PERFORMANCE OF INBRED AND HYBRID RICE VARIETIES TO DIFFERENT LEVELS OF PHOSPHORUS

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CERTIFICATE

This is to certify that thesis entitled, "**PERFORMANCE OF INBRED AND HYBRID RICE VARIETIES TO DIFFERENT LEVELS OF PHOSPHORUS**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY**, embodies the result of a piece of *bona fide* research work carried out by **MD. MAHABUB ALAM**, Registration No. 00933 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by him.

Dated: June 2008
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

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ABBREVIATIONS AND UNITS

Abbreviation

AEZ	Agro Ecological Zone
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
CGR	Crop growth rate
C.V.	Coefficient of Variation
cv.	Cultivar
DAT	Days after transplanting
DM	Dry matter
et al.	*et alibi* (and others)
etc.	*et cetra* (and so on)
FAO	Food and Agricultural Organization
Fig.	Figure
HI	Harvest index
HYV	High yielding variety
i.e.	id est (that is)
IW	Irrigation water
LSD	Least significant difference
No.	Number
NS	Non-significant
P_2O_5	Phosphorus pentaoxide
RGR	Relative growth rate
SA	Surface area
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TDM	Total dry matter
TSP	Triple superphosphate
viz.	Videlicet (namely)

Unit

%	Percentage
^0C	Degree Celsius
cm	Centimeter
g	Gram
ha	Hectare
kcal	Kilocalorie
kg	Kilogram
m	Meter
mm	Millimeter
q	Quintal
t	Ton

ABSTRACT

The experiment was carried out at the Agronomy Field of the Sher-e-Bangla Agricultural University, Dhaka during the period from December, 2006 to June, 2007 study the relative performance of inbred and hybrid rice varieties at different levels of phosphorus. Three varieties of inbred and hybrid rice (BRRI dhan 29, Aloron and Hira-2) and five levels of phosphorus-(0, 24, 48, 72 and 96 Kg P_2O_5 ha^{-1}) were the treatment variables. The experiment was laid out fallowing spilt plot design with three replications having varieties in the main plot and phosphorus rate in the sub-plot. Plant height, number of tillers $hill^{-1}$, fresh weight of plant, dry matter partitioning, total grains $panicle^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, spikelt sterility, 1000-grain weight, grain yield, straw yield and harvest index varied significantly due to the variations of variety. Hybrid variety Hira-2 produced the maximum number of filled grains $panicle^{-1}$ (106.00) and minimum in BRRI dhan 29. Variety Hira-2 (7.50 t ha^{-1}) and Aloron (7.41 t ha^{-1}) produced the highest grain yields which were significantly different from BRRI dhan 29 (6.86 t ha^{-1}). The yield increase due to variety Hira-2 and Aloron was 0.64 and 0.55 t ha^{-1}, which was 9.32% and 8.01%, respectively over BRRI dhan 29. All the studied parameters of rice varieties except harvest index also differed significantly with the application of phosphorus fertilizer. An application of 72 kg P_2O_5 ha^{-1} showed to produced better yield attributes. Phosphorus level at 72 kg ha^{-1} (P_3) produced the highest grain yield (7.23 t ha^{-1}) of rice. Plants grown without added phosphorus gore the lowest grain yield (4.99 t ha^{-1}). A significant interaction between varieties and phosphorus levels in respect of yield and yield attributes of rice was observed. Plants grown at any varieties without P fertilizer produced lowest grain yield. Highest grain yield (7.68 t ha^{-1}) was recorded variety Hira-2 with 72 kg P_2O_5 ha^{-1}. Number of effective tillers $hill^{-1}$, panicle length, number of filled grains $hill^{-1}$ and 1000-grain weight had a significant correlation with grain yield t ha^{-1}.

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Introduction

Chapter 1

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world. There are 111 rice-growing countries in the world that occupies about 146.5 million hectares more than 90% is in Asia (Anon., 1999). It is the staple food for more than two billion people in Asia and many millions in Africa and Latin America. About 95% of the world rice is consumed in Asia (Rotshield, 1996). To feed the fast increasing global population, the world's annual rice production must increase to 760 million tons by the year 2020 (Kundu and Ladha, 1995).

In Bangladesh, majority of food grains come from rice (*Oryza sativa* L.). About 80% of cropped area of this country is used for rice cultivation, with annual production of 25.18 million tons from 10.29 million ha of land (IRRI, 2006). The average yield of rice in Bangladesh is 2.45 t ha^{-1} (BRRI, 2007). This average yield is almost less than 50% of the world average rice grain yield. Thus, rice plays a vital role in the livelihood of the people of Bangladesh (Hasanuzzaman *et al.*, 2007). The increased rice production has been possible largely due to the adoption of modern rice varieties on around 70.24% of the rice land which contributes to about 83.39% of the country's total rice production. However, there is no reason to be complacent. The population of Bangladesh is still growing by two million every year and may increase by another 30 millions over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Rice (clean) yield therefore, needs to be increased from the present 2.45 to 3.74 t ha^{-1} (BRKB, 2007). Therefore, it is an urgent need of the time to increase the production of rice through increasing the yield.

Rice yield can be increased in many ways – of them developing new high yielding variety and by adopting proper agronomic management practices to the existing varieties to achieve their potential yield is important. So to develop the high yielding varieties, Japan initiated first breeding programme in 1981 (Wang, 2001). In 1989, IRRI started super rice breeding programme to give up to 30% more yield (13-15 t ha^{-1}) than the current modern high yielding plant types (IRRI, 1993). Generally the yield of hybrid rice varieties is 10% - 15% more than the improved inbred varieties. It has great potentiality for food security of poor countries where arable land is scarce, populations are expanding and labour is cheap. In our country BRRI has started breeding programme for the development of super high yielding varieties with large panicles and high yield potentialities.

Proper fertilization is an important management practice which can increase the yield of rice. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Youshida, 1981). Phosphorus is essential nutrient for plant life. Without adequate supply of phosphorus plants can not reach its maximum yield. Among potential of three primary elements (NPK), phosphorus is relatively absorbed by the plants in smaller amount than the other two, but plays an equally important role. Phosphorus deficiency symptoms appear in the lower part of the plant and results decreased leaf number, decreased leaf blade length, reduced panicles $plant^{-1}$, reduced seeds $panicle^{-1}$ and reduced filled seeds $panicle^{-1}$ (Aide and Picker, 1996). Phosphorus not only enhances the yield of rice but also reduce the spikelet sterility.

George *et al.* (2001) reported that the large increases from P plus other inputs observed for the improved varieties indicate that economical management of inputs should not be overlooked in improving productivity in Asia rice uplands.

Phosphorus (P) status in Bangladesh soil is quite low. Application of phosphatic fertilizers is essential to obtain higher yield. The chemical phosphatic fertilizers are also in short supply in the country since long. Every years Bangladesh has to import huge amount of triple superphosphate (TSP) or its raw materials to meet up the phosphorus requirement of the crops. But the main problem concerning phosphatic fertilizers is its fixation with soil complex within a very short period of application rendering mare than two-thirds unavailable (Sahrawat *et al.*, 2001). So it is necessary to know the optimum dose of phosphorus fertilizer for maximum yield and to reduce spikelet sterility of rice.

Keeping this view in mind, the present experiment was under taken with the following objectives:

i. to observe the performance of different phosphorus levels on growth and spikelet sterility of rice,

ii. to find out the optimum phosphorus level for maximum yield of rice by reducing spikelet sterility; and

iii. to determine the interaction effect of phosphorus level and variety on yield and yield attributes of rice.

Chapter 2
Review of Literature

Chapter 2

REVIEW OF LITERATURE

High production of any crops depends on manipulation of basic ingredients of agriculture. The basic ingredients include variety, environment and agronomic practices (planting density, fertilizer, irrigation etc.). Among the above factors variety and P-fertilization are more responsible for the growth and yield of rice. High yielding varieties (HYV) are generally more adaptive to phosphorus application and they produce higher yield with increasing phosphorus levels up to a certain limit. The available relevant reviews of the related works done in the recent past have been presented and discussed in this chapter.

2.1 Effect of variety

Variety has profound effect on different plant characters. The genetic make-up of a variety and environment mainly influence the varietals performance of a crop.

2.1.1 Effect on crop characters

BRRI (2007) reported that the BRRI dhan28 produced the highest number of tiller and panicle per unit area than that BRRI dhan29 but higher grain yield was observed in BRRI dhan29 than the BRRI dhan28.

Bisne *et al.* (2006) conducted an experiment with eight promising varieties of rice using four CMS lines of rice and showed that plant height differed significantly among the varieties and Pusa Basmati gave the highest plant height in each line.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on

Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin1 and Saegyehwa varieties.

Gill *et al*. (2002) evaluated twenty-four rice genotypes on the response to P application at 16 and 160 µM in a hydroponics study. The 24 genotypes differed significantly in their shoot growth, root development and root:shoot ratio. Concentration and total uptake of P in shoot and root, P specific absorption rate, P transport rate and P utilization efficiency was also significantly different for the various genotypes. Shoot dry matter yield, root dry matter yield and total biomass production of all genotypes correlated significantly with their total P uptake and P utilization.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice with five levels of phosphorus fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) and filled grains $panicle^{-1}$ (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07g) and number of panicles m^{-2} than other tested varieties.

Choudhury *et al*. (2000) conducted an experiment on N, P, K and Fe contents in 10 rice cultivars grown under wetland field conditions in Jorhat, Assam, India, in 1997. The mineral contents varied considerably among cultivars, and it increased from tillering to flowering stage in all the cultivars. Grain yield ranged from 2.08 to 3.93 t ha^{-1}.

Mahajan *et al.* (1995) conducted a pot experiment on a clay soil while three rice cultivars received 0-120 kg P_2O_5. Highest grain yield was obtained with 80 kg P_2O_5 ha^{-1}.

BINA (1993) conducted an experiment with four varieties/advance lines (IRATOM24, BR14, BINA13 and BINA19) and reported significant variation in plant height, number of non-bearing tillers $hill^{-1}$, panicle length and unfilled spikelets $panicle^{-1}$. They also noted that grain yield did not differ significantly among the varieties.

Hassan *et al.* (1993) carried out experiment to observe the yields response of rice cv. Basmati 385 to 0, 33, 66, and 99 kg P ha^{-1}. All treatments received 125-62-4.2 kg NKZn ha^{-1}. They observed that yield increased significantly up to 33 kg ha^{-1} for all the soil P test values, but significant response to the next higher dose observed only when the test values were less than or equal to 11 mg P kg^{-1}.

BRRI (1991) reported that the number of effective tillers produced by some transplant Aman rice varied from 7 to 14 $hill^{-1}$ and it differed significantly from variety to variety.

Hossain and Alam (1991) reported that the growth characters like plant height, total tillers $hill^{-1}$ and the number of grains $panicle^{-1}$ differed significantly among BR3, BRIl, BR14 and Pajam rice in boro season.

Idris and Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties. Shamsuddin *et al.* (1988) conducted an experiment with nine varieties of rice and showed that plant height differed significantly among the varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice cv. R-73-1-1, R-R-711 and the traditional cv. Ratna and reported that the lowest plant height was found in traditional cv. Ratna rice variety.

2.1.2 Effect on grain and straw yield

BRRI (2007) reported that the BRRI dhan29 and advanced line BR 4828-54-4-1-9 produced significantly higher grain yield compare to BRRI dhan28 and BR6144-36-5-2 advanced lines. Xie *et al.* (2007) also found that Shanyou63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti. Among the varieties Mukti out yielded (5268 kg ha^{-1}) than the other genotypes and also recorded the maximum number of filled grains $panicle^{-1}$ compared to the others.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding cultivars as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the highest yield (7.0 t ha^{-1}) among them.

Yadav *et al.* (2004) conducted a study to determine the effects of split application of P and K on yield and uptake of nutrients by rice hybrids RTNRH-1, RTNRH-2, RTNRH-3, RTNRH-4, RTNRH-5 and Sahyadri in recorded 50.13 and 13.66% higher grain yields compared to RTNRH-3 and RTNRH-5, respectively. Grain yield was highest (51.1 q ha^{-1}) upon treatment with P and K in three splits. P and K applied in three splits (50% basal + 25% at tillering + 25% at panicle initiation stage) was superior over the other application times in terms of P and K uptake by grain and straw, and total P and K uptake.

Dongarwar *et al.* (2003) comprised an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna with 4 fertilizer rates, viz. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg

NPK ha^{-1}. They reported that the variety KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Fageria and Santos (2002) conducted a greenhouse experiment to evaluate 12 genotypes of lowland rice. The P treatments were: low (0 mg P kg^{-1}), medium (100 mg P kg^{-1}), and high (400 mg P kg^{-1}). Based on P use efficiency, genotypes were classified as efficient and responsive, efficient and non-responsive, inefficient and responsive, and inefficient and non-responsive. From a practical point of view, efficient and responsive and efficient and non-responsive genotypes were the most desirable ones. Among the yield components, panicle length and harvest index were significantly affected by P levels and genotypes and P and genotypes interactions were significant for these two parameters. However, panicle number was significantly influenced only by P treatment. Among the yield components, panicle number, harvest index, and panicle length were significantly related to grain yield.

Om *et al.* (1999) conducted a field experiment with four varieties (3 hybrids: ORI 161, PMS 2A, PMS 10A and I inbred variety HKR 126) during rainy season and observed that hybrid ORI 161 exhibited superiority to other varieties in grain and straw yield.

Tac *et al.* (1998) conducted an experiment with two rice varieties- Akitakomachi and Hitombore in Tohoku region of Japan. It was found that Hitombore yielded the highest (7.10 g m^{-2}) and Akitakomachi yielded the lowest (660 g m^{-2}).

Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced an average grain yield of 7.1 t ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9.

BRRI (1995) conducted an experiment with rice cv. BR10, BR22, BR23 and Rajasail (ck.) at three locations in the aman season. It was found that BR23 gave the highest yield (5.71 t ha^{-1}) which was similar to BR22 (5.02 t ha^{-1}) and the check Rajasail yielded the lowest (3.63 t ha^{-1}).

BRRI (1994) stated that four varieties of rice (BR14, Pajam, BR5 and Tulsimala) were grown in the field and observed that BR14 produced the highest tillers $hill^{-1}$ and the lowest number of spikelet $panicle^{-1}$ and finer grain size.

Ali and Murship (1993) conducted an experiment during July to December 1989 to find out the suitable variety for late transplant Aman rice. They reported that local variety-Kumargoir significantly out yielded than the modern rice cultivars BR23 and BR11.

Chowdhury *et al.* (1993) observed that the cultivar BR23 showed superior performance over cultivar Pajam in respect of number of productive tillers $hill^{-1}$, length of panicle, 1000-grain weight, grain and straw yields but cultivar Pajam produced significantly taller plants, more number of total spikelet $panicle^{-1}$, grain $panicle^{-1}$ and sterile spikelet $panicle^{-1}$. They also observed that the finer the grain size the higher the number of spikelet.

BINA (1992) reported in a field experiment that under transplanting conditions the grain yield of BINA13 and BINA19 were 5.39 and 5.57 t ha^{-1} respectively and maturity of the above strains were 160 and 166 days, respectively.

Kamal *el al.* (1988) conducted a field trail with three rice varieties BR3 produced the highest grain yield and Pajam yielded the lowest. Bhuiyan and Saleque (1989) also reported that BR4 and BR10 were higher yielders than Rajasail the superiority of promising line over the high yielding varieties in respect of grain yield.

Islam and Ahmed (1981) reported that the varieties Naizersail, Latishail, IR5 and IR20 differed significantly in respect of their performance. The two exotic cultivars of rice IR5 and IR20 independently gave significantly higher yield of grain than either of the other two local cultivars; and of the two exotic cultivars, IR5 was higher yielder (5188 kg ha^{-1}) though it was statistically identical with IR20 (5022 kg ha^{-1}) in respect of yield.

2.2 Effect of phosphorus

2.2.1 Effect of P on growth and yield of rice

A field experiment was carried out with rice cv. Jia-9312 by Iqbal (2004) in China, involving P at 0, 40 and 60 kg ha^{-1} under irrigated conditions. He stated that a positive effect on rice biomass and grain yield for P application was observed which varied from 5.8 to 7.8 t ha^{-1}. Yield of rice also increased by 50-60% in response to the application of P interaction with water.

A study was conducted by Kumar *et al*. (2004) to evaluate the performance of rice cv. ADT 36 under different manure fertilizer schedules adopted in the permanent manorial rice monoculture in Tamil Nadu, India. Nitrogen, P and K were applied at 120, 60 and 60 kg ha^{-1}, while organic manures (farmyard manure, green manure and urban compost) were applied at 12.5 t ha^{-1}. They reported that grain, straw and total dry matter yields were highest with the application of any of the manures or urban compost and N at 120 kg ha^{-1}, regardless of the P and K applications. P content in straw was higher in treatments receiving one of the organic manures with K at 60 kg ha^{-1}compared to other treatments.

A field experiment was conducted 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 and number of tillers $plant^{-1}$, paddy grain and straw yields were influenced significantly by the application of P. Application of 50-50 kg P_2O_5 ha^{-1} gave the higher yield following by 100 kg P_2O_5 ha^{-1}

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

Kendaragama *et al*. (2003) carried out a field experiments to investigate the seasonal and long-term influence of rice crop on the availability of soil P in relation to five rates of triple super phosphate application (0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}) in well drained, imperfectly drained and poorly drained soil. This study indicates that practice of correct P supply is needed for sustaining available P status in soil and crop yield although rice does not immediately respond for irregularities in phosphate fertilizer application.

Field experiments were conducted by Rao (2003) in India, on a sandy clay loam soil during kharif to determine the utilization pattern of phosphorus (P) rates (30, 60 and 90 kg ha^{-1}) and sources (ammonium polyphosphate, urea nitric phosphate and diammonium phosphate) in rice crop in terms of apparent recovery factor, physiological and agronomic efficiency. He stated that 60 kg P ha^{-1} gave the highest agronomic efficiency when P was applied in the form of ammonium polyphosphate followed by urea nitric phosphate and diammonium phosphate and the lowest term P rates.

The assessment mach by Burbey and Sahar (2003) on the age of NPK and zeolite on the growth and yield of irrigated rice. Results showed that no significant effect of NPK and zeolite on the growth and yield of irrigated rice, except numbers of panicle and 1000 grains weight. However, the highest yield (5.95 t ha^{-1}) was obtained with the application of 200 kg urea + 100 kg SP-36 + 200 kg zeolite per hectare, and in wet season (7.0 t/ha) with the application of 150 kg urea + 100 kg SP-36 + 200 kg zeolite per hectare.

Singh (2003) conducted a field experiment under rainfed condition in Jharkhand, India during wet season 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 and also due to seasons. Drought at panicle initiation and delayed weeding reduced the rice grain yield by 50% due to low filled grain per panicle and reduced panicle length.

Mondal *et al*. (2003) conducted a field experiment to investigate the effect of P application on rice cv. IET-5656-lathyrus cv. Nirmal utera cropping under rainfed situation. The treatments comprised 4 fertilizer management levels, i.e. fertilizer application as per farmer's practice (40:20:20 kg $N:P_2O_5:K_2O$ ha^{-1}) to rice and no fertilizer application to lathyrus (T_1); 100% of recommended dose of fertilizer (RDF) both rice and lathyrus (T_2); 100% of RDF to rice + recommended dose of P for lathyrus to rice (T_3); and RDF for lathyrus + recommended dose of P for rice to lathyrus at sowing (T_4). The RDF for rice was 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} and that for lathyrus was 10:20:20 kg $N:P_2O_2:K_2O$ ha^{-1}. They reported that highest number of effective tillers m^{-2} (425.0), number of grains per panicle (92.8) and grain yield (4886 kg ha^{-1}) of rice was obtained with T_3 treatment.This treatment recorded 34.71% higher grain yield than that obtained with the farmer's practice.

The relative agronomic efficiency of four phosphate sources (triple superphosphate, ordinary Yoorin thermophosphate, coarse Yoorin thermophosphate and North Carolina phosphate rock) were evaluated by Brasil *et al*. (2002). The soils received three rates of phosphorus (40, 80 and 120 mg P kg^{-1} of soil) plus the control treatment. The results showed that the highest dry matter yield and P uptake for rice were obtained in soils fertilized with triple superphosphate.

Nadeem and Ibrahim (2002) carried out a study to determine the P requirement of rice crop grown after wheat, under submerged condition. Rice crop was 100 kg P_2O_5 and 120 kg N ha^{-1} and highest paddy yield was obtained from the treatment where 37.5 kg (50 percent) P was applied. It showed that when wheat received its recommended dose of P then for rice only 50 percent of the recommended rate (75 kg ha^{-1}) is enough to achieve the optimum yield of rice.

Zubaidah and Munir (2002) conducted an experiment on phosphorus fertilization on paddy rice. 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 gave yield of paddy rice 4.236 and 4.320 t ha^{-1}, respectively.

Lal *et al*. (2000) conducted a field experiment during the kharif season in India, to study the individual and interactive effects of P (0, 11, 22 and 33 kg ha^{-1}) and Zn (0, 6 and12 kg ha^{-1}) on the yield and P uptake of lowland rice. They reported that maximum grain yield (33.35 q ha^{-1}) and P uptake (10.06 kg ha^{-1}) were observed with the combined application of 33 kg P and 12 kg Zn ha^{-1}. Available P in soil samples after harvest increased considerably with increasing rates of P and Zn application.

The effects of P fertilizer application in the nursery and field on the growth and yield of the rice cultivars ADT 39, MDU 2, CO 43, MDU 4, and IR 20 were studied in Tamil Nadu by Sucharitha and Boopathi (2000). Treatments consisted the application of diammonium phosphate (DAP) in the nursery at 2 kg $cent^{-1}$; 1/3 of the recommended fertilizer in the field (120:50:50 kg $N:P_2O_5:K_2O$ ha^{-1}); and 2 kg DAP $cent^{-1}$ in the nursery + 1/3 of the recommended fertilizer in the field. ADT 39 had the greatest number of panicles and total number of grains per panicle; plant height; root weight; leaf area index; dry matter production; and N, P, and K uptake. The application of 2 kg DAP $cent^{-1}$ in the nursery + the recommended fertilizer in the field gave the highest values of the aforementioned yield components. ADT 39 combined with the application of 2 kg DAP $cent^{-1}$ + the recommended fertilizer in the field were the optimum combination for increased yield.

Two field experiments were conducted by Rajendran (1999) at Coimbatore, India, during kharif season to study the effect of different sources and levels of P on growth and yield of hybrid rice cv. ADTRH 1. Mean grain yield was 4.34 t ha^{-1} without applied P, 5.48-5.73 t with different sources of 60 kg P_2O_5 ha^{-1}, and 5.32 t with P applied based on the basis soil test results. The highest yield was given by rock phosphate incubated with FYM, although there was no statistically significant difference from P applied as superphosphate.

In pot trials by Jiang *et al.* (1999) on whitish lacustrine soil, rice was given 0, 2, 4, 6 or 8 kg P_2O_5 mu^{-1}. The total number of panicles increased up to 6 kg P_2O_5 mu^{-1}. Grain number $panicle^{-1}$ increased with up to 6 kg P_2O_5 mu^{-1}.

Annadurai and Palaniappan (1998) in a field trial in India in monsoon season, rice was given 0, 9.5, 19 or 38 kg P_2O_5 ha^{-1} with or without spraying 2% diammonium phosphate (DAP) at 2-3 growth stages. Grain yield increased significantly with up to 19 kg P_2O_5 ha^{-1}, and was increased by DAP application with no significant difference between the 3 treatment schedules. Similar results were given by a follow-up trial with rice cv. IR 20. Data on and recommended that 19 kg P_2O_5 ha^{-1} and 2 sprays of DAP at the boot-leaf stage and at 50% flowering or the post-milk stage should be applied to rice.

A field experiment was conducted by Saleque *et al.* (1998) to study the effect of P deficiency in soil on the P nutrition and yield of the modern rice cultivars Purbachi, BR-1, BR-3, BR-14, and BR-29, popular with the rice farmers of Bangladesh. Soil-available P in the different plots of the experimental field varied widely, from 2.8 to 16.4 ppm. This variation in soil-available P content resulted from differences in the total amounts (0 to 480 kg ha^{-1}) of P the plots had received over a period of 8 years in a long-term P fertilizer trial conducted previously in the same field. Phosphorus deficiency in soil drastically reduced the grain yield of all the rice cultivars. In severely P deficient plots, where soil-available P was around 3 ppm, the yield was less than 1 ton ha^{-1} while in plots containing an adequate P level, i.e., >6 ppm, the yield was more than 4 t ha^{-1}. Rice yield increased linearly with an increase in soil P content up to 6 ppm, and the highest grain yield for any variety, obtained at 6-7 ppm of soil-available P.

Fageria and Baligar (1997) carried out an experiment to evaluate on the growth and P use efficiency of 20 upland rice cultivars at low (0 mg P kg^{-1}), medium (75 mg P kg^{-1}), and high (150 mg P kg^{-1}) levels of applied P on an Oxisol. Plant height, tillers, shoot and root dry weight, shoot: root ratio, P concentration in root and shoot, P uptake in root and shoot, and P use efficiency were significantly affected by level of soil P as well as cultivar. Shoot weight and P uptake in shoot were the plant parameters most sensitive to P deficiency, suggesting that these two parameters may be most suitable for screening rice cultivars for P use efficiency under greenhouse conditions.

Rao and Shukla (1997) conducted a field trial with rice cv. Sarjoo 52 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 ammonium polyphosphate.

Chen *et al.* (1997) conducted a field experiment at the Rice Research Institute of Yunnan Agricultural University, on soils low in P and Zn and rice cultivars-Xunza 29, Hexi 35 and Yungeng 34 were given 0 or 5 kg Zn ha^{-1} and 60, 150 or 200 kg P ha^{-1}. Application of Zn and P significantly increased yield, especially in Hexi 35 and Yungeng 34. Grain protein contents were increased by P application and amylose contents of milled rice were increased by Zn application. Patel *et al.* (1997) recorded significant increase of grain yield with the increase in P_2O_5 levels from 30-90 kg ha^{-1}, the effect being more pronounced in rice than rapeseed. Raju *et al.* (1997) also found significant increase in grain yield with increase in P_2O_5 levels from 30-90 Kg ha^{-1}, the effect being more pronounced in rice than rapeseed.

Shah (1996) found that application of 12 kg P ha^{-1} gave higher grain yield than the P control in Aus and T. Aman seasons under rainfed conditions.

Wilson *et al.* (1996) conducted on-farm field experiments on soils with insufficient P and K for rice production. They reported that the yield was significantly increased by P application (40 lb P_2O_5 $acre^{-1}$) but there was no response to K application.

Matsuo *et al* (1995) stated that when the soil was deficient in P, the absorption of N and K decreased significantly and the yield of brown rice became lower than in case of K or N deficiency.

Annadurai and Palaniappan (1994) conducted a field trial at Coimbatore, India with rice cv. IR-50 grown with no fertilizers or 2% diammonium phosphate at boot leaf stage + 50% flowering, boot leaf + post-milk stages or boot leaf + 50% flowering + post-milk stages or 0, 9.5, 19 or 38 kg P_2O_5 ha^{-1}. They stated that DAP spray increased grain yield which was highest with 3 sprays. Grain yield was highest with 38 kg P_2O_5 ha^{-1}.

Momuat *et al.* (1992) conducted a field experiment using several rates of triple super phosphate (TSP) to evaluate the response of rice crop. They reported that application of TSP up to 200 kg ha^{-1} did not increase yield significantly.

2.2.2 Effect of Spikelet Sterility

Shah (2002) examined the P deficiency, in control plots caused stunted growth with limited tillers and decreased filled spikelet percentage per panicle. Dobermann and Fairhust (2000) also reported that when P deficiency was severe, rice plants might not flower at all.

Ortega and Rojas (1999) reported that the P application decreased floret sterility. Fageria *et al.* (1997) reported that grain yield and percent sterility correlation was negative and accounted for 7.14% variations in yield with application of P 30 kg ha^{-1}.

Zaman *et al.* (1995) found significant increased of panicle m^{-2} and grain yield with P application over control treatment in dry season. Yoshida (1981a) reported that the spikekets number m^{-2} and filled-spikelets percentage contributed 75.7% to total grain yield.

Yoshida (1981b) examined the relative importance of each yield components for grain yield (the grain yield of crops ranged from 4.6 to 7.1 t ha^{-1}) and found number of spikelet per square meter alone 60%, and filled-spikelet percentages and

100-grain weight together were responsible for 21% field variation. Thus, the higher number of panicle m^{-2} and filled grains m^{-2} as well as 100-grain weight would played a major role to increase such a high yield with 30 kg P ha^{-1}.

Chapter 3

Materials and Methods

Chapter 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Boro season from December 2006 to June 2007. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Description of the experimental site

The experimental site was under the Agro-ecological zone of Modhupur Tract-AEZ-28, situated at $23^0 41'$ N latitude and $90^0 22'$ E longitude at with an elevation of 8.6 m from the mean sea level. For better understanding about the experimental site it has been shown in the Map in Appendix-I.

3.2 Climate

The experimental area was under the sub-tropical climate that characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during Rabi season (October-March). During the study period the weather data of the experimental site are shown in Appendix-II.

3.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the experimental field. The soil analyses were done at the laboratory of Soil Resource Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix-III.

3.4 Crop / planting material

High yielding variety BRRI dhan29 and the hybrid varieties, Aloron (HB 8) and Hira-2 (HS-273) of boro season were used as test crop. BRRI dhan29 were developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The grains of BRRI dhan29 are medium-slender with light-golden husks. Aloron (HB-8) was introduced in Bangladesh by BRAC Seed Enterprise Limited and Hira-2 (HS-273) was introduced by Supreme Seed Company Limited from China. The grains of Aloron (HB 8) are golden, slightly slender and comparatively larger in size. The grains of Hira-2 (HS-273) are medium, thick with light golden husks.

3.5 Seed collection

Healthy seeds of BRRI dhan 29 were collected from the Breeding Division of BRRI, Joydebpur, Gazipur. Seeds of Aloron (HB 8) and Hira-2 (HS-273) were collected from BRAC Seed Enterprise Limited and Supreme Seed Company Limited respectively.

3.6 Sprouting of seeds

Seeds were soaked in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing after 72 hours.

3.7 Raising of seedling

A common procedure was followed in raising of seedling in seed bed. The nursury bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown uniformly as possible on December 11, 2006. Irrigation was gently provided to bed as and when needed. Proper measures were taken to raise seedlings in the nursery bed. The beds were kept weed free throughout the period of seedling raising.

3.8 The uprooting of seedlings

Seedlings of 30 days old for BRRI dhan29 and 25 days old hybrid varieties were uprooted from the nursery beds carefully.

3.9 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental area and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a sieve and stored in a clean plastic container for physical and chemical analysis.

3.10 Preparation of experimental land

The experimental field was first opened with a tractor drawn disc plough 15 days before transplanting. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a power tiller subsequently leveled by laddering. The field layout was made on January 10, 2007 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were leveled properly by wooden plank so that no water pocket could remain in the puddled field.

3.11 Fertilizer application

A fertilizer dose of 250-120-70-10 kg N, K, S and Zn ha^{-1} as urea, muriate of potash, gypsum and zinc sulphate were applied in the field. Phosphorus fertilizer was need as per treatment from triple super phosphate. Full dose of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at the time of final land preparation and incorporated well into the soil. Besides, cowdung at the rate of 10 t ha^{-1} was applied before final ploughing. Urea was applied in three equal splits at 15, 30 and 55 days after transplanting (DAT) for all varieties.

3.12 Experimental design

The experiment was laid out in a split plot design with three replications. Variety was randomly assigned to the main plots and fertilizer doses in the sub-plots. There were 15 treatment combinations. The total number of unit plots was 45. The size of the unit plot was 4.5m × 2.5m = 11.25 m^2. The distances between replication to replication and plot to plot were 1.5 m, and 1m respectively. For better understanding, the layout of the experiment has been presented in Appendix IV.

3.13 Experimental Treatments

Two sets of treatments included in the experiment are as follows:

Main Factor: Varieties

i) V_1= BRRI dhan29

ii) V_2= Aloron (HB-8)

iii) V_3= Hira-2 (HS-273)

Sub-Factor: Levels of phosphorus

i) P_0= Control (Without phosphorus)

ii) P_1= 24 Kg P_2O_5 ha^{-1}

iii) P_2= 48 Kg P_2O_5 ha^{-1}

iv) P_3= 72 Kg P_2O_5 ha^{-1}

v) P_4= 96 Kg P_2O_5 ha^{-1}

3.14 Transplanting

Seedlings were transplanted on January 11, 2007 in the well-puddled experimental plots. Spacing's were given 20cm × 15cm for BRRI dhan29 and 20cm ×

20cm for hybrid varieties. Soil of the plots was kept moist without allowing standing water at the time of transplanting. Two seedlings for BRRI dhan29 and one seedling for hybrid varieties were transplanted $hill^{-1}$.

3.15 Inter-cultural operations

3.15.1 Gap filling

Seedlings of some hills died off and these were replaced by gap filling after one week of transplanting with seedlings from the same source.

3.15.2 Weeding

To minimize weed infestation, manual weeding through hand pulling was done three times during entire growing season. The first weeding was done at 15 days after transplanting (DAT) followed by second and third weeding were done at 15 days interval after first and second weeding.

3.15.3 Irrigation and drainage

Irrigation was done by alternate wetting and drying from transplanting to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Water was removed from the plots during ripening stage.

3.15.4 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which were successfully controlled by applying three times of Diazinon® 60 EC on 15 and 25 March, 2007 and one times of Ripcord on 02 April 2007. Crop was protected from birds during the grain filling period.

3.15.5 Harvesting and processing

The crop of each plot was harvested separately on different dates at full maturity when 90% of the grains become golden yellow in color. The harvesting was done in two different dates for inbred variety as well as hybrid variety. For hybrid variety harvesting was done on May 29 and for inbred variety harvesting was done on June 03, 2007. Ten samples hills were collected from each plot for collection of data on plant characters and yield components. An area of 3 m^2 was harvested from centre of each plot avoiding the border effect. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The crops were threshed by pedal thresher and then grains were cleaned. The grain and straw weights for each plot were recorded after proper sun drying and then converted into t ha^{-1}. The grain yield was adjusted at 12% moisture level.

3.16 Recording data

Data were recorded from 25 days of transplantation and continued up to harvest. The following data were recorded during the study period.

A. Crop Growth parameter

i. Plant height (cm) (25 days interval starting from 25 DAT)

ii Number of tillers $hill^{-1}$ (25 days interval starting from 25 DAT)

iii. Fresh weight $plant^{-1}$ (g) (25 days interval starting from 25 DAT)

iv. Dry weight $plant^{-1}$ (g) (25 days interval starting from 25 DAT)

v. Crop growth rate ($g\ m^{-2}\ d^{-1}$)

vi. Relative growth rate ($g\ g^{-1}\ d^{-1}$)

B. Yield and yield contributing parameters

i. Number of effective tillers $hill^{-1}$

ii. Number of ineffective tillers $hill^{-1}$

iii. Length of panicle (cm)

iv. Number of filled grains $panicle^{-1}$

v. Number of unfilled grains $panicle^{-1}$

vi. Spikelet sterility (%)

vii. Weight of 1000-grains (g)

viii. Grain yield (t ha^{-1})

ix. Straw yield (t ha^{-1})

xi. Biological yield (t ha^{-1})

xii. Harvest index (%)

3.17 Data recording procedure

A brief outline on data recording procedure followed during the study is given below:

A. Crop growth characters

i. Plant height (cm)

The first plant height was measured at 25 DAT and continued up to harvesting period with 25 days interval. On the selected sample plants height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of the flag leaf after heading. The collected data were finally averaged.

ii. Number of tillers $hill^{-1}$

Number of tillers $hill^{-1}$ was counted at 25 days interval starting from 25 DAT and continued up to harvest from 10 pre selected hills and finally averaged them to have of tiller number $hill^{-1}$.

iii. Dry weight of plant

Five hills from each plot were uprooted and oven dried at 85 ± 5^0c for 72 hours from which the dry matter weight was recorded at 25 days interval up to 100 days. The sample was partitioned into root, stem, leaf and panicle.

iv. Crop growth rate (CGR)

The dry matter accumulation of the crop per unit land area in unit of time is referred to crop growth rate (CGR), expressed as g m^{-2} d^{-1}. The mean CGR values for the crop during the sampling intervals was computed using the formula

$$CGR = \frac{W_2 - W_1}{SA(t_2 - t_1)} g\ m^{-2}\ d^{-1}$$

Where,

SA= Ground area occupied by the plant at each sampling. W_1 and W_2 are the total dry matter production in grams at the time t_1 and t_2, respectively.

v. Relative growth rate (RGR)

The relative growth rate at which a plant incorporates new material into its sink is measured by Relative Growth Rate of dry matter accumulation and is expressed in g $g^{-1}d^{-1}$. Relative growth rate was worked out by following the formula

$$RGR = \frac{L_n W_2 - L_n W_1}{T_2 - T_1}\ g\ g^{-1}\ d^{-1}$$

Where, W_1 and W_2 is initial and final dry matter weight at the time T_1 and T_2 respectively. L_n refers to Natural Logarithm.

B. Yield, yield components and other crop characters

The sample plants of 10 hills were harvested randomly from each plot and tagged them separately. Data on yield components were collected from the sample plants of each plot.

i. Number of tillers hill^{-1}

Tillers with at least one visible leaf were counted. It included both effective and non-effective tillers.

ii. Number of effective tillers hill-1

The effective tillers from ten hills were counted and averaged to hill^{-1} basis. The tillers which had at least one grain in the panicle^{-1} were considered as effective tillers.

iii. Number of non-effective tillers hill^{-1}

The non-effective tillers from ten hills were counted and mean was expressed on hill^{-1} basis. The tillers which had no grain in the panicle^{-1} were considered as non-effective tillers.

iv. Panicle length (cm)

Panicle length was measured from the first node of the rachis to the tip of each panicle and then average was recorded.

v. Number of filled grains panicle^{-1}

Presence of any kernel in the spikelet was considered as grain and total number of filled grain on each panicle was counted.

vi. Number of unfilled grains panicle^{-1}

Spikelet having no food material inside was considered as unfilled spikelet i.e. sterile spikelet and the number of such spikelet present in each panicle was recorded.

vii. Sterility (%)

The percentage of sterility was calculated by using the following formula:

$$\text{Sterility (\%)} = \frac{\text{Number of sterile spikelet of the panicle}}{\text{Number of total spikelet of the panicle}} \times 100$$

viii. Weight of 1000-grain (g)

One thousand clean dried grains from the seed stock of each plot were counted separately and weighed by using a digital electronic balance at the stage of the grain retained at 12% moisture and the mean weight was expressed in gram.

ix. Grain yield (t ha^{-1})

Grains obtained from the central 3 m^2 areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 12% of moisture level. Dry weight of grains of each plot was converted into t ha^{-1}.

x. Straw yield (t ha^{-1})

Straw obtained from the central 3m^2 area of each plot were sun dried, cleaned, weighed separately and finally converted into t ha^{-1}.

xi. Biological yield (t ha^{-1})

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

$$\text{Biological yield (t ha}^{-1}) = \text{Grain yield (t ha}^{-1}) + \text{Straw yield (t ha}^{-1})$$

xii. Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.18 Statistical analyses of the data

After completion of the data collection, efforts have been made to process and tabulated the collected data. The data was analyzed using MSTAT-C (Russel, 1994) programme. The mean differences among the treatments were compared by multiple comparison tests using Duncan's Multiple Range Test (DMRT).

Chapter 4

Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The experiment was conducted to investigate the performance of different varieties and phosphorus levels on the yield of rice. In this chapter the results of the present investigation have been presented, discussed and compared with the results of other researchers.

4. 1 Plant height

Effect of variety

A significant difference in plant height at different growth stage was observed due to the varietal difference (Table 1). Plant height increased progressively over time attaining the highest at maturity. The rate of increase of increase, however, varied depending on the growth stages. At all the growth stages, maximum plant height was observed with BRRI dhan 29 which was followed by Aloran. Two hybrid varieties viz. 'Aloron' and 'Hira-2' resulted statistically similar plant height up to 100 days after transplanting (DAT). The increase rate of plant height was very first from 50 DAT to 75 DAT. The plant height was varied mainly due to its genetic characters and thus the differences were observed in such cases.

Effect of phosphorus

Significant variation in plant height was observed due to different levels of phosphorus at all growth stages except 50 DAT (Table 1). Regardless of treatment differences, plant increased progressively up to maturity. A rapid growth rate followed after 25 DAT that continued till at all the P levels. The plants grown with 96 kg P ha^{-1} produced maximum height at all growth stages which was statistically at a with other P doses except 25 DAT. At 25 DAT, the maximum plant height was obtained with 96 kg P ha^{-1} and it was statistically similar with 72 kg P ha^{-1}. It revealed that when rice plant attained the vegetative stage then the differences in P did not affect the plant height significantly. It can be said that P can increase the plant height at initial stage of rice life cycle. Morgan (1997) also reported the similar effect of phosphorus on the plant height. Plants grown without P fertilizer produced the shortest plant irrespective of growth stages. De Datta (1981) reported stunted plant height due to deficiency of phosphorus.

Table 1. Effect of variety and phosphorus on plant height at different days after transplantation (DAT)

Treatments	Plant height (cm) at different DAT				
	25	50	75	100	At Harvest
			Variety		
BRRI dhan 29	36.83 a	47.01 a	72.00 a	99.40 a	100.26 a
Aloron	35.05 b	45.58 ab	70.22 ab	97.80 b	99.63 a
Hira-2	35.04 b	45.03 b	70.01 b	97.70 b	98.24 b
$S_{\bar{x}}$	**0.39**	**0.48**	**0.48**	**0.39**	**0.28**
CV (%)	**5.30**	**8.35**	**8.42**	**6.35**	**7.36**
			Levels of Phosphorus		
P_0	35.23 b	47.03	70.22 b	97.76 b	99.70 b
P_1	35.93 b	47.25	71.11 ab	98.96 ab	100.40 ab
P_2	36.08 b	47.59	71.52 ab	99.01 ab	100.80 ab
P_3	37.80 a	48.22	72.45 a	99.99 a	100.90 ab
P_4	37.85 a	48.33	72.70 a	100.23 a	101.40 a
$S_{\bar{x}}$	**0.497**	**NS**	**0.59**	**0.50**	**0.50**
CV (%)	**6.30**	**7.20**	**9.67**	**7.02**	**8.06**

Means sharing common letters are not significantly different at alpha=0.05 as per DMRT
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

Varieties and P levels interaction effect on plant height was also statistically significant (Fig 1). At 25 DAT, the tallest plant (36.40 cm) was recorded by the interaction effect of BRRI dhan 29 and 72 kg P_2O_5 ha^{-1} which was statistically similar with all the interactions except where no P was applied. The lowest plant height (30.77 cm) was observed from the treatment combination of V_1P_0. Similar trend was observed at 50 and 75 DAT. At 50 DAT, the tallest plant height was observed from V_1P_4 (47.28 cm) and the shortest from V_3P_0 (41.11 cm). At 75 DAT, the tallest plant (73.75 cm) was resulted by V_1P_3 where the lowest plant height was found with V_3P_0. At 100 DAT, the tallest plants were observed from V_1P_4 which was at par with V_1P_2, V_1P_2, V_1P_3, V_2P_3, V_2P_4, P_3P_3 and V_3P_4. At harvest, the tallest plant was observed from V_1P_4 (102.63 cm) while the shortest plant was found with V_1P_0 (97.23 cm). Application of phosphorus at any doses increases the plant metabolism and thus the cell growth was increased compared to control. This result was supported by Morgan (1997).

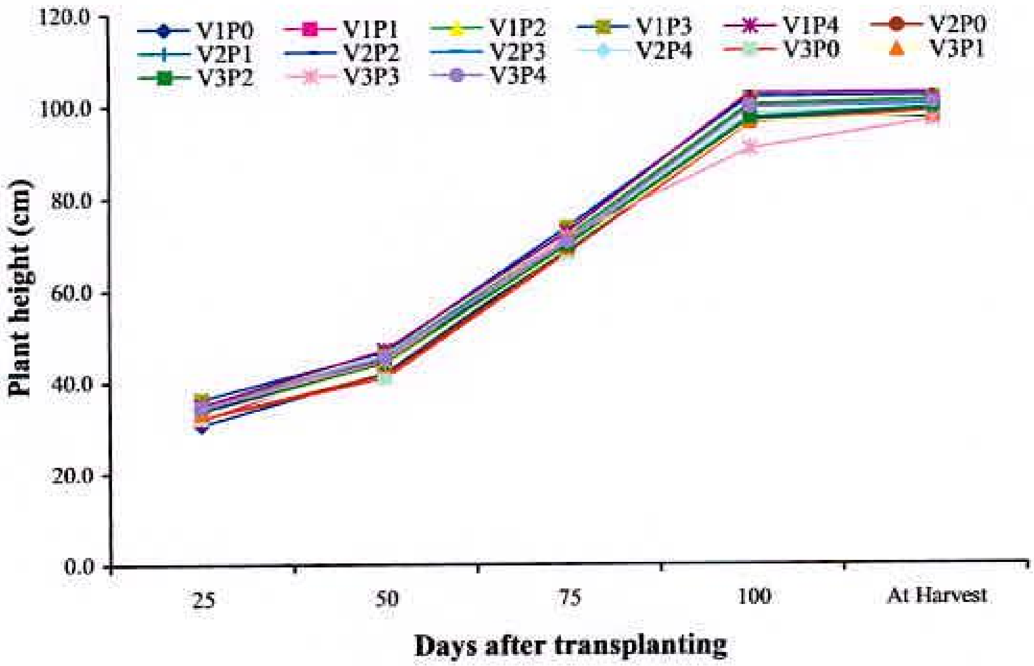

Fig 1. Interaction effect of variety and phosphorus on plant height at different days after transplantation ($S_{\bar{x}}$ =1.025, 1.233, 1.388, 1.490 and 1.551 at 25, 50, 75, 100 DAT and at harvest respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} andP_4= 96 Kg P_2O_5 ha^{-1}

4.2 Tiller number hill^{-1}

Effect of variety

Rice varieties showed significantly differences for tiller production which ranged between 4.60 and 20.51 (Table 2). Tiller number increased sharply with age reaching maximum at 75 DAT and then decreased irrespective varieties. The rate of increase, however, varied depending on variety and the stage of growth. The maximum tillering occurred during 25-50 DAT irrespective of varieties and BRRI dhan 29 gave the maximum number of tillers. The lowest number of tillers was observed from the variety Aloron from 25 to 75 DAT. On the contrary the lowest tiller hill^{-1} was obtained from Hira-2 at later stages (Table 2). It revealed that tiller mortality of Hira-2 at later stages was more than Aloron and BRRI dhan 29. However, variety Aloron and Hira-2 produced statistically similar tillers hill^{-1} at all the growth stages. At harvest variety BRRI dhan 29 produced more tillers hill^{-1} (16.83) which was 12.27% higher than Hira-2. Bhowmick and Nayak (2000) found similar results with hybrid rice varieties.

Effect of phosphorus

Tiller production was also highly responsive to phosphorus levels. The application of phosphorus fertilizer increased tiller production hill^{-1} at all the growth stages (Table 2). Tiller number increased with age reaching a peak at 75 DAT and there after decline. Application of 72 kg P_2O_5 ha^{-1} (P_3) produced maximum tillers hill^{-1} followed by P_1, P_2 and P_4 irrespective of growth stages. Addition of P fertilizer beyond 72 kg P_2O_5 ha^{-1} decreased tiller production hill^{-1} at all growth stages. Tiller production was less responsive to P at initial stage (25 DAT) where the difference only observed with 72 kg P_2O_5 ha^{-1}. The maximum changes in tiller production were noticed at 50 DAT regardless of P levels. At 75 DAT, P_3 produced the higher tiller hill^{-1} and it was statistically identical with P_4. All the P levels gave statistically similar results in the later stages (at 100 DAT and harvest). De Datta (1981) also reported similar results who found a significant increase in tiller due to application of P.

Table 2. Effect of variety and phosphorus on tillers number hill^{-1} at different days after transplantation

Treatments	Tillers hill^{-1}(no.) at different DAT				
	25	50	75	100	At Harvest
			Variety		
BRRI dhan 29	5.17 a	19.56 a	20.51 a	18.93 a	16.83 a
Aloron	4.60 b	15.13 b	17.29 b	17.97 ab	15.29 ab
Hira-2	4.73 b	15.67 b	17.38 b	16.93 b	14.99 b
$S_{\bar{x}}$	0.10	0.33	0.37	0.39	0.44
CV (%)	5.68	6.51	6.36	8.21	8.06
			Levels of Phosphorus		
P_0	3.92 b	16.04 b	16.96 c	15.39 b	13.65 b
P_1	4.22 b	16.37 ab	17.18 c	16.28 ab	15.03 ab
P_2	4.26 b	16.78 ab	17.70 bc	16.33 ab	15.21 ab
P_3	4.92 a	17.41 a	19.67 a	17.61 a	16.63 a
P_4	4.33 b	17.33 a	19.44 ab	17.54 a	16.54 a
$S_{\bar{x}}$	0.16	0.38	0.60	0.55	0.55
CV (%)	9.03	5.61	7.64	6.35	6.09

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and P levels showed significant influence on the tiller dynamic of the boro rice. All the doses of P coupled with any variety gave the higher tiller at all the sampling dates (Fig. 2). All the varieties seen to have a lag phase in early growth stage (25 DAT) and there after plants had sharp rise in the tiller number continued till 75 DAT irrespective of P levels. At 25 DAT, maximum tiller occurred with the interaction effect of BRRI dhan 29 and 48 kg P_2O_5 ha^{-1} (V_1P_0)

where the lowest number of tillers was produced by V_2P_0. The highest number of tiller at 50 DAT was attained by V_1P_4 in this study. From 75 DAT to harvest the maximum tiller was observed from the treatment V_1P_3 which was statistically identical with all the P doses except no P treatment combination. A decreasing trend of tiller production was observed from 100 DAT irrespective of treatment variables. It was due to tiller mortality of rice plants after reproductive stages (Yoshida, 1981).

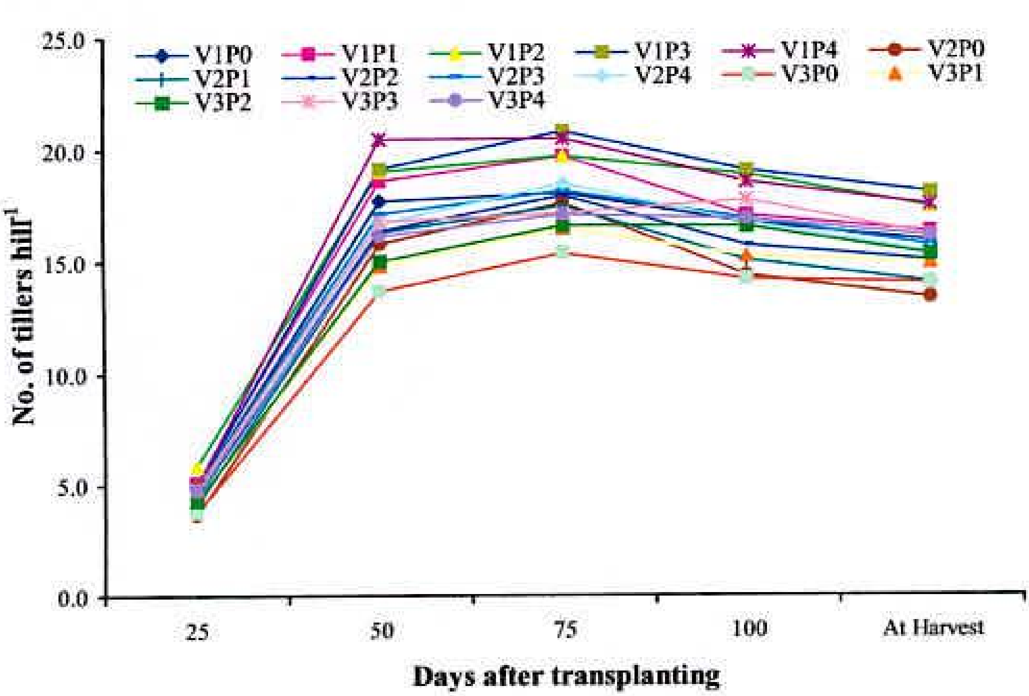

Fig. 2 Interaction effect of variety and phosphorus on tiller number hill^{-1} at different days after transplantation ($S_{\bar{x}}$ =0.64, 1.03, 1.23, 1.37 and 1.290 at 25, 50, 75, 100 DAT and at harvest respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)

P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.3 Fresh weight of plant

Effect of variety

Significant variation due to varieties was found in respect of fresh weight of plant (Table 3). Fresh plant weight gradually increased with increase of age irrespective of varieties. Higher rate of fresh plant weight was observed from 25 to 75

DAT in all the varieties. At initial stages (25 and 50 DAT) the highest fresh weight of plant was observed in BRRI dhan 29 followed by Hira-2 and Aloron. The lowest fresh biomass was observed from Aloron at 25 DAT and Hira-2 at 50 DAT. Changes in fresh weight in plant were increased rapidly at all the growth stages. At 75 and 100 DAT, the maximum fresh weight was observed from Hira-2 because of its better growth at later stages and of the increased plant height. At harvest the highest fresh biomass of plants (211.40 g) was also found with Hira-2 and the lowest from BRRI dhan 29 (Table 3). Similar results were reported for aman rice by Main (2006).

Effect of phosphorus

Phosphorus levels significantly affected the production of plant foliage and thus the differences in fresh weight of plant occurred (Table 3). Fresh plant weight of rice varieties increased progressively over time. However, the pattern of fresh biomass differed due to different levels of P fertilizer. The maximum fresh weight of plant was observed from 96 kg P_2O_5 and it was statistically identical with 72 kg P_2O_5 ha^{-1}. Plants growth with P fertilizer produced the lowest fresh weight of plant. At harvest the maximum fresh weight of plant (216.50 g) was reported from P_4 treatment followed by P_1, P_2, P_3 and the lowest from control (201.60 g). In the present study application of phosphorus fertilizer increased the biomass of plant which was supported by Tisdle and Nelson (1975).

Table 3. Effect of variety and Phosphorus on fresh weight of plant at different days after transplantation

Treatments	Fresh weight of plants hill^{-1} (g) at different DAT			
	25	50	75	100
		Variety		
BRRI dhan29	4.51 a	41.30 a	96.30 b	200.10 b
Aloron	3.88 b	36.11 b	100.00 a	201.20 b
Hira-2	4.17 ab	34.28 c	102.80 a	211.40 a
$S_{\bar{x}}$	0.14	0.42	0.74	0.77
CV (%)	6.46	6.43	6.46	5.46
		Levels of Phosphorus		
P_0	3.44 b	35.11 c	101.90 c	201.60 b
P_1	4.28 a	37.40 b	102.00 c	213.20 a
P_2	4.35 a	38.79 ab	107.60 b	214.60 a
P_3	4.72 a	39.48 a	112.50 a	215.60 a
P_4	4.45 a	39.57 a	111.95 a	216.50 a
$S_{\bar{x}}$	0.15	0.49	0.91	1.06
CV (%)	8.09	6.53	7.05	5.12

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and P doses had significant effect on fresh weight plant^{-1} (Fig. 3). Fresh weight plant of rice varieties increased progressively over time. In the beginning of the growth cycle, the difference in fresh weight within and between the varieties due to P fertilizer application was less conspienons but over time the difference. Significantly highest fresh weight was observed with V_1P_4 at 50, 75 and 100 DAT and the lowest from V_2P_0 at 50 and 75 DAT. At 100 DAT, the lowest fresh weight was found from V_3P_0. At 100 DAT the maximum plant weight (231.4 g) was 16.98% lower than V_3P_0 (197.8 g). it reveals that to attain a maximum biomass it should maintain an optimum dose of P but extra dose does not give more benefit. Dobermann and Fairhust (2000) reported the same response of phosphorus on fresh weight of plant.

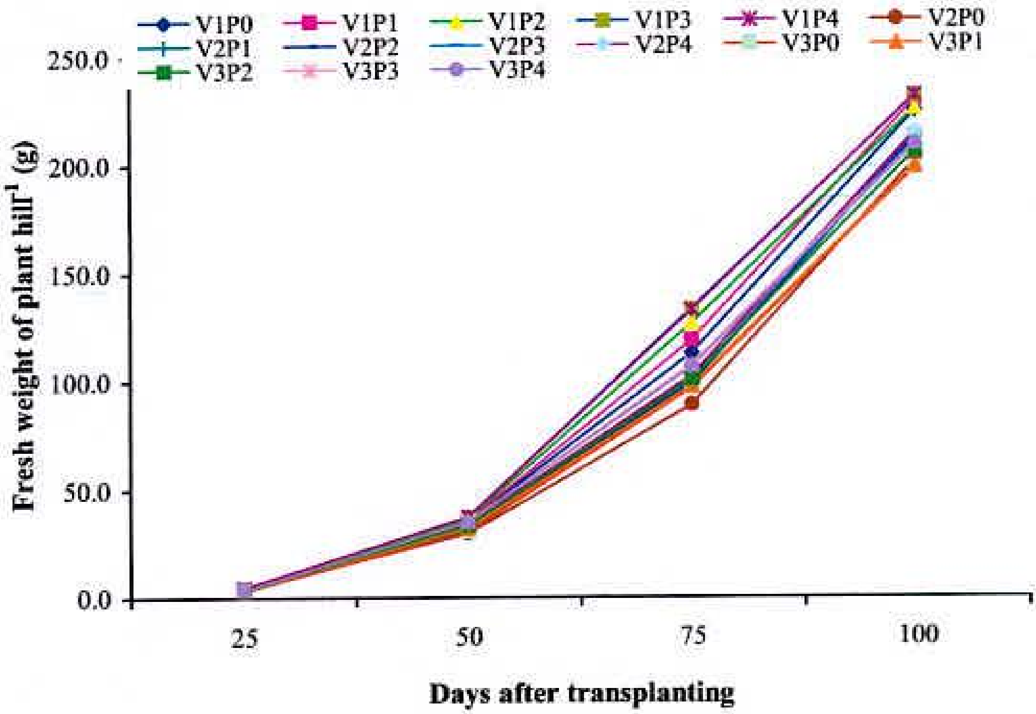

Fig. 3 Interaction effect of variety and phosphorus on fresh weight at different days after transplanting ($S_{\bar{x}}$ = 0.38, 0.64, 1.38 and 1.74 at 25, 50, 75 and 100 DAT respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.4 Dry weight of root

Effect of variety

Root dry weight of rice varied significantly across varieties (Table 4). Root weight increased almost linearly with the advancement of plant age in all the varieties. The root dry matter was increased rapidly from 50 to 75 DAT. Significantly the highest dry weight of root was found with the variety BRRI dhan 29 and it was statistically similar with Aloron at 50 and 100 DAT. The variety Hira-2 produced the lowest dry weight of root. However, the maximum dry matter in root at harvest was observed from the variety BRRI dhan 29 (9.00 g) which was at par with Aloron (8.00 g). Hira-2 produced the lowest dry weight in root (7.80 g) at harvest.

Effect of phosphorus level

Levels of phosphorus fertilizer exerted significant effect on the root dry matter at 25, 50 and 75 DAT (Table 4). No significant difference in root dry weight observed at 100 DAT due to variations of P levels. Root biomass increased progressively over time. The rate of increase, however, varied depending on the stage of growth and P fertilizer application. At 25 DAT the maximum dry weight of root hill^{-1} (0.232 g) was observed by 72 kg P_2O_5 ha^{-1} and was statistically identical with 96 kg P_2O_5 ha^{-1} (0.227 g). Generally the highest root dry weight hill^{-1} (2.73 g) was attained by 72 kg P_2O_5 ha^{-1} and the lowest in control (Without phosphorus). Further increase in phosphorus fertilizer treated to decrease the root biomass. The root dry weight with 48, 72 and 96 kg P_2O_5 ha^{-1} was statistically similar at 75 DAT. Matsuo *et al*. (1995) reported that root dry mater is disturbed due to lack of phosphorus.

Table 4. Effect of variety and phosphorus on dry weight of root at different days after transplantation

Treatments	Dry weight of root $hill^{-1}$ (g) at different DAT			
	25	50	75	100
		Variety		
BRRI dhan29	0.247 a	2.23 a	7.20 a	9.00 a
Aloron	0.194 b	1.87 ab	6.98 b	8.00 ab
Hira-2	0.184 b	1.78 b	6.94 b	7.80 b
$S_{\bar{x}}$	**0.011**	0.13	0.03	**0.29**
CV (%)	**6.43**	**6.43**	**8.46**	**3.56**
		Levels of Phosphorus		
P_0	0.188 b	1.66 d	7.07 b	8.47 a
P_1	0.198 b	1.72 d	7.17 ab	8.40 a
P_2	0.201 b	2.14 c	7.90 a	8.54 a
P_3	0.232 a	2.73 a	8.00 a	9.06 a
P_4	0.227 a	2.63 b	7.96 a	8.59 a
$S_{\bar{x}}$	**0.006**	**0.02**	**0.26**	**NS**
CV (%)	**6.23**	**5.98**	**9.05**	**8.32**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus levels

The interaction effect of variety and phosphorus levels had a significant effect on the root dry weight of plant (Fig. 4). At 25 DAT the highest dry weight was found with V_1P_3 (0.28 g) and the lowest from V_3P_0 (0.17 g). 50 DAT, the variety V_3 (Hira-2) with 72 kg P_2O_5 ha^{-1} (V_3P_3) produced the highest root dry weight (2.49 g) which was statistically at with V_3P_4, V_1P_3 and V_1P_4. The lowest dry weight of root $hill^{-1}$ was observed at 50 DAT by V_1P_0. At 75 and 100 DAT the maximum root dry weight of 7.79 g and 10.88 g $hill^{-1}$ respectively was observed from the interaction of V_1P_3 and the lowest from V_3P_0 treatment.

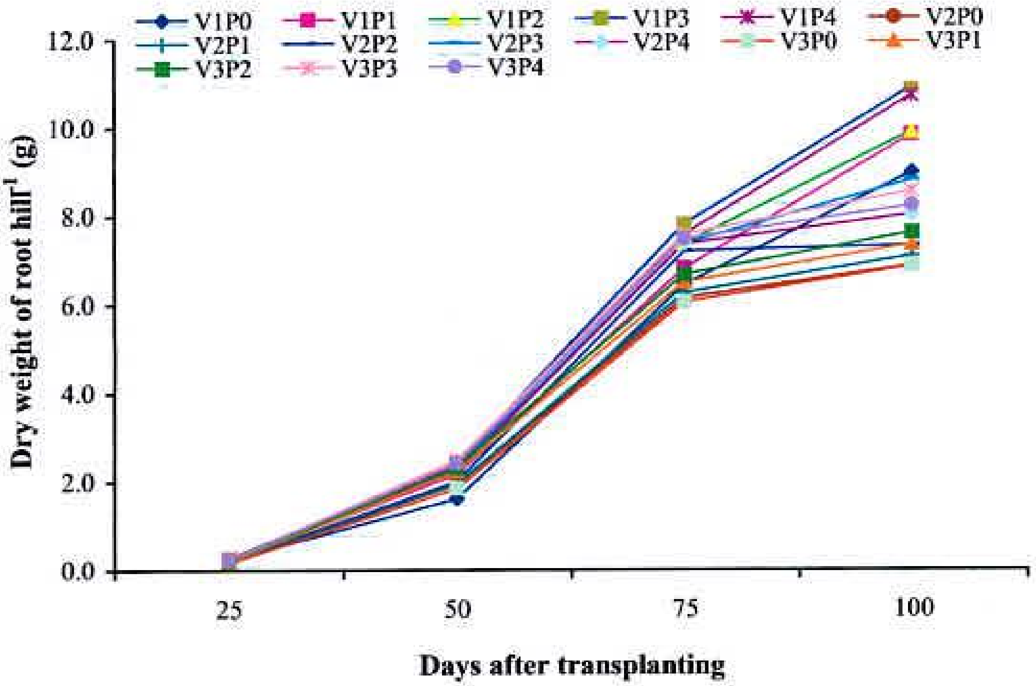

Fig. 4 Interaction effects of variety and phosphorus on root dry weight hill^{-1} different days after transplantation ($S_{\bar{x}}$ =0.018, 0.051, 0.057, 0.16 at 25, 50, 75 and 100 DAT respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)

P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4.5 Dry weight of leaf blade hill^{-1}

Effect of variety

Leaf blade of rice is important parts which use the light energy for photosynthesis. Dry weight of leaf blade of rice increased progressively over time. However, the pattern of dry matter in leaf blade differed due to different levels of phosphorus. The highest rate dry weight of leaf blade was observed from 25 to 75 DAT. The dry matter of leaf blade was significantly affected by different varieties at all the growth stages except 25 DAT (Table 5). At 50 DAT the maximum dry matter in leaf blade was observed with BRRI dhan 29 while at 75 and 100 DAT Hira-2 had the higher leaf dry weight. These findings are in agreement with Obaidullah (2007).

Effect of phosphorus level

Different phosphorus levels also affected the leaf blade dry matter production (Table 5). Dry weight of leaf blade $hill^{-1}$ increased progressively with the increase of advancement of plant age across the varieties At 50, 75 and 100 DAT the maximum dry weight was observed from 72 kg P_2O_5 ha^{-1} which was statistically at par with 96 kg P_2O_5 ha^{-1}. At all the growth stages, the lowest dry weight of leaf blade was observed where phosphorus was not applied. Tandon (1987) also observed that the plant which uptake more P resulted more dry matter in leaf.

Table 5. Effect of variety and phosphorus on dry weight of leaf blade different days after transplantation

Treatments	Dry weight of leaf blade $hill^{-1}$ (g) at different DAT			
	25	50	75	100
		Variety		
BRRI dhan 29	0.32 a	2.47 a	6.82 b	9.00 b
Aloron	0.28 a	2.33 b	6.92 b	9.12 b
Hira-2	0.30 a	2.34 b	7.69 a	9.78 a
$S_{\bar{x}}$	**NS**	**0.025**	**0.08**	**0.06**
CV (%)	**6.46**	**5.68**	**5.69**	**6.36**
		Levels of Phosphorus		
P_0	0.25 c	2.16 d	6.10 b	7.41 c
P_1	0.30 c	2.19 cd	7.00 ab	8.35 bc
P_2	0.31 c	2.32 bc	7.07 ab	8.53 ab
P_3	0.38 b	2.47 a	7.55 a	9.56 a
P_4	0.89 a	2.41 ab	7.40 a	9.53 a
$S_{\bar{x}}$	**0.02**	**0.04**	**0.33**	**0.35**
CV (%)	**6.71**	**7.35**	**8.06**	**7.74**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and phosphorus revealed that there was a significant influence on dry weight of leaf blade (Fig. 5). Dry weight of leaf blade of rice increased with the advancement of time. However, initial rate of increase was very low but other 50 DAT there was a general trend of rapid increase of leaf blade weight up to 100 DAT across the varieties and P levels. At 50 DAT the highest dry weight of leaf blade was observed from V_1P_3 (2.64 g) and the lowest dry weight was observed from V_1P_0 (1.68 g). The effect was also very similar in respect of treatment combinations at 75 and 100 DAT. This result is supported by Shah (2002) who reported that BRRI dhan 29 had high P use efficiency.

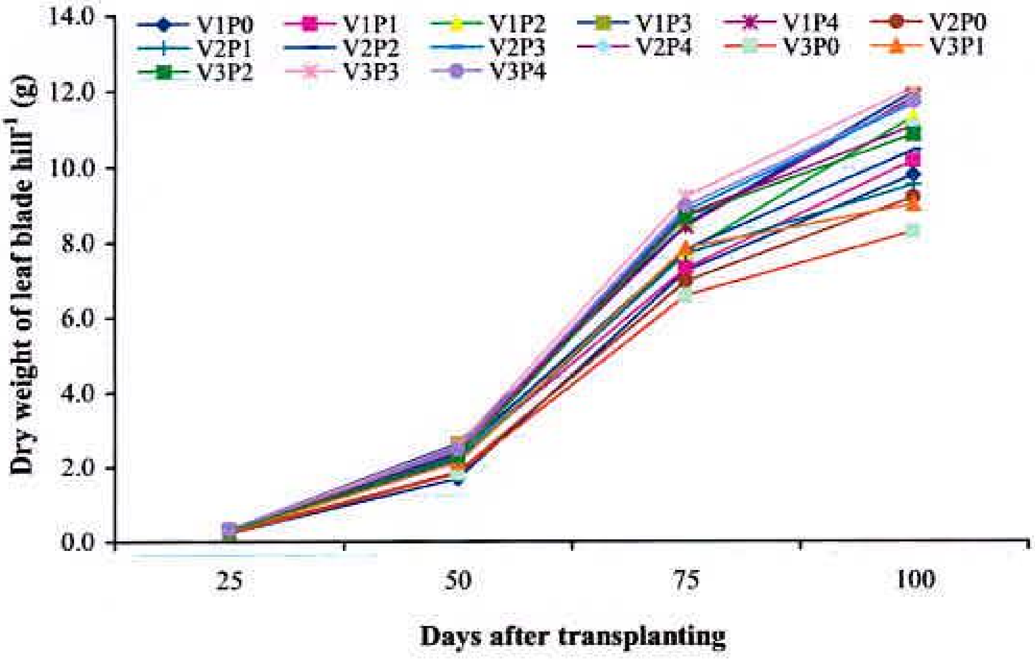

Fig. 5 Interaction effect of variety and phosphorus dose on dry weight of leaf blade at different days after transplantation ($S_{\bar{x}}$ = 0.087, 0.194, 0.668, 1.018 at 25, 50, 75 and 100 DAT respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)

P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.6 Dry weight of leaf sheath hill^{-1}

Effect of variety

Different variety produced variable amount of leaf sheath dry matter at different ages in boro season which ranged between 0.26 and 9.81 g. Dry weight of leaf sheath of rice varieties increased with age reaching a maximum at 100 DAT. The trend was similar in all the varieties (Table 6). Hybrid varieties produced more leaf sheath dry matter at all the growth stages, but at initial stage, the effect was not statistically significant. Two hybrid varieties Aloron and Hira-2 produced statistically similar dry matter in leaf sheath. The maximum dry matter at 100 DAT was 9.81 g with Hira-2 and the lowest was produced by BRRI dhan 29 (8.79 g) trend was reported by Obaidullah (2007).

Effect of phosphorus

Different levels of phosphorus also significantly affected the dry matter production in leaf sheath (Table 6). Dry weight of leaf sheath increased with the increase in plant age due to P levels. At all the growth stage, the highest dry weight of leaf sheath was found with 72 kg P_2O_5 ha^{-1} and it was statistically identically with 24 96 kg P_2O_5 ha^{-1}. Plants grown without fertilizer had lowest dry weight of leaf sheath irrespective of growth stages. Addition of P fertilizer beyond 72 kg ha^{-1} decreased dry weight of leaf sheath. Similar results of applied phosphate fertilizer to rice was reported by Shah (2002).

Table 6. Effect of variety and phosphorus on dry weight of leaf sheath at different days after transplantation

Treatments	Dry weight of leaf sheath $hill^{-1}$ (g) at different DAT			
	25	50	75	100
		Variety		
BRRI dhan29	0.26 a	2.69 b	7.59 b	8.79 b
Aloron	0.28 a	2.92 a	7.89 b	9.79 a
Hira-2	0.29 a	2.90 a	7.91 a	9.81 a
$S_{\bar{x}}$	**NS**	**0.04**	**0.03**	**0.09**
CV (%)	**6.46**	**5.46**	**6.49**	**7.36**
		Levels of Phosphorus		
P_0	0.20 b	2.01 c	8.24 b	9.41 b
P_1	0.30 ab	2.14 bc	8.64 ab	9.34 b
P_2	0.31 ab	2.24 b	9.22 ab	10.18 ab
P_3	0.35 a	2.70 a	9.28 a	10.95 a
P_4	0.34 ab	2.68 a	9.10 ab	10.25 ab
$S_{\bar{x}}$	**0.04**	**0.06**	**0.31**	**0.40**
CV (%)	**5.35**	**9.98**	**8.87**	**7.56**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

Interaction of variety and phosphorus levels showed significant influence on the dry matter accumulation in leaf sheath (Fig. 6) at all the growth stage except 25 DAT. The accumulation of dry matter in leaf sheath varied depending on growth stages and levels of P fertilizer in all the three varieties of rice. At 50 and 75 DAT the highest dry weight of leaf sheath was observed by the combined effect of Hira-2 and 72 kg P_2O_5 ha^{-1}. At 50 DAT the lowest dry matter was produced by V_1P_0 while V_2P_0 produced the lowest dry matter in leaf sheath at 75 DAT. The treatment combination did not significantly affect the dry accumulation at 100 DAT (Fig. 6).

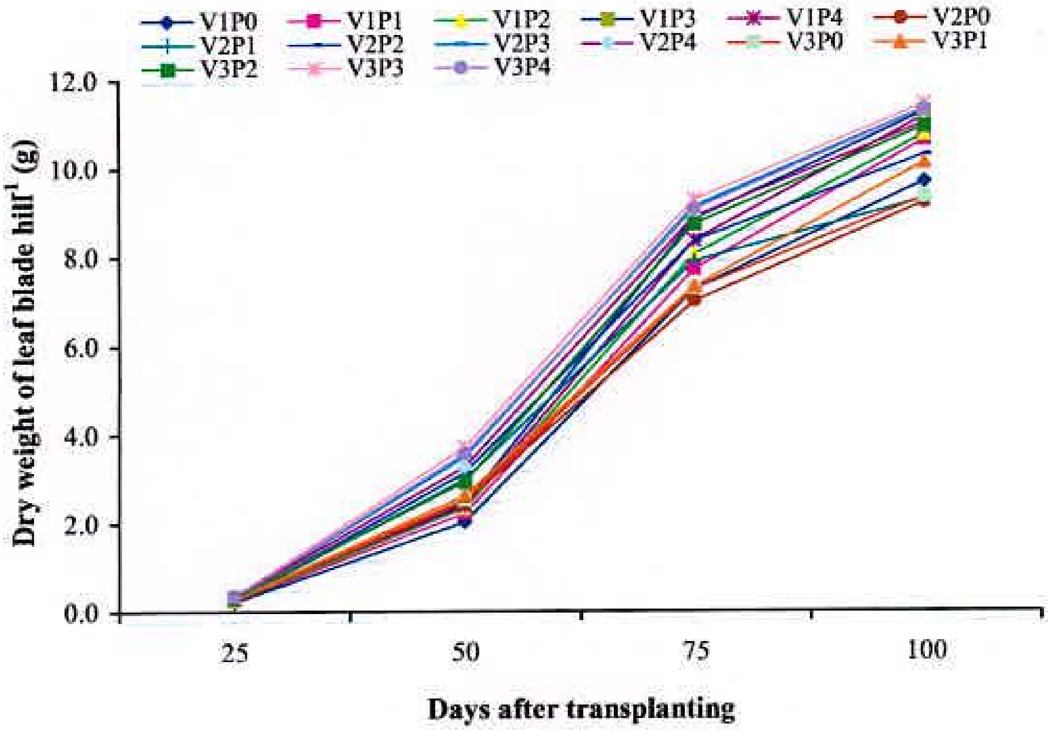

Fig 6. Interaction effect of variety and phosphorus on dry weight of leaf sheath at different days after transplantation ($S_{\bar{x}}$ = NS, 0.432, 0.64 and NS at 25, 50, 75 and 100 DAT respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.7 Dry weight of stem hill^{-1}

Effect of variety

Among the three sampling dates the effect of variety on the dry matter accumulation in stem was significant only at 75 and 100 DAT (Table 7). At 50 DAT the effect of different variety was statistically identical. Both at 75 and 100 DAT the highest dry matter was observed from the variety Hira-2. At 75 DAT BRRI dhan29 produced the lowest dry matter in stem while at 100 DAT it was found the lowest dry matter with the variety Aloron.

Effect of phosphorus

Like the variety phosphorus also did not affected the dry matter production in stem at 50 DAT. But significant differences were observed at 75 and 100 DAT (Table 7). At 75 DAT maximum dry matter (1.77 g) was produced by 72 kg P_2O_5 ha^{-1} (P_3) which was statistically similar with P_2 (48 kg P_2O_5 ha^{-1}) and P_4 (96 kg P_2O_5 ha^{-1}). At 100 DAT the maximum dry matter in stem was observed with 72 kg P_2O_5 ha^{-1} (6.96 g) and it was statistically identical with 48 kg P_2O_5 ha^{-1} (6.15 g) and 96 kg P_2O_5 ha^{-1} (6.62 g). This result are in agreement with Fageria and Filho (1982).

Table 7. Effect of variety and phosphorus on dry weight of stem at different days after transplantation

Treatments	Dry weight of stem $hill^{-1}$ (g) at different DAT		
	50	75	100
		Variety	
BRRI dhan29	0.36	1.48 b	6.38 ab
Aloron	0.39	1.54 b	6.14 b
Hira-2	0.40	1.68 a	7.16 a
$S_{\bar{x}}$	**NS**	**0.02**	**0.98**
CV (%)	**6.46**	**9.65**	**6.35**
		Levels of Phosphorus	
P_0	0.34	1.49 b	5.44 c
P_1	0.36	1.50 b	5.77 bc
P_2	0.38	1.62 ab	6.15 a-c
P_3	0.39	1.77 a	6.96 a
P_4	0.40	1.68 ab	6.62 ab
$S_{\bar{x}}$	**NS**	**0.08**	**0.33**
CV (%)	**7.35**	**6.53**	**5.79**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and phosphorus had the significant effect on the stem dry weight (Fig 7). Stem dry weight increased progressively with time reaching the peak at 75 DAT regardless of treatment. At 50 DAT the highest dry weight of stem was observed from the treatment combination of V_1P_3 (0.44 g). At 75 DAT the highest dry weight was found with V_3P_3 (1.89 g). The rapid increase in stem dry weight was observed at 100 DAT where the maximum dry weight was observed with V_3P_1. The lowest dry matter was found with the combination of V_1P_0 at 50 and 75 DAT while at 100 DAT it was observed with V_3P_0.

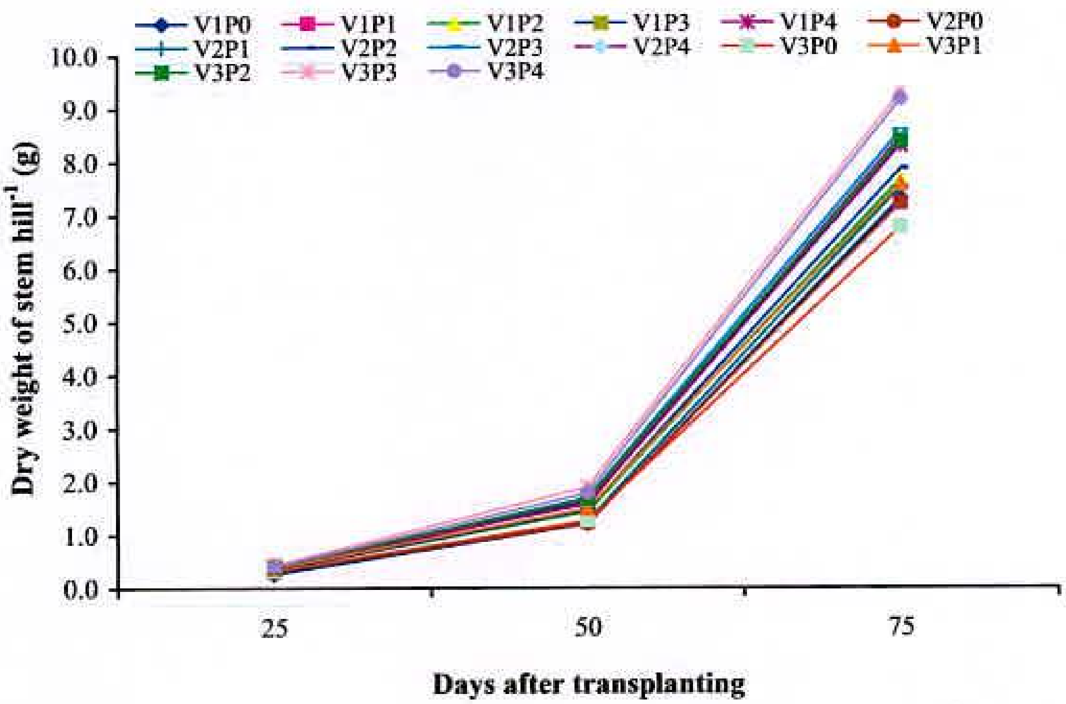

Fig 7. Interaction effect of variety and phosphorus and on dry weight of stem rice at different days after transplantation ($S_{\bar{x}}$ = 0.0483, 0.177 and 0.1721 at 50, 75 and 100 DAT, respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)

P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.8 Dry weight of panicle hill^{-1}

Effect of variety

Hybrid varieties were more response to produce more dry weight in panicle than the inbred variety (Table 8). Maximum dry weight in panicle was observed with Hira-2 (15.46 g) which was statistically at par with Aloron. BRRI dhan 29, however, produced the lowest dry matter in panicle. Obaidullah (2007) observed similar result.

Effect of phosphorus

Dry weight of panicle hill^{-1} also varied significantly due to variation of P fertilizer. Increasing rates of applied phosphorus up to 72 kg P_2O_5 ha^{-1} produced the maximum dry matter in panicle (14.00 g) and it was statistically identical with 24 and 96 kg P_2O_5 ha^{-1}. Addition of phosphorus fertilizer beyond 72 kg P_2O_5 ha^{-1} decreased dry matter in panicle. Plants growth without P fertilizer produced the lowest dry matter. Increase in dry matter of panicle with increased P doses was also reported by Dobermann and Fairhust (2000).

Table 8. Effect of variety and phosphorus on dry weight of panicle at 100 days after transplantation

Treatments	Dry weight of panicle hill^{-1} (g)
	Variety
BRRI dhan29	10.52 b
Aloron	14.84 a
Hira-2	15.46 a
$S_{\bar{x}}$	**0.40**
CV (%)	**6.43**
	Levels of Phosphorus
P_0	12.35 b
P_1	12.73 ab
P_2	13.01 ab
P_3	14.00 a
P_4	13.63 ab
$S_{\bar{x}}$	**0.47**
CV (%)	**7.98**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and phosphorus had the significant effect on the accumulation of dry matter in panicle (Fig. 8). The treatment combination V_3P_3

produced the highest dry matter in panicle (16.53 g) which was statistically similar with V_3P_4 (16.48 g). The lowest dry matter in panicle was observed with V_1P_0 (6.92 g) in this study.

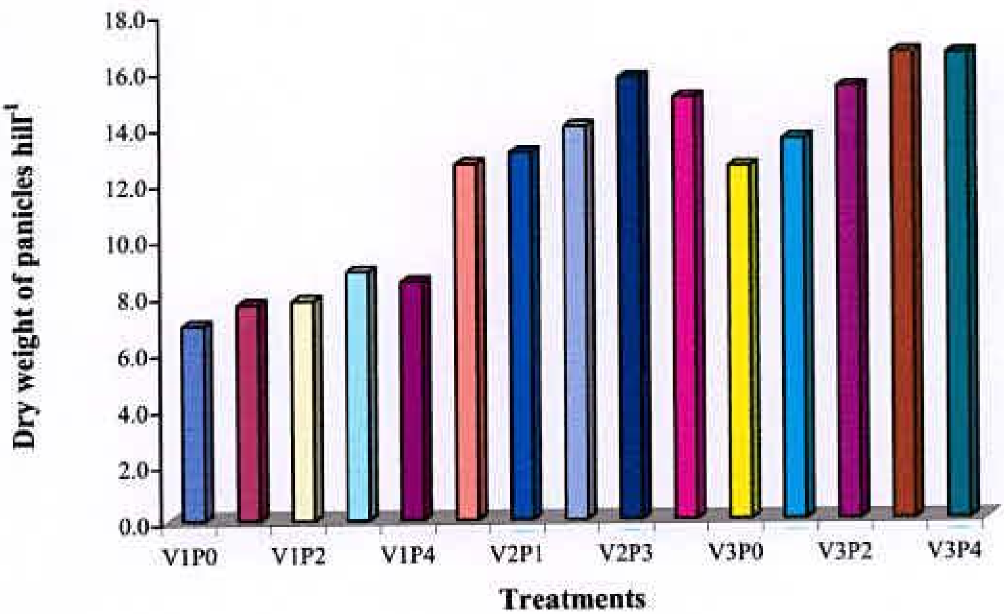

Fig 8. Interaction effect of variety and phosphorus on dry weight of panicle at 100 days after transplantation ($S_{\bar{x}}$ =0.5859)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4.9 Total dry matter plant^{-1}

Effect of variety

The significant effect of variety on total dry matter production in plant was observed at 75 DAT and 100 DAT (Table 9). At 25 and 50 DAT, dry matter plant^{-1} was influence non-significantly across the varieties. But numerically the highest dry matter of plant was observed with the variety Hira-2 and the lowest from BRRI dhan 29 at all the growth stages except 25 DAT. At 75 DAT the maximum dry weight (17.28 g) was found with Hira-2 variety followed by Aloron (16.06 g). At 100 DAT the highest dry weight was obtained by Hira-2 (42.2 g) which was statistically similar with Aloron (39.91 g). Main (2006) also observed that hybrid rice produced more dry matter in plant than inbred varieties.

Effect of phosphorus

In case of different phosphorus levels, a significant variation was found in the total dry matter accumulation at different growth stages. Accumulation of dry matter increased progressively over time attaining the highest at 100 DAT. The rate of increase, however, varied depending on variety and the stage of growth. At 25 DAT except the control all the levels of P has no significant difference to accumulate the total dry matter in rice plant. At 50 DAT the significantly higher total dry matter was found with 72 (5.57 g) and 96 kg P_2O_5 ha^{-1} (5.51 g). Plants grown without P fertilizer (P_0) produced the lowest dry matter yield which was statistically similar with P_1 and P_2. At 75 DAT, 24 kg to 96 kg P_2O_5 ha^{-1} gave identical results, where the lowest dry matter was observed with control (15.83 g). At 100 DAT, the highest dry matter was observed from P_3 treatment which was at par with P_4. The second highest dry matter was found with 48 kg P_2O_5 ha^{-1}. Generally the control treatment where no phosphorus was applied produced the lowest dry matter. Positive influence of phosphorus on total dry matter in rice was also reported by Gupta and Bhadra (1980) and Shasrkar and Chowdhury (1988).

Table 9. Effect of variety and phosphorus on total dry weight of plant at different days after transplantation

Treatments	Total Dry weight of plant hill^{-1} (g) at different DAT			
	25	50	75	100
		Variety		
BRRI dhan29	0.59	5.53	15.91 b	34.70 b
Aloron	0.56	5.64	16.06 b	39.91 a
Hira-2	0.60	5.64	17.28 a	42.22 a
$S_{\bar{x}}$	**NS**	**NS**	**1.12**	**2.36**
CV (%)	**6.30**	**5.68**	**9.36**	**6.44**
		Levels of Phosphorus		
P_0	0.45 b	4.53 b	15.83 b	34.61 d
P_1	0.60 a	4.71 b	17.15 ab	36.20 cd
P_2	0.62 a	4.94 b	17.92 a	37.87 bc
P_3	0.74 a	5.57 a	18.61 a	41.48 a
P_4	0.74 a	5.51 a	18.19 a	40.03 ab
$S_{\bar{x}}$	**0.04**	**0.18**	**0.62**	**0.86**
CV (%)	**6.43**	**8.36**	**5.86**	**6.45**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

Significant interaction effect of variety and phosphorus was observed to accumulate dry mater in plant at all the growth stages (Fig. 9). Regardless of the treatment difference, TDM increased progressively over time. In the beginning of the growth cycle, the difference in TDM was not significant due to varieties and P levels. Sharp differences among the varieties in TDM emerged from 50 DAT and it progressively irrespective of P levels. At all the growth stages significantly highest total dry matter was observed with the treatment combination of V_3P_3. At 25 DAT the highest total dry matter was obtained with V_3P_3 (0.72 g) which was statistically similar with all other treatments except V_1P_0 and V_3P_0. At 50 DAT the highest total dry matter (6.74 g) was found with V_3P_3, where the lowest dry matter was found with V_1P_0. Significantly highest dry matter accumulation was also observed at 75 DAT with V_3P_3 (20.36 g) while the lowest dry matter was noticed with V_3P_0. At 100 DAT highest total dry matter was observed with V_3P_3 (49.33 g) which was statistically at par with V_3P_4, V_3P_2, V_2P_3 and V_2P_4. The lowest total dry matter in this stage was observed with the interaction of V_1P_0. Sarkar and Chowdhury (1988) observed more dry matter with increased P doses combined with hybrid varieties.

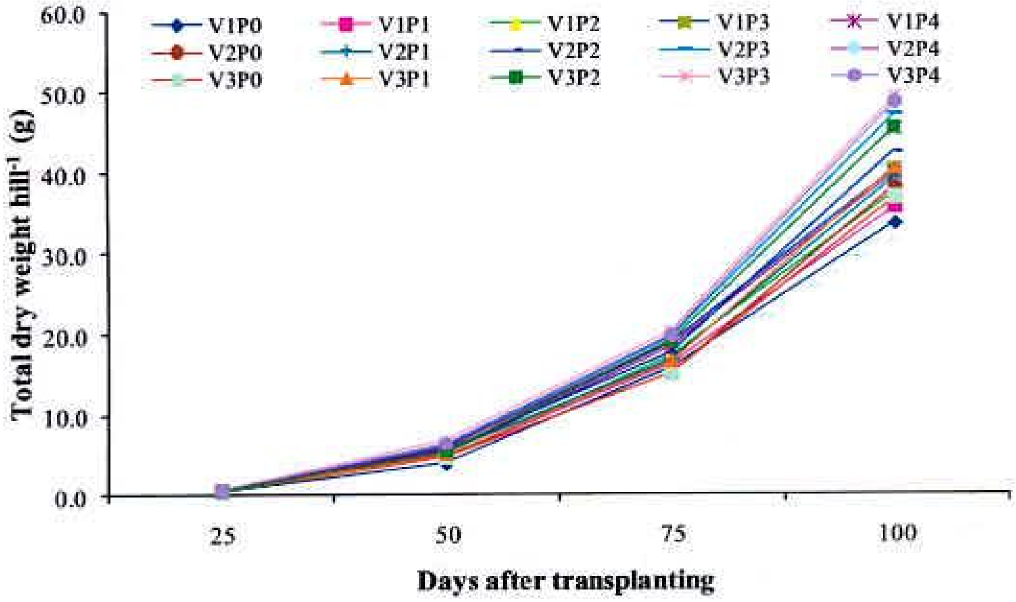

Fig 9. Interaction effect of variety and phosphorus on total dry weight of plant at different days after transplantation ($S_{\bar{x}}$ = 0.0577, 0.435, 1.072 and 1.692 at 25, 50, 75 and 100 DAT, respectively)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.10 Crop growth rate

Effect of variety

Among three different sampling dates only significant differences in crop growth rate (CGR) due to variety was observed at 75 to 100 DAT (Table 10).

However, the CGR values increased progressively with time reaching the highest at 75-100 DAT regardless of variety. Numerically the maximum crop growth rate was observed with Hira-2. At 75-100 DAT the maximum CGR (33.24 g m^{-2} d^{-1}) was observed with Hira-2 and it was statistically identical with Aloron (31.79 g m^{-2} d^{-1}), which revealed that hybrid variety got more growth habit than inbred variety. BRRI dhan 29 showed the lowest CGR value during the whole growth period, Shah (2002) also observed the similar result in respect of CGR

with rice varieties.

Effect of phosphorus

Different levels of phosphorus had significant effect on crop growth rate of rice varieties (Table 10). Irrespective P levels, CGR values increased progressively with the advancement of plant age. The highest CGR value was associated with 72 kg P_2O_5 ha^{-1} (P_3) at all the growth duration. Addition of P fertilizer beyond 72 kg P_2O_5 ha^{-1} decreased CGR value irrespective of growth stages. During 25-50 DAT the maximum CGR value was observed with P_3 (6.44 g m^{-2} d^{-1}) which was statistically at par with P_4 (6.35 g m^{-2} d^{-1}). At 50-75 DAT the highest CRG was obtained from P_3 (17.38 g m^{-2} d^{-1}) and it was statistically identical with P_2 (17.30 g m^{-2} d^{-1}) and P_4 (16.91 g m^{-2} d^{-1}). Plant grown without P fertilizer had the CGR values at all the growth stages. Such information of rice was also reported by Fageria *et al.* (1997).

Table 10. Effect of variety and phosphorus on crop growth rate at different days after transplantation

Treatment	CGR (g m^{-2} d^{-1}) at different DAT		
	25 to 50	50 to 75	75 to 100
		Variety	
BRRI dhan29	6.58	13.83	25.05 b
Aloron	6.72	13.89	31.79 a
Hira-2	6.77	15.51	33.24 a
$S_{\bar{x}}$	NS	NS	1.114
CV (%)	6.58	6.89	7.50
		Levels of Phosphorus	
P_0	5.43 b	15.06 c	25.03 d
P_1	5.48 b	16.58 b	25.39 cd
P_2	5.75 b	17.30 a	26.60 c
P_3	6.44 a	17.38 a	30.49 a
P_4	6.35 a	16.91 ab	29.12 b
$S_{\bar{x}}$	0.14	0.20	0.45
CV (%)	8.65	5.36	7.25

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

The interaction effect of variety and phosphorus had a significant influence on crop growth rate at all the growth duration (Table 11). Regardless of treatment, CGR values increased progressively with time reaching the highest at 75-100 DAT. From 25 to 50 DAT the highest CGR was observed with the treatment V_3P_3 (8.03 g m^{-2} d^{-1}) and the lowest (4.71 g m^{-2} d^{-1}) from the treatment V_1P_0. During 50 to 75 DAT the highest CGR was found with V_3P_3 (18.15 g m^{-2} d^{-1}) where the lowest CGR was observed with V_3P_0 (13.89 g m^{-2} d^{-1}). Maximum CGR during 75 to 100 DAT was observed with V_3P_3 (38.61 g m^{-2} d^{-1}) which was statistically identical with V_3P_4

(38.48 g m^{-2} d^{-1}) and V_2P_3 (36.78 g m^{-2} d^{-1}). The lowest CGR value at this duration was observed with V_1P_0 (24.02 g m^{-2} d^{-1}) and V_1P_1 (25.91 g m^{-2} d^{-1}).

Table 11. Interaction effect of variety and phosphorus on crop growth rate at different days after transplantation

Treatment	CGR (g m^{-2} d^{-1}) at different DAT		
	25 to 50	**50 to 75**	**75 to 100**
V_1P_0	4.71 e	15.58 cde	24.02 i
V_1P_1	5.61 de	15.28 de	25.91 hi
V_1P_2	5.64 de	16.47 a-d	27.07 gh
V_1P_3	6.41 b-d	17.88 a	28.62 f-g
V_1P_4	6.30 b-d	17.28 a-c	28.48 f-g
V_2P_0	5.51 de	14.00 e	30.74 d-f
V_2P_1	6.64 a-d	15.08 de	30.02 e-g
V_2P_2	7.03 a-d	15.72 b-e	33.22 cd
V_2P_3	7.63 ab	17.65 a	36.78 ab
V_2P_4	7.22 a-c	17.52 ab	35.02 bc
V_3P_0	5.58 de	13.89 e	29.03 e-h
V_3P_1	6.08 cde	15.36 de	31.88 de
V_3P_2	6.68 a-d	17.92 a	35.19 bc
V_3P_3	8.03 a	18.15 a	38.61 a
V_3P_4	7.66 ab	17.77 a	38.48 a
$S_{\bar{x}}$	**0.45**	**0.58**	**0.97**
CV (%)	**8.65**	**5.36**	**7.25**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4. 11 Relative growth rate

Effect of variety

Variety did not influence the relative growth rate at all the growth duration (Table 12). However, numerically the highest RGR value was observed with Aloron variety and the lowest from the variety BRRI dhan 29 at all the growth duration.

Effect of phosphorus

Relative growth rate (RGR) at different growth durations significantly influenced by phosphorus levels (Table 12). Irrespective of P levels, RGR was more at early stage (25-50DAT) and showed a decreasing trend with the advancement of plant age. At 25 to 50 DAT the highest RGR was observed with P_0 (0.092 g g^{-1} d^{-1}) where the lowest RGR (0.08 g g^{-1} d^{-1}) was observed from P_4. During 50 to 75 DAT P_1 and P_2 (0.052 g g^{-1} d^{-1}) showed the highest RGR values followed by P_0. Generally the highest RGR was observed with 72 and 96 kg P_2O_5 ha^{-1} (0.032 g g^{-1} d^{-1}) but the effect was not statistically different. The trend of RGR was partially supported by Fageria and Baligar (1993) in rice plant.

Table 12. Effect of variety and phosphorus on relative growth rate at different days after transplantation

Treatment	RGR (g g^{-1} d^{-1}) at different DAT		
	25 to 50	50 to 75	75 to 100
		Variety	
BRRI dhan29	0.089	0.042	0.031
Aloron	0.092	0.045	0.036
Hira-2	0.089	0.042	0.036
$S_{\bar{x}}$	**NS**	**NS**	**NS**
CV (%)	**6.45**	**6.38**	**6.35**
		Levels of Phosphorus	
P_0	0.092 a	0.050 ab	0.031
P_1	0.082 b	0.052 a	0.030
P_2	0.083 b	0.052 a	0.030
P_3	0.081 b	0.048 b	0.032
P_4	0.080 b	0.048 b	0.032
$S_{\bar{x}}$	**0.0014**	**0.0010**	**NS**
CV (%)	**5.64**	**5.68**	**9.23**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

Significant effect of the interaction of variety and phosphorus was observed in relation to relative growth rate in this study (Table 13). RGR values were more at early stage in the season and showed a decreasing trend with the advancement of plant age irrespective of treatments. The decrease RGR was probably due to the increase of metabolically active tissue and as obtained less to the plant growth. During 25 to 50 DAT the highest RGR was observed with the treatment V_2P_2 (0.094 g g^{-1} d^{-1}) which was followed by the interaction effect of V_2P_1, V_2P_3, V_2P_4, V_3P_0 and V_3P_3. The lowest RGR was observed by V_1P_3 (0.082 g g^{-1} d^{-1}). During 50 to 75 DAT V_1P_0 resulted the highest RGR (0.055 g g^{-1} d^{-1}) followed by V_1P_2 (0.051 g g^{-1} d^{-1}). The lowest RGR (0.044 g g^{-1} d^{-1}) was found with V_2P_2 and V_3P_3. During 75 to 100 DAT the highest RGR (0.037 g g^{-1} d^{-1}) was noticed by the treatment V_2P_0, and the lowest RGR (0.030 g g^{-1} d^{-1}) from V_1P_3.

Table 13. Interaction effect of variety and phosphorus on relative growth rate at different days after transplantation

Treatment	RGR ($g\ g^{-1}\ d^{-1}$) at different DAT		
	25 to 50	50 to 75	75 to 100
V_1P_0	0.086 cde	0.055 a	0.031 bc
V_1P_1	0.086 cde	0.049 bc	0.031 bc
V_1P_2	0.083 de	0.051 ab	0.031 bc
V_1P_3	0.082 e	0.049 bc	0.030 c
V_1P_4	0.083 de	0.049 bc	0.031 bc
V_2P_0	0.087 b-e	0.047 b-d	0.037 a
V_2P_1	0.092 ab	0.045 cd	0.034 ab
V_2P_2	0.094 a	0.044 d	0.035 a
V_2P_3	0.090 a-c	0.045 cd	0.035 a
V_2P_4	0.089 a-c	0.046 cd	0.034 ab
V_3P_0	0.089 a-c	0.047 b-d	0.036 a
V_3P_1	0.087 b-e	0.047 b-d	0.036 a
V_3P_2	0.088 b-d	0.049 bc	0.035 a
V_3P_3	0.089 a-c	0.044 d	0.035 a
V_3P_4	0.088 b-d	0.045 cd	0.036 a
$S_{\bar{x}}$	**0.0015**	**0.0014**	**0.0010**
CV (%)	**5.64**	**5.68**	**9.23**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4.12 Yield components

4.12.1 Effective and non-effective tillers

Effect of variety

Significant differences in effective and non effective tiller $hill^{-1}$ were observed among the varieties (Fig. 10). Variety BRRI dhan 29 produced higher number of effective tillers $hill^{-1}$ at harvest (13.85) than Aloron and Hira-2. The lowest number of effective tillers was observed with Aloron (12.95) and it was statistically similar with Hira-2 (13.01). However, non-effective tillers $holl^{-1}$ were not affected by the varietal differences.

Effect of phosphorus

Effective tillers $hill^{-1}$ of rice varieties also varied significantly due to P fertilizer application (Fig. 11). Application of 72 kg P_2O_5 ha^{-1} produced the highest number of effective tillers $hill^{-1}$ (14.23) which was statistically at par with P_4 or 96 kg P_2O_5 ha^{-1} (13.99). Plant grown without P fertilizer had the lowest effective tillers $hill^{-1}$ (11.03) followed by P_1 (11.12). Application of 72 kg P_2O_5 ha^{-1} also produced 29.01% higher effective tillers over the control treatment (Fig. 11). The plots having no phosphorus (P_0) produced the highest number of non-effective tillers $hill^{-1}$ which was statistically at par with 24 kg P_2O_5 ha^{-1} (P_1). Similar results of applied P fertilizer to was reported by Katyal (1978). Matsuo *et al.* (1995) also reported that it is necessary to apply much P fertilizers to help rice plants to accelerate the phosphate absorption for increased tillering.

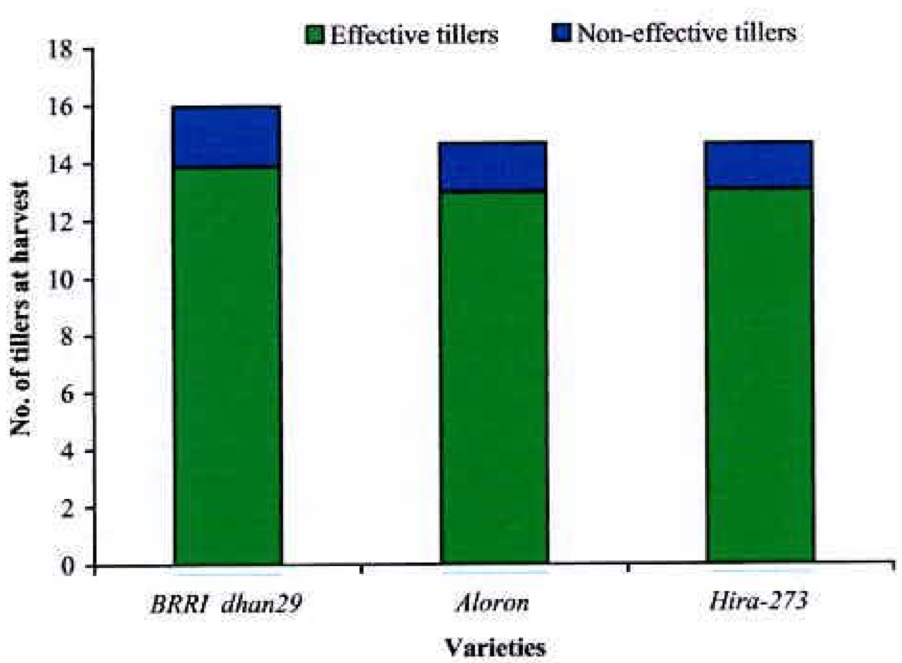

Fig 10. Effective and non-effective tillers of boro rice at harvest affected by variety ($S_{\bar{x}}$ = 03916 and 0.0365)

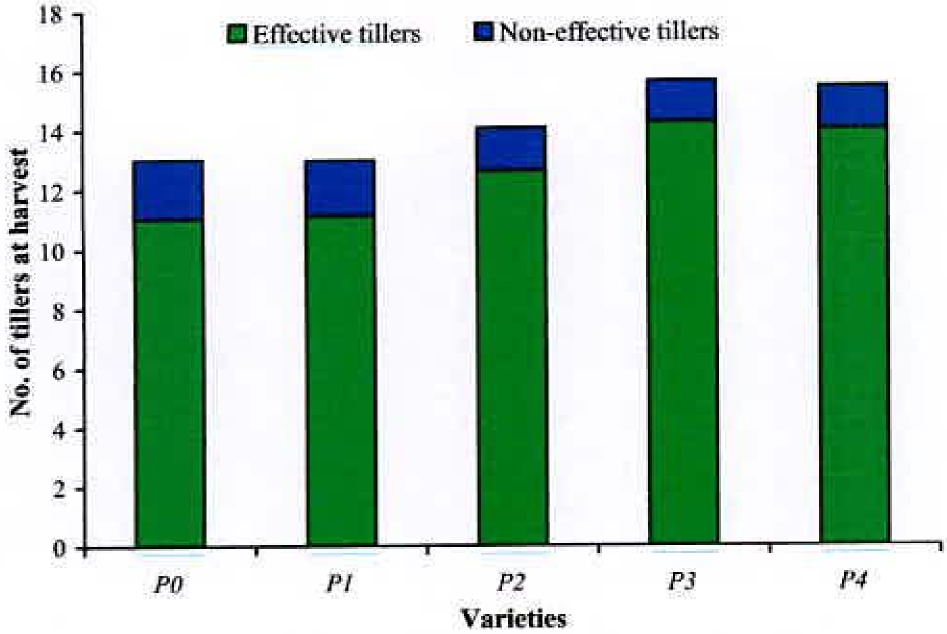

Fig 11. Effective and non-effective tillers at harvest affected by phosphorus levels($S_{\bar{x}}$ =1.079 and 0.137)

P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Interaction effect of variety and phosphorus

Significant variation in number of effective and non-effective tillers $hill^{-1}$was observed due to variation of P fertilizer and variety (Fig. 12). Among the treatment combination, V_3P_3 (15.30) produced the highest number of effective tillers followed by V_3P_4 (15.23) and the lowest from V_1P_0 (12.07). Non-effective tillers were also significantly affected by the interaction of variety and P levels (Fig. 12). Treatments, V_1P_0 showed the highest number of non-effective tillers (2.32) which was at par with V_2P_0 (2.25), V_3P_0 (2.22) and V_1P_1 (2.13). However, the lowest number of non-effective tillers was observed from V_3P_4 (1.12) and V_3P_3 (1.13). this might be due to the increase in tiller fertility with increased P doses (Fig. 12).

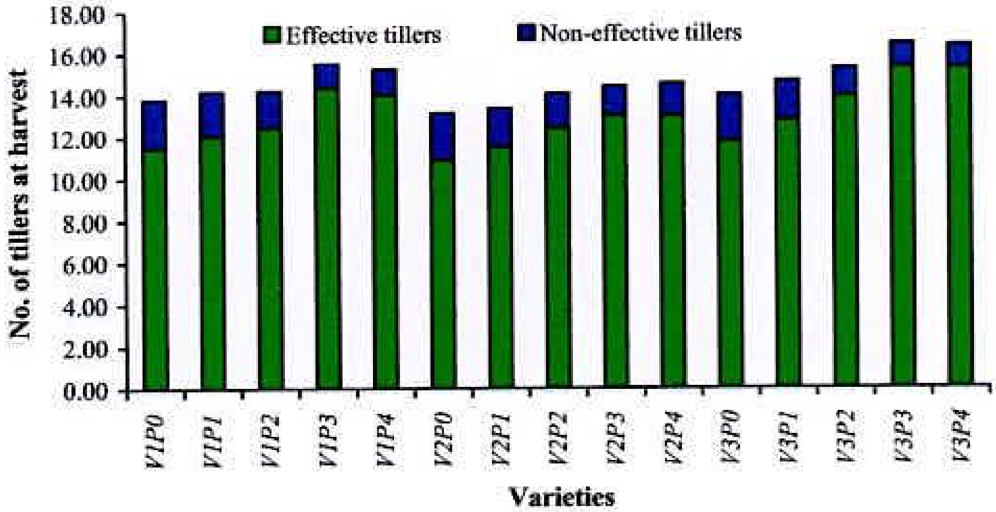

Fig 12. Effective and non-effective tillers hill^{-1} at harvest affected by variety and phosphorus ($S_{\bar{x}}$ = 0.663 and 0.0605)

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4.12.2 Panicle length

Effect of variety

Varieties did not show any significant variation in respect of panicle length (Table 14). However, numerically the longest panicle was observed from Hira-2 (25.50 cm) and the shortest from Aloron (24.17 cm).

Effect of phosphorus

Phosphorus had significant role in increasing the panicle length (Table 14). Panicle length of three rice varieties increased with the increasing rate of P fertilizer. Application of 96 kg P_2O_5 ha^{-1} produced the longest panicle and it was statistically at par with 72 kg P_2O_5 ha^{-1}. However, higher the levels of N longest the panicle although panicle increase was no proportional to increase the level of P fertilizer. The untreated control plants (without phosphorus) produced the shortest panicle which was similar 24 kg P_2O_5 ha^{-1} (P_1).similar results were reported for low land rice by Sahar and Burbey (2003).

Interaction effect of variety and phosphorus

The interaction of variety and phosphorus levels had also significant effect on the panicle length (Table 15). The treatment V_3P_3 produced the longest panicle (26.03 cm) while the shortest panicle was observed from the interaction treatment of V_2P_0 (23.30 cm).

4.12.3 Filled grain and un-filled grains panicle^{-1}

Effect of variety

Variations exerted significant influence on the filled grains panicale^{-1} (Table 14). Variety Hira-2 produced the maximum number of filled grains panicles^{-1} (106.00) which was statistically at par with Aloron (105.40) the lowest number of filled grain panicles^{-1} was observed from BRRI dhan 29. Hira-2 produced 11.09% higher filled grain over BRRI dhan 29. On the contrary, the unfilled grains was highest with BRRI dhan 29 (25.69 panicle^{-1}) followed by Aloron and the lowest from variety Hira-2 (15.57). Obaidullah (2007) reported that there were varietal differences in number of filled grains panicle^{-1}.

Effect of phosphorus

Filled as well as unfilled grains panicles^{-1} was also significantly affected by different phosphorus levels (Table 14). Phosphorus at 72 kg P_2O_5 ha^{-1} (P_3) produced the highest number of filled grain panicles^{-1} (105.80) and it was statistically identical with 96 kg P_2O_5 ha^{-1} (104.70). Addition of P fertilizer beyond kg P_2O_5 ha^{-1} decreased of filled grains panicle^{-1}. Control treatment produced lowest number of filled grains (99.83) which was 5.64% and 4.65% lower than P_3 and P_4 In this experiment it was observed that the highest number of unfilled grain was produced with P_0 (without P). Due to lack of phosphorus unfilled grains panicle^{-1} was highest with lower doses of phosphorus. Treatment P_3 (13.27) and P_4 (12.89) produced the lowest number of unfilled grains per panicle. Application of 72 and 96 kg P_2O_5 ha^{-1} can reduce the unfilled grain up to 30.41% and 32.40%, respectively. The findings are in agreement with those of Fageria and Barosa-Filho (1982). Sahar and Burbey (2003) showed that increasing the rate the panicles^{-1} of P compound significantly affected the grain number panicles^{-1}.

Interaction effect of variety and phosphorus

Interaction of variety and phosphorus significantly affected the number of filled and unfilled grains panicle^{-1} (Table 15). The variety Hira-2 coupled with 72 kg P_2O_5 ha^{-1} (V_3P_3) produced the highest number of filled grains panicles^{-1} (109.80) which was statistically similar with the values of V_3P_4, V_2P_3 and V_2P_4. The lowest number of filled grains, however, produced by the treatment V_1P_0 (92.67). It was observed in the table 15 that the filled grains produced by V_3P_3 and V_3P_4 was 18.48% and 16.32% higher than the filled grains produced by V_1P_0. This might be due to larger panicle size and translocation of photosynthesis to the respiration organs for setting grains. The highest unfilled grains panicles^{-1} (22.40) was found in combination of V_1P_0. This was mainly due to the lack of phosphorus as it is a limiting nutrient for grain filling. Unfilled grains was minimum with the treatment combination of V_2P_4 (14.83) and V_2P_3 (15.03).

4.12.4 Spikelet sterility

Effect of variety

Spikelet sterility varied significantly among the by varieties (Table 14). Significantly the highest sterility percentages (21.21%) was found in case of BRRI dhan 29. This might be due to more number of unfilled grains in the panicles. The lowest sterility percentage (12.81%) occurred in the variety Hira-2 which was at par with Aloron (15.77%). The hybrid varieties produced lower percentage of sterility might be due to their hybrid vigour and higher number of fertile grains. However, spikelet sterility also affected by genetic potential and response of the varieties to stress conditions. Similar spikelet sterility percentage differences across the varieties have been reported by Obaidullah (2007).

Effect of phosphorus

The effect of phosphorus levels on the spikelet sterility was significant (Table 14). As the doses of P increased, the sterility percentage decreased. Among the P levels P_0 (without phosphorus) showed the highest spikelet sterility while P_4 (96 kg P_2O_5 ha^{-1}) showed the lowest spikelet sterility percentage. The spikelet sterility obtained with P_4 was statistically identical with P_3 and P_2. Application of 48, 72 and 96 kg P_2O_5 ha^{-1} reduced the sterility up to 18.32%, 30.54% and 31.67%, respectively over control (Without P). IRRI (1995) and Raju *et al.* (1997) observed similar findings. Ortega and Rojas (1999) also reported that P application decreased floret sterility.

Interaction effect of variety and phosphorus

Interaction of variety and P fertilizer affected significant difference in spikelet sterility percentage (Table 15). The highest spikelet sterility occurred with V_1P_0 (19.47%) which was statistically at par with V_1P_1, V_2P_0 and V_3P_0. this was mainly due the lack of phosphorus with which more number of unfilled grains $panicles^{-1}$. However, the lowest percent of spikelet sterility occurred with V_2P_3 and V_3P_4 (12.31%). The higher doses of phosphorus in these combination produced more filled grains and less unfilled grains which resulted the minimum spikelet sterility.

4.12.5 1000-grain weight

Effect of variety

Varieties did not show any significant response on 1000-grain weight (Table 14). However, numerically the maximum weight of 1000 grain was observed with the variety Hira-2 (23.79 g) and the lowest from BRRI dhan 29 (19.95 g). the findings of the present study are in agreement with Shah (2002).

Effect of phosphorus

Thousand grain weight of rice varieties also varied significantly due to phosphorus fertilizer application (Table 14). It ranged between 21.22 and 23.69 g, the highest being recorded for 72 kg P_2O_5 ha^{-1} which was statistically similar with 96 kg P_2O_5 ha^{-1}, P_2 (22.76 g) and P_1 (21.84 g). The lowest weight of 1000-grain (21.22 g) was observed in control treatment (without phosphorus). Shah (2002) reported that application of 30 kg P ha^{-1} gave the highest 1000-grain yield which was different from all other doses.

Interaction effect of variety and phosphorus

Interactive effect of variety and phosphorus had a significant effect on the weight of 1000-grain (Table 15). The highest 1000-grain weight was observed with V_2P_4 (25.58 g) which was followed by V_2P_3 (25.50 g). However, the lowest seed weight was observed in combination V_1P_0 (19.07 g).

Table 14. Effect of variety and phosphorus on yield components of boro rice

Treatments	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Spikelet sterility (%)	1000-grain weight (g)
			Variety		
BRRI dhan 29	24.49	95.41 b	25.69 a	21.21 a	19.95
Aloron	24.17	105.40 a	19.74 ab	15.77 b	23.25
Hira-2	25.50	106.00 a	15.57 b	12.81 b	23.97
$S_{\bar{x}}$	**NS**	**0.55**	**0.40**	**0.29**	**NS**
CV (%)	**5.46**	**5.69**	**6.89**	**5.69**	**4.69**
			Levels of Phosphorus		
P_0	23.30 b	99.83 d	19.07 a	16.04 a	21.22 b
P_1	23.36 b	100.30 cd	18.98 a	15.91 a	21.84 ab
P_2	24.33 ab	102.69 bc	15.48 b	13.10 b	22.76 ab
P_3	25.32 a	105.80 a	13.27 c	11.14 b	23.69 a
P_4	25.97 a	104.70 ab	12.89 c	10.96 b	23.58 a
$S_{\bar{x}}$	**0.62**	**0.91**	**0.61**	**0.71**	**0.60**
CV (%)	**6.35**	**8.25**	**7.54**	**6.23**	**8.25**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Table 15. Interaction effect of variety and phosphorus on yield components of boro rice

Treatments	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	Spikelet sterility (%)	1000-grain weight (g)
V_1P_0	23.80 ab	92.67 h	22.40 a	19.47 a	19.07 c
V_1P_1	24.80 ab	93.73 gh	20.67 ab	18.07 ab	19.55 c
V_1P_2	25.33 ab	95.50 f-g	18.60 b-e	16.30 b-d	19.73 c
V_1P_3	25.42 ab	99.43 ef	17.03 c-f	14.62 c-f	20.59 c
V_1P_4	25.30 ab	97.70 e-h	15.77 ef	13.90 d-f	20.80 c
V_2P_0	23.30 b	99.20 e-g	20.23 ab	16.94 a-c	23.08 b
V_2P_1	24.18 ab	100.70 d-f	19.70 a-c	16.36 b-d	24.62 ab
V_2P_2	25.07 ab	103.20 b-e	18.90 b-d	15.48 b-f	24.66 ab
V_2P_3	25.50 ab	107.10 a-c	15.03 f	12.31 f	25.50 a
V_2P_4	25.42 ab	105.60 a-d	14.83 f	12.31f	25.58 a
V_3P_0	23.79 ab	100.60 d-f	20.57 ab	16.98 a-c	24.50 ab
V_3P_1	24.09 ab	101.50 cde	19.57 a-c	16.16 b-d	24.35 ab
V_3P_2	25.60 ab	103.40 b-e	18.93 b-d	15.47 b-f	23.10 b
V_3P_3	26.03 a	109.80 a	16.73 c-f	13.22 ef	23.97 ab
V_3P_4	25.78 a	107.80 ab	16.07 d-f	12.97 ef	23.95 ab
$S_{\bar{x}}$	**0.72**	**1.76**	**0.92**	**0.84**	**0.69**
CV (%)	**6.35**	**8.25**	**7.54**	**6.23**	**8.25**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

4.13 Yield

4.13.1 Grain yield

Effect of variety

The rice varieties different significantly in respect of grin yield ha^{-1} (Table 16). The hybrid variety Hira-2 produced the highest grain yield (7.50 t ha^{-1}) which was statistically similar with the yield of Aloron (7.41 t ha^{-1}). These two varieties, however, were significantly different from BRRI dhan 29. The yield increase by Hira-2 and Aloron was 0.64 and 0.55 t ha^{-1}, which was 9.32% and 8.01% respectively, over

BRRI dhan 29 (6.86 t ha^{-1}). The results are in conformity with the observation of Obaidullah (2007) in hybrid rice and Main (2006) in T. aman rice.

Effect of phosphorus

The impact of P application on grain yield ha^{-1} was significant (Table 16). Grain yield ha^{-1} increased linear with the increment of the fertilizer doses of P up to 72 kg P_2O_5 ha^{-1} and there after decreased. Application of 72 kg P_2O_5 ha^{-1} (P_3) produced the highest grain yield (7.23 t ha^{-1}) and it was statistically identical with P_2, P_3 and P_4 treatments. Plants grown without P fertilizer had the lowest yield (4.99 t ha^{-1}). The increase in yield by the use of 72 kg P_2O_5 ha^{-1} was 45% over the control (without P). Higher yield under 72 kg P_2O_5 ha^{-1} may be due to more filled grains panicle and larger grains. Shha (2002) also reported the similar response of P on grain yield. Zaman *et al*. (1995) found significant increase in grain yield with P application over P control. Tandon (1987) reported that the application of 26 kg P ha^{-1} increased paddy yield by 2.5 t ha^{-1} in kharif and 5.7 t ha^{-1} in rabi. Mahajan *et al*. (1995) reported that highest grain yield with the application of 80 kg P_2O_5 ha^{-1}.

Interaction effect of variety and phosphorus

The interaction effect of variety and phosphorus exerted significant influence on the grain yield (Table 17). Combination of V_3P_3 produced the highest grain yield (7.68 t ha^{-1}) followed by V_3P_4 (7.49 t ha^{-1}) and V_3P_2 (7.42 t ha^{-1}) and the lowest (5.05 t ha^{-1}) from V_1P_0. Variety Hira-2 gave the highest grain yield t ha^{-1} t ha^{-1} irrespective of P levels. The yield advantage was mainly due to more filled grain panicle and largest grains. When the varieties grown without added P fertilizer produced significantly the grain yield. Matsuo *et al*. (1995) also found differences in grain yield of rice varieties with variable P levels.

4.13.2 Straw yield

Effect of variety

Straw yield remained unaltered due to variety (Table 16). However, numerically the highest straw yield was observed with Hira-2 (8.60 t ha^{-1}) and the lowest from BRRI dhan 29 (14.76 t ha^{-1}). Shah (2002) and Xie *et al.* (2007) reported that biomass production varied with variety which rendering different straw yield.

Effect of phosphorus

Significant difference on straw yield of boro rice was observed when P was applied (Table 16). The highest straw yield (8.23 t ha^{-1}) was obtained from 72 kg P_2O_5 ha^{-1} (P_3) and it was statistically identical with- P_2 and P_4. The lowest straw yield (5.83 t ha^{-1}) was obtained from control treatment which was 27.57%, 29.16% and 26.20% lower than 96, 72 and 48 kg P_2O_5 ha^{-1}, respectively. Application of 24 and 0 kg P_2O_5 ha^{-1} gave statistically identical straw yield ha^{-1}. Gupta (1999) also reported similar effect of phosphorus.

Interaction effect of variety and phosphorus

Interaction effect of variety and phosphorus levels was also observed significant on straw yield (Table 17). The highest straw yield was obtained from the treatment combination of V_3P_3 (7.68 t ha^{-1}) and the lowest from the treatment V_1P_0 (5.05 t ha^{-1}). Addition of 48, 72 and 96 kg P_2O_5 ha^{-1} fertilizer showed similar response towards straw yield irrespective of varieties.

4.13.3 Biological yield

Effect of variety

From the Table 16, it was observed that two hybrid varieties of rice viz. Aloron and Hira-2 produced higher biological yield compared than BRRI dhan 29.

Among the varieties, Hira-2 produced the highest biological yield (16.10 t ha^{-1}) which was statistically at par with Aloron (15.92 t ha^{-1}). Two varieties- Aloron and Hira-2 produced 7.85% and 9.07% higher biological yield than BRRI dhan 29 which produced the lowest yield (14.76 t ha^{-1}). Obaidullah (2007) and Main (2006) also reported a significant differences in biological yield of rice with different rice varieties.

Effect of phosphorus

Biological yield of boro rice was also significantly affected by different levels of phosphorus (Table 16). Among the P levels application of 72 kg P_2O_5 ha^{-1} produced the maximum biological yield (15.46 t ha^{-1}) which was statistically similar with 48 and 96 kg P_2O_5 ha^{-1}. However, the treatment without phosphorus resulted the lowest biological yield of boro rice. The highest biological yield was supported by the highest weight of rice plant with these levels of phosphorus.

Interaction effect of variety and phosphorus

From table 17 it was observed that the interaction effect of variety and phosphorus was significantly influenced (Table 17). The maximum biological yield (16.28 t ha^{-1}) was found from the treatment combination of V_3P_3 (Hira-2 and 72 kg P_2O_5 ha^{-1}). However, the trend of biological yield was almost similar to straw yield which indicated that biological is mostly mediated by straw yield. The lowest biological yield (11.55 t ha^{-1}) was obtained from the treatment V_1P_0 which was 29.05% lower than the yield obtained from V_3P_3.

4.13.4 Harvest index

Effect of variety

The difference in harvest index due to variety was not significant (Table 16). However, numerically the maximum harvest index was obtained from the variety

Hira-2 and the lowest harvest index was obtained from BRRI dhan 29.

Effect of phosphorus

There was no significant effect of phosphorus was found on the harvest index of boro rice (Table 16). Nevertheless, the maximum harvest index was obtained from the treatment of P_3 (72 kg P_2O_5 ha^{-1}) and the lowest from control plots (without P). Similar response of P on harvest index was reported by IRRI (1973).

Interaction effect of variety and phosphorus

The interactive effect of variety and phosphorus had significant effect on the harvest index (HI) of boro rice (Table 17). HI differed from 43.72 to 47.70 across the variety and P fertilizer levels. Application of P fertilizer generally increased HI across varieties but the response was not linear. Increase in HI observed up to 72 kg P_2O_5 ha^{-1} at all the varieties and then decreased. Among the treatment combination, V_2P_3 produced the highest harvest index (47.70%) which was followed by V_3P_3 and V_1P_3. The lowest value of harvest index (43.65%) was obtained from the treatment combination of V_2P_0. In general, the HI was higher in hybrid rice indicating efficient translocation of assimilates for grain production of economic yield.

Table 16. Effect of variety and phosphorus on grain yield, straw yield, biological yield and harvest index of boro rice

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
		Variety		
BRRI dhan29	6.86 b	7.90	14.76 b	46.47
Aloron	7.41 a	8.51	15.92 a	46.54
Hira-2	7.50 a	8.60	16.10 a	46.58
$S_{\bar{x}}$	0.03	NS	0.05	NS
CV (%)	3.64	7.98	6.36	6.49
		Phosphorus levels		
P_0	4.99 c	5.83 b	10.82 c	46.12
P_1	5.85 bc	6.78 b	12.63 b	46.31
P_2	6.89 ab	7.90 a	14.79 a	46.58
P_3	7.23 a	8.23 a	15.46 a	46.76
P_4	6.98 a	8.05 a	15.03 a	46.44
$S_{\bar{x}}$	0.36	0.37	0.484	NS
CV (%)	6.56	8.53	6.75	9.04

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

Table 17. Interaction effect of variety and different levels of phosphorus on grain yield, straw yield, biological yield and harvest index of boro rice

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
V_1P_0	5.05 e	6.50 c	11.55 e	43.72 bc
V_1P_1	5.55 de	7.11 a-c	12.66 cde	43.83 bc
V_1P_2	6.56 a-e	7.50 a-c	14.06 a-d	46.65 a-c
V_1P_3	6.99 a-c	7.87 a-c	14.86 a-c	47.03 a
V_1P_4	6.72 a-d	7.70 a-c	14.42 a-c	46.60 a-c
V_2P_0	5.19 e	6.70 bc	11.89 de	43.65 c
V_2P_1	6.05 b-e	7.23 a-c	13.28 b-e	45.55 a-c
V_2P_2	6.76 a-d	7.89 a-c	14.65 a-c	46.14 a-c
V_2P_3	7.34 ab	8.13 ab	15.47 ab	47.70 a
V_2P_4	7.01 a-c	8.03 a-c	15.04 a-c	46.60 a-c
V_3P_0	5.85 cde	7.02 a-c	13.02 b-e	44.93 a-c
V_3P_1	6.76 a-d	7.87 a-c	14.63 a-c	46.20 a-c
V_3P_2	7.42 a	8.45 a	15.87 a	46.75 ab
V_3P_3	7.68 a	8.60 a	16.28 a	47.17 a
V_3P_4	7.49 a	8.55 a	16.04 a	46.69 a-c
$S_{\bar{x}}$	**0.3873**	**0.4726**	**0.7461**	**0.90**
CV (%)	**6.56**	**8.53**	**6.75**	**9.04**

V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2 = 48 Kg P_2O_5 ha^{-1}, P_3 = 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}

4.14 Correlation study

4.14.1 Interrelationships between yield and yield contributing characters

Table 18 shows the correlation matrix between different plant characters. Number of effective tillers hill^{-1}, panicle length, number of filled grains hill^{-1}, 1000-grain weight and seed yield (t ha^{-1}) were positively correlated with each other. However, number of unfilled grains per hill^{-1} was negatively correlated with other parameters. The intercorrelations were also significant in most of the cases except 1000-grain weight with number of effective tillers hill^{-1}, panicle length and unfilled grains panicle^{-1}. Number of effective tillers hill^{-1}, panicle length, number of filled grains per hill^{-1} and number of unfilled grains per hill^{-1} had significant correlation with grain yield (t ha^{-1})

Table 18. Correlation between grain yield and yield attributes of boro rice as affected by the combination effect of variety and levels of phosphorus

Parameters	Effective tillers hill^{-1}	Panicle length	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight	Grain yield (t ha^{-1})
Effective tillers hill^{-1}	1.00	0.851 **	0.598 *	-0.695 **	0.094 NS	0.860 **
Panicle length		1.00	0.542 *	-0.768 **	0.081 NS	0.870 **
Filled grains panicle^{-1}			1.00	-0.667 **	0.819 **	0.789 **
Unfilled grains panicle^{-1}				1.00	-0.392 NS	-0.796 **
1000-grain weight					1.00	0.440 NS
Grain yield (t ha^{-1})						1.00

** significant at the 0.01 level.

* significant at the 0.05 level.

NS = not-significant

Chapter 5

Summary and Conclusion

Chapter 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the Boro season of December 2006 to June 2007 to determine the relative performance of one inbred (BRRI dhan 29) and two hybrid (Aloron and Hira-2) rice varieties under 5 levels of phosphorus (P_0= Control, P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4 = 96 Kg P_2O_5 ha^{-1}). From the study it was observed that variety as well as phosphorus levels significantly affected the growth and yield of boro rice.

A significant difference in plant height at different plant ages was observed due to the varietal difference. At harvest the tallest plant was recorded with BRRI dhan 29 (100.26 cm) and it was statistically similar with variety Aloron (99.63 cm). At all the growth stages the tallest plant was observed with 96 kg P ha^{-1} which was statistically at par with other P doses except 25 DAT where the maximum plant height with 96 kg ha^{-1} followed by with 72 kg ha^{-1}. At harvest the tallest plant was observed from V_1P_4 (102.63 cm) while the shortest plant was found with V_1P_0 (97.23 cm).

Number of tillers $plant^{-1}$ increased up to 75 DAT and then decreased irrespective of treatment variables. The lowest number of tillers was observed from the variety Aloron. In all the growth stages, the maximum tillers were observed with 72 kg P_2O_5 ha^{-1}. Tiller production was less responsive to P fertilizer at early stage (25 DAT) where the difference only observed with 72 kg P_2O_5 ha^{-1}. From 75 DAT to harvest the maximum tiller was observed from the treatment combination of V_1P_3 which was statistically identical with all the P doses except the control treatment irrespective of varieties.

At harvest the highest fresh weight of plants (211.40 g) was found by variety Hira-2 where the lowest fresh biomass was found with BRRI dhan 29. At all the growth stages, the minimum fresh weight of plant was observed from 96 kg P_2O_5 ha^{-1} but it was statistically at par with 72 kg P_2O_5 ha^{-1}. The growth stages where the control treatment (without P) produced the lowest fresh weight of plant. Significantly highest fresh weight was observed with V_1P_4 at 50, 75 and 100 DAT and the lowest from V_2P_0 at 50 and 75 DAT.

Significantly the highest dry weight of root was observed with the variety BRRI dhan 29 irrespective of growth stages and the lowest from variety Hira-2. Significantly highest root dry weight $hill^{-1}$ (2.73 g) was attained by 72 kg P_2O_5 ha^{-1} and the lowest from P_0 (without P). The highest root dry weight was observed from the combination effect of V_3P_3 (2.49 g) which was statistically at par with V_3P_4 (2.42 g), V_1P_3 (2.42 g) and V_1P_4 (2.37 g).

At 50 DAT the maximum dry matter in leaf blade was observed with BRRI dhan 29. But at 75 and 100 DAT the leaf blade dry weight was highest with Hira-2. At 50, 75 and 100 DAT the maximum dry weight was obtained from 72 kg P_2O_5 ha^{-1} which was statistically at par with 96 kg P_2O_5 ha^{-1}. At all the growth stages, the lowest dry weight of leaf blade was observed where phosphorus was not applied. The highest dry weight of leaf blade was observed from the combination of V_1P_3 (2.64 g) and the lowest from V_1P_0 (1.68 g).

Two hybrid varieties Aloron and Hira-2 produced statistically identical dry matter in the leaf sheath. The maximum dry matter at 100 DAT was 9.81 g with Hira-2 while the lowest dry matter was produced by BRRI dhan 29 (8.79 g). At all the growth stages, the highest dry weight of leaf sheath was found with 72 kg P_2O_5 ha^{-1} and the lowest with control treatment (no phosphorus). At 50 and 75 DAT, the highest dry weight of leaf sheath was observed by the combined effect of Hira-2 and 72 kg P_2O_5 ha^{-1}. At 50 DAT the lowest dry matter was found by V_1P_0 while V_2P_0 produced the lowest dry matter in leaf sheath at 75 DAT.

Both at 75 and 100 DAT the highest dry matter was observed from the variety Hira-2. At 75 DAT BRRI dhan29 produced the lowest dry matter in stem while at 100 DAT it was found the lowest dry matter with the variety Aloron. At 100 DAT the maximum dry matter in stem was observed with 72 kg P_2O_5 ha^{-1} (6.96 g) which was statistically at par with 48 kg P_2O_5 ha^{-1} (6.15 g) and 96 kg P_2O_5 ha^{-1} (6.62 g). The rapid increase in stem dry weight was observed at 100 DAT where the maximum dry weight was observed with V_3P_1 while the lowest dry matter was found with the combination of V_3P_0.

Maximum dry weight in panicle was observed with Hira-2 (15.46 g) followed by Aloron while BRRI dhan 29, however, produced the lowest dry matter in panicle. Application of 72 kg P_2O_5 ha^{-1} produced the maximum dry matter in panicle (14.00 g) and it was statistically identical with other P doses. Control treatment (i.e. no phosphorus) produced the lowest dry matter (12.35 g). The treatment combination V_3P_3 produced the highest dry matter in panicle (16.53 g) which was statistically similar with the combination of V_3P_4 (16.48 g). The lowest dry matter $panicle^{-1}$ of 6.92 g was observed with V_1P_0 treatment.

At 100 DAT the highest dry weight $hill^{-1}$ was obtained by Hira-2 (42.2 g) which was statistically identical with Aloron (39.91 g). At 100 DAT the highest dry matter was observed from P_3 treatment which was at par with P_4. The control treatment where phosphorus was not applied showed the lowest dry matter accumulation. At 100 DAT highest total dry matter $hill^{-1}$ was observed with the treatment combination of V_3P_3 (49.33 g) which was statistically at par with V_3P_4,

V_3P_2, V_2P_3 and V_2P_4. The lowest total dry matter in this stage was observed with V_1P_0.

The maximum CGR (33.24 g m^{-2} d^{-1}) was observed with Hira-2 which was statistically similar with Aloron. Application of 72 kg P_2O_5 ha^{-1} produced significantly highest CGR value (30.49 33.24 g m^{-2} d^{-1}) and the lowest in control (without P) at all the growth duration. Maximum CGR was observed with the combination of V_3P_3 which was statistically identical with V_3P_4 while the lowest CGR value at this duration was observed with V_1P_0 and V_1P_1.

RGR was not significantly affected by varieties. Among the P levels, the highest RGR value was observed with P_0 and the lowest RGR was observed from P_4. The highest RGR was noticed by the treatment V_2P_0 and the lowest RGR was found with V_1P_3.

Maximum number of effective tillers at harvest (13.85) was produced by BRRI dhan 29 while the lowest number of effective tillers was observed with Aloron (12.95) However, non-effective tillers were not affected by varietal differences. Effective tillers $hill^{-1}$ significantly affected by phosphorus levels. Application of 72 kg P_2O_5 ha^{-1} produced the highest number of effective tillers $hill^{-1}$ (14.23). The treatment having no phosphorus (P_0) produced the highest non-effective tillers. Treatment combination V_3P_3 (15.30) produced the highest number of effective tillers and the lowest by V_1P_0 (12.07). Treatment V_1P_0 showed the highest number of non-effective tillers (2.32).

Varieties showed statistically similar effect on panicle length. Phosphorus had positive role in increasing the panicle length. Application of 96 kg P_2O_5 ha^{-1} produced the longest panicle. The treatment V_3P_3 produced the longest panicle (26.03 cm) while the shortest panicle was observed from the combination of V_2P_0 (23.30 cm).

Among the variety Hira-2 produced the maximum number of filled grains panicle^{-1} (106.00) and the lowest from BRRI dhan 29. In this study 72 kg P_2O_5 ha^{-1} (P3) produced the highest number of filled grains panicle^{-1} (105.80). Variety Hira-2 coupled with 72 kg P_2O_5 ha^{-1} (V_3P_3) produced the highest number of filled grains panicle^{-1} (109.80). The lowest number of filled grains, however, produced by the treatment of V_1P_0 (92.67).

In this study the maximum sterility was found in case of BRRI dhan 29 (21.21%). Minimum sterility occurred in the variety Hira-2 (12.81%) which was at par with Aloron (15.77%). As the levels of P increased, the sterility decreased. Control treatment (no phosphorus) showed the highest spikelet sterility while P_4 (96 kg P_2O_5 ha^{-1}) showed the lowest sterility of spikelet. Among the treatment combination the highest spikelet sterility occurred with V_1P_0 (19.47%).

Varieties did not show any significant response in 1000-grain weight. However, significantly highest 1000-grain weight was observed with 72 kg P_2O_5 ha^{-1}. The lowest weight of 1000-grain (21.22 g) was observed in control treatment (without phosphorus). The highest 1000-grain weight was observed with combination treatment of V_2P_4 (25.58 g) and the lowest from V_1P_0 (19.07 g) treatment.

Varieties Hira-2 (7.50 t ha^{-1}) and Aloron (7.41 t ha^{-1}) produced the highest (identical) grain yield which were significantly different from BRRI dhan 29. Grain yield found by Hira-2 and Aloron was 9.32% and 8.01% higher than the yield produced by BRRI dhan 29. Phosphorus level at 72 kg P_2O_5 ha^{-1} (P_3) produced the highest grain yield (7.23 t ha^{-1}) of rice and the lowest P_3 (72 kg P_2O_5 ha^{-1}). Among the different treatments combination V_3P_3 produced the highest grain yield (7.68 t ha^{-1}).

Straw yield was not significantly influenced by different varieties. Significant difference in straw yield of boro rice was observed when P was applied. The highest straw yield (8.23 t ha^{-1}) were obtained from 72 kg P_2O_5 ha^{-1} (P_3). The highest straw yield was obtained from the treatment combination of V_3P_3 (7.68 t ha^{-1}) and the lowest from the treatment combination of V_1P_0 (5.05 t ha^{-1}).

Variety Aloron and Hira-2 produced higher biological yield compared than BRRI dhan 29. Among the varieties Hira-2 produced the highest biological yield (16.10 t ha^{-1}). Among the levels of P, application of 72 kg P_2O_5 ha^{-1} produced the maximum biological yield (15.46 t ha^{-1}). The maximum biological yield (16.28 t ha^{-1}) was obtained from the treatment of V_3P_3 (Hira-2 and 72 kg P_2O_5 ha^{-1}).

The highest harvest index was obtained from the variety Hira-2 and the lowest from BRRI dhan 29. The maximum harvest index was obtained from the dose of P_3 (72 kg P_2O_5 ha^{-1}). When the plant growth without P fertilizer grown the lowest harvest index. Combination of V_2P_3 produced the highest harvest index (47.70%) followed by V_3P_3 and V_1P_3 and the lowest (43.65%) the treatment V_2P_0.

Number of effective tillers $hill^{-1}$, panicle length and number of filled grains $hill^{-1}$ had significant positive correlation with grain yield. Number of unfilled grain $hill^{-1}$ was found negatively correlated with grain yield.

Based on the result of the present study, the following conclusions may be drawn-

- The hybrid variety showed higher yield than the inbred variety. Variety Hira-2 (HS-273) showed the best performance in respect of yield and yield attributes.
- Application of P fertilizer is necessary for raising yield. The experimental results suggest that application of 72 kg P_2O_5 ha^{-1} for hybrid rice (Aloron and Hira-2) would be needed for obtaining moderate yields.

However, to reach a specific conclusion and recommendation, more research work on other popular varieties under different P levels should be done over different Agro-ecological zones of Bangladesh.

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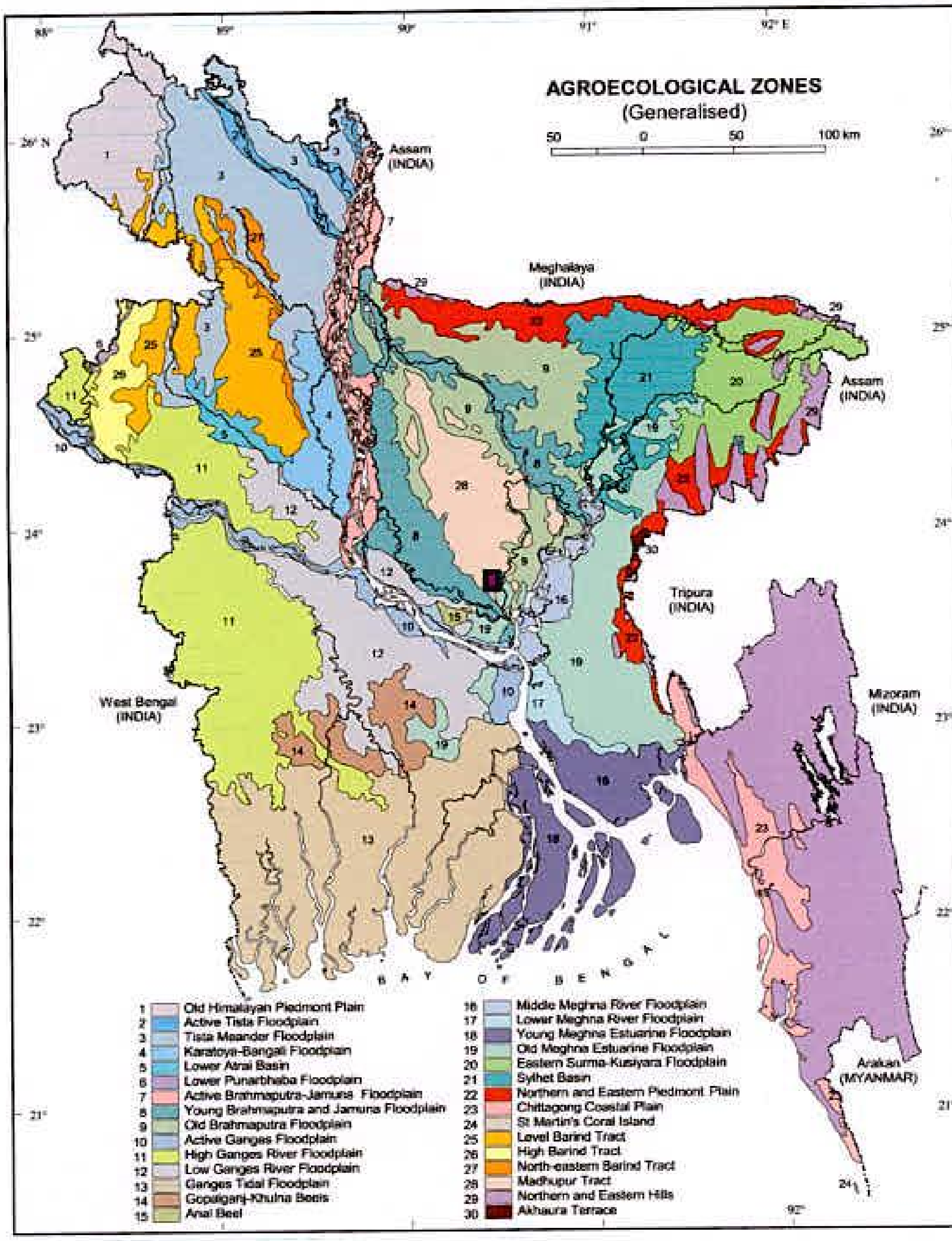
Appendices

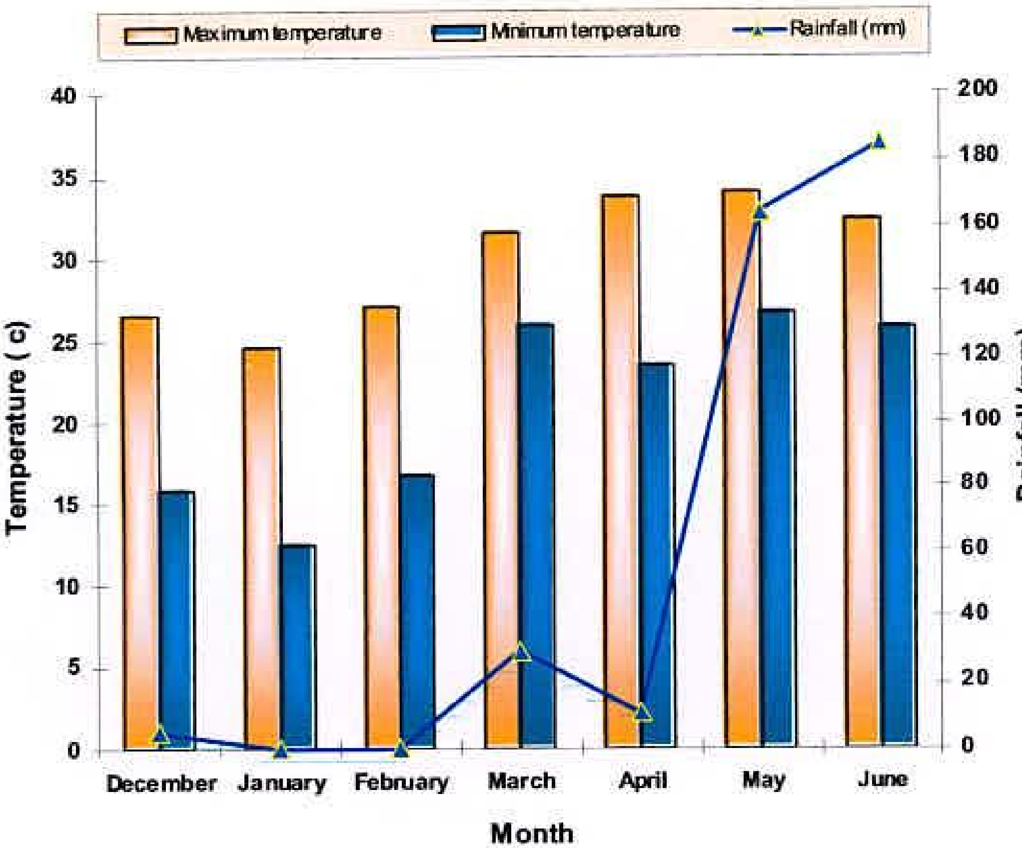
APPENDICES

Appendix I Map showing the experimental sites under study



■ **The experimental site under study**

Appendix II Monthly record of average air temperature and total rainfall of the experimental site during the period from December 2006 to June 2007



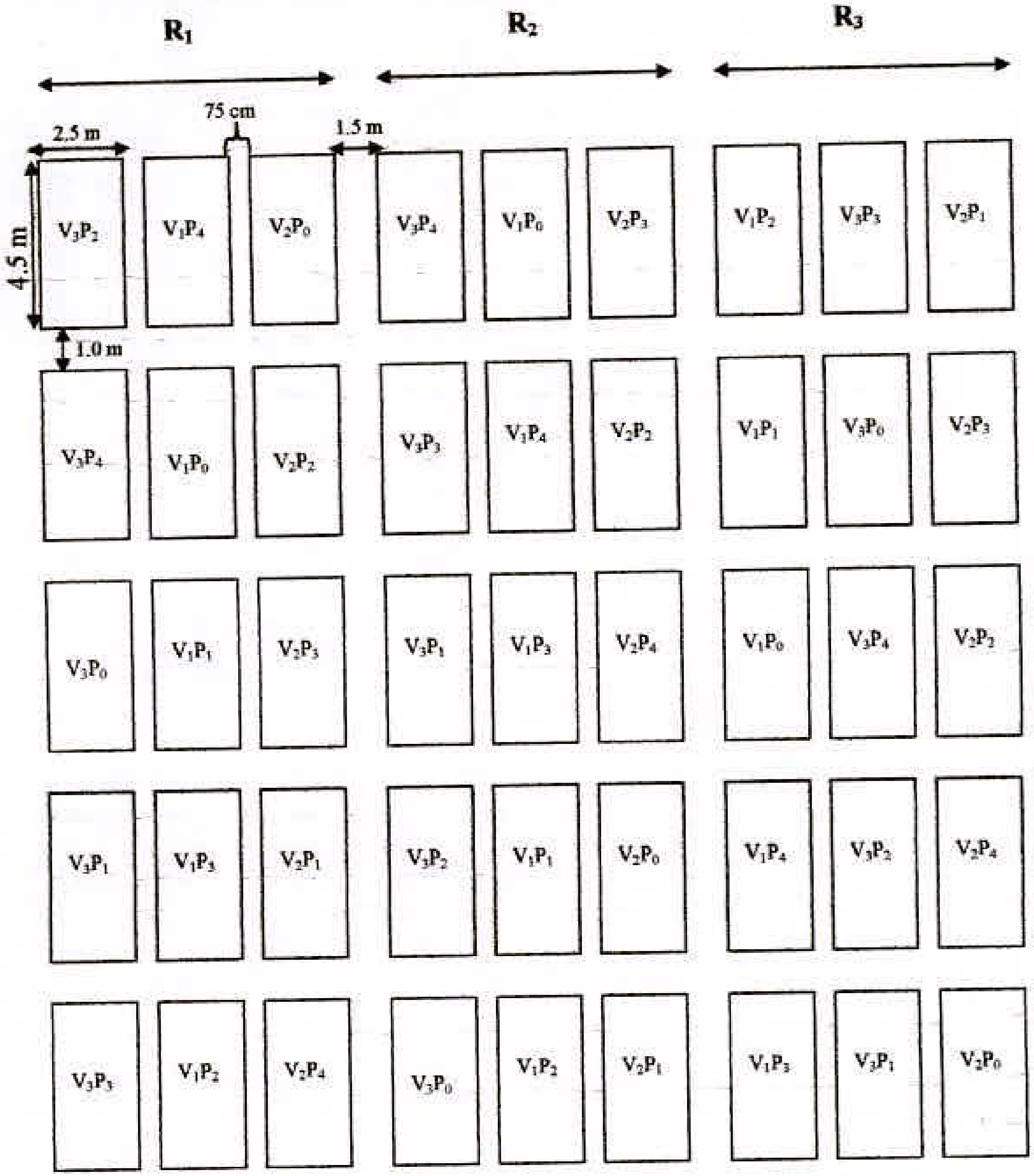
Source: Bangladesh Meteorological Department, Dhaka-1212

Appendix III Chemical properties of soil in the study area

Characteristics	Amount
p^H	7.20
Organic matter (%)	1.47
Total nitrogen (%)	0.07
Available Phosphorus (ppm)	58.80
Exchangeable Potassium (ml/100gm soil)	0.16
Zinc (ppm)	6.58
Sulphur (ppm)	20.77
Boron (ppm)	0.60

Source: SRDI, Dhaka

Appendix IV Layout of the experimental field



Factor-A: Variety

V_1= BRRI dhan-29
V_2= Hira-2 (HS-273)
V_3= Aloron (HB-8)

Factor-B: levels of Phosphorus

P_0 = 0 kg P_2O_5 ha^{-1} (control)
P_1 = 24 kg P_2O_5 ha^{-1}
P_2 = 48 kg P_2O_5 ha^{-1}
P_3 = 72 kg P_2O_5 ha^{-1}
P_4 = 96 kg P_2O_5 ha^{-1}