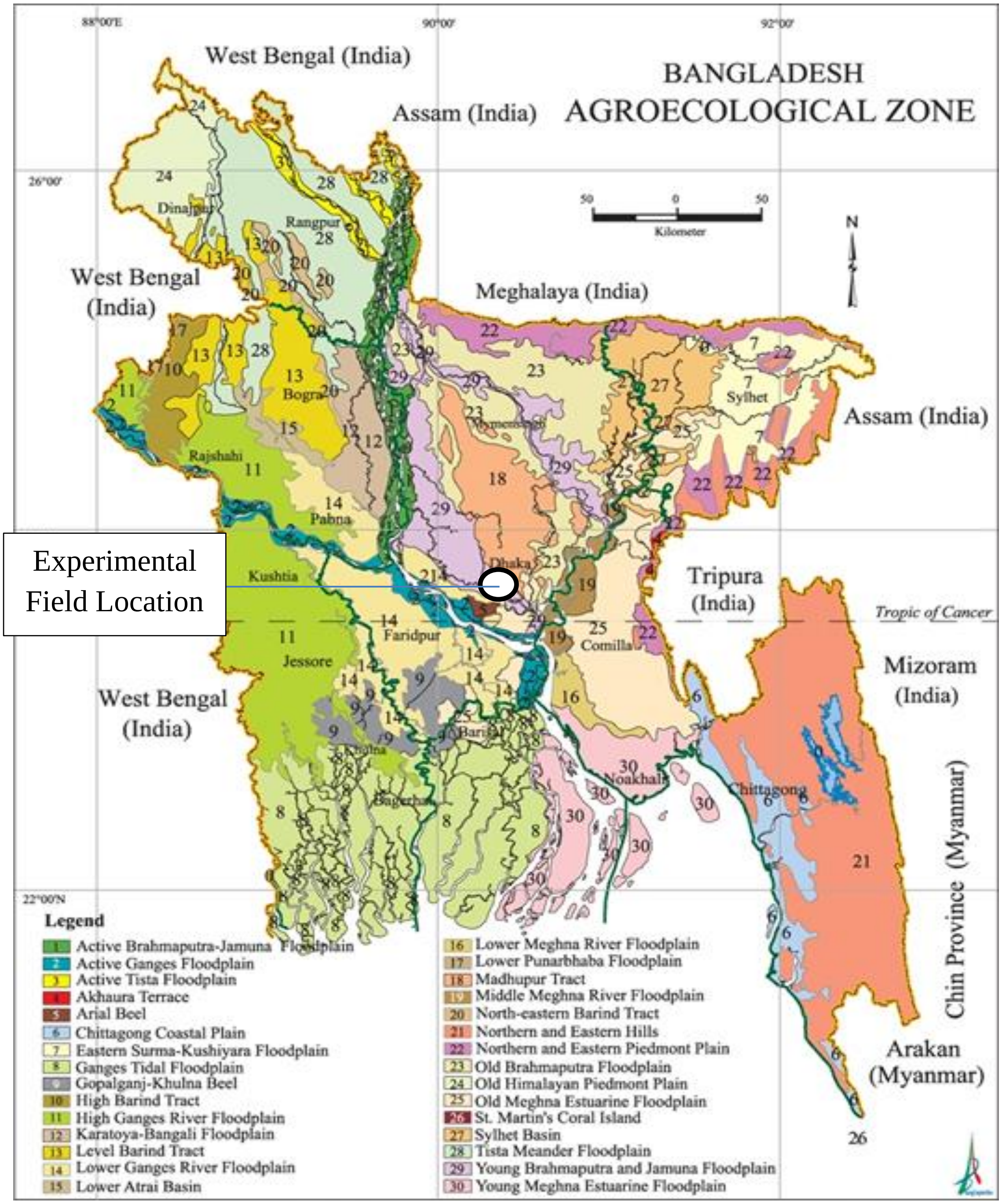
APPENDICES

Appendix 1. The map of experimental Site


BANGLADESH
AGROECOLOGICAL ZONE
Experimental
Field Location
West Bengal (India)
Assam (India)
Meghalaya (India)
Tripura (India)
Mizoram (India)
Chin Province (Myanmar)
Arakan (Myanmar)
Tropic of Cancer
Kilometer
N
Dinajpur
Rangpur
Bogra
Rajshahi
Pabna
Kushtia
Dhaka
Faridpur
Jessore
Khulna
Bagerhat
Barisal
Comilla
Noakhali
Chittagong
Sylhet
Legend
1 Active Brahmaputra-Jamuna Floodplain
2 Active Ganges Floodplain
3 Active Tista Floodplain
4 Akhaura Terrace
5 Arial Beel
6 Chittagong Coastal Plain
7 Eastern Surma-Kushiyara Floodplain
8 Ganges Tidal Floodplain
9 Gopalganj-Khulna Beel
10 High Barind Tract
11 High Ganges River Floodplain
12 Karatoya-Bangali Floodplain
13 Level Barind Tract
14 Lower Ganges River Floodplain
15 Lower Atrai Basin
16 Lower Meghna River Floodplain
17 Lower Punarbhaba Floodplain
18 Madhupur Tract
19 Middle Meghna River Floodplain
20 North-eastern Barind Tract
21 Northern and Eastern Hills
22 Northern and Eastern Piedmont Plain
23 Old Brahmaputra Floodplain
24 Old Himalayan Piedmont Plain
25 Old Meghna Estuarine Floodplain
26 St. Martin's Coral Island
27 Sylhet Basin
28 Tista Meander Floodplain
29 Young Brahmaputra and Jamuna Floodplain
30 Young Meghna Estuarine Floodplain

Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2019 to June, 2020.

Month	Air Temperature (^{0} C)		Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November	29.1	14.3	61	63
December	27.4	10.1	56	51
January	26.2	8.9	52	54
February	30.1	20.2	60	71
March	35.2	21.3	62	90
April	33.4	23.2	67	160
May	34.7	25.9	70	185
June	35.4	22.5	80	277

* Monthly average,

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

Appendix III: Characteristics of Sher-e-Bangla Agricultural University soil is analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

a) Morphological characteristic of the experimental field

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University
AEZ	Madhupur Tract (28)
General soil type	Shallow Red Brown Terrance Soil
Land type	High land
Soil Series	Tejgaon
Topography	Fairly leveled
Food level	Above flood level
Drainage	Well drained
Cropping pattern	Fellow Aman

b) Physical and Chemical properties of initial soil

Characteristics value	**Particle Size Analysis**
% Sand	27
% Silt	43
% Clay	30
Textural Class	
Organic carbon %	0.46
Organic matter %	0.83
Total N %	0.05
Available P (ppm)	20.00
Exchangeable K (me/100 gm soil)	0.12

Available S (ppm)	46
PH	5.47-5.63

Appendix IV: Variance analysis of data on plant height at various transplanting days (DAT).

Source of variation	Degree of freedom	Mean Square			
		Plant Height (cm) at different (DAT)			
		35 DAT	60 DAT	85 DAT	110 DAT
Replication	2	6.28	6.91	9.22	54.82
Phosphorus	3	614.77	3172.76	4400.05	3811.38
Potassium	3	161.56	368.50	290.31	281.88
Phosphorus* Potassium	9	83.8	91.47	142.98	29.21
Error	30	125.93	79.09	112.20	124.93
CV%		6.40	4.43	4.19	3.22
LSD(0.05)%		3.42	2.71	3.23	3.41

Appendix V: Variance analysis of data on number of tillers at various transplanting days (DAT).

Source of variation	Degree of freedom	Mean Square			
		Number of tillers at different (DAT)			
		35 DAT	60 DAT	85 DAT	110 DAT
Replication	2	0.52	1.02	0.27	1.19
Phosphorus	3	6.24	49.13	48.81	18.75
Potassium	3	7.24	69.52	59.69	22.81
Phosphorus* Potassium	9	0.54	3.71	1.38	0.66

Error	**30**	**0.25**	**0.42**	**0.78**	**0.41**
CV%		**6.42**	**4.48**	**4.43**	**4.38**
LSD(0.05)%		**0.84**	**1.08**	**1.47**	**1.07**

Appendix VI: Variance analysis of data on Leaf area index (LAI) at various transplanting days (DAT).

Source of variation	Degree of freedom	Mean Square			
		Leaf area index (LAI) at different (DAT)			
		35 DAT	60 DAT	85 DAT	110 DAT
Replication	**2**	**0.0026**	**0.0028**	**0.015**	**0.008**
Phosphorus	**3**	**0.073**	**1.29**	**13.8**	**6.29**
Potassium	**3**	**0.038**	**0.57**	**8.444**	**3.47**
Phosphorus* Potassium	**9**	**0.0027**	**0.07**	**0.77**	**0.27**
Error	**30**	**0.005**	**0.0014**	**0.012**	**0.02**
CV%		**5.82**	**3.37**	**3.04**	**3.74**
LSD(0.05)%		**0.04**	**0.06**	**0.19**	**0.24**

Appendix VII: Variance analysis of data on dry matter accumulation at various transplanting days (DAT).

Source of variation	Degree of freedom	Mean Square			
		Dry matter accumulation at different (DAT)			
		35 DAT	60 DAT	85 DAT	110 DAT
Replication	**2**	**0.0031**	**0.04**	**2.54**	**0.07**
Phosphorus	**3**	**0.09**	**23.74**	**366.49**	**1230.66**
Potassium	**3**	**0.07**	**20.35**	**163.59**	**1085.28**
Phosphorus*	**9**	**0.007**	**1.47**	**16.20**	**36.27**

Potassium					
Error	**30**	**0.008**	**0.026**	**2.95**	**4.71**
CV%		**8.98**	**4.64**	**7.63**	**4.89**
LSD(0.05)%		**0.05**	**0.27**	**2.86**	**3.62**

Plate 1: A visual presentation of the experiment’s several stages.

(a) Individual plots of seedling stages

(b) Tillering stages

(c) Stem elongation stage

(d) Booting stage of rice

(e) Traditional process of drying of the rice grain in the sunlight after harvest.

(f) Separating rice grains manually into filled and unfilled grains.

(g) Grain weight measurements using an electric balance.

(h) Drying rice straw with an electric oven dryer.