Advances in Biological Research 3 (3-4): 132-139, 2009
ISSN 1992-0067
© IDOSI Publications, 2009

Yield Attributes, Yield and Harvest Index of Three Irrigated Rice Varieties under Different Levels of Phosphorus

M.M. Alam, M.H. Ali, A.K.M. Ruhul Amin and Mirza Hasanuzzaman

Department of Agronomy, Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

Abstract: A field experiment was carried out at the Agronomy Field of the Sher-e-Bangla Agricultural University, Dhaka during December, 2006 to June, 2007 to study the relative performance of inbred and hybrid rice varieties at different levels of phosphorus (P). Three varieties of inbred and hybrid rice (BRRI dhan29, Aloron and Hira-2) and five levels of P (0, 24, 48, 72 and 96 kg P_2O_5 ha^{-1}) were used as treatment. Number of tillers $hill^{-1}$, 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 variety. Hira-2 produced the maximum number of filled grains $panicle^{-1}$ (106.0) and minimum in BRRI dhan29. Variety Hira-2 (7.50 t ha^{-1}) and Aloron (7.41 t ha^{-1}) produced the highest grain yields (7.4-7.5 t ha^{-1}) compared to BRRI dhan29 (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 dhan29. All the studied parameters of rice varieties except harvest index also differed significantly with the application of P fertilizer. Phosphorus at 72 kg ha^{-1} (P_3) produced the highest grain yield (7.23 t ha^{-1}) of rice. Plants grown without added P gave 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 the lowest grain yield. The highest grain yield (7.68 t ha^{-1}) was recorded with Hira-2 at 72 kg P_2O_5 ha^{-1}.

Key words: *Oryza sativa* · Phosphorus · Spikelet sterility · Yield

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 [1]. 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 [2].

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 [3]. The average yield of rice in Bangladesh is 2.45 t ha^{-1} [4]. This average yield is almost less than 50% of the world average rice grain yield. 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. 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.

Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice [5]. Phosphorus is essential nutrient for plant life. Without adequate supply of phosphorus plants can not reach its maximum yield. 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 $panicle^{-1}$ [6]. Phosphorus not only enhances the yield of rice but also reduce the spikelet sterility. But the main problem concerning P fertilizers is its fixation with soil

Corresponding Author: Mirza Hasanuzzaman, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

complex within a very short period of application rendering mare than two-thirds unavailable [7]. So it is necessary to know the optimum dose of P fertilizer for maximum yield and to reduce spikelet sterility of rice. Thus, the present experiment was undertaken to determine the effect of phosphorus level and variety on yield and yield attributes of rice.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during December 2006 to June 2007. The soil of the experimental field belongs to soil type, Shallow Red Brown Terrace Soils. Two sets of treatments included in the experiment are as follows: Varieties {V_1= BRRI dhan29, V_2= Aloron (HB-8) and V_3= Hira-2 (HS-273)} and five Levels of P (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}). 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.

A common procedure was followed in raising of seedling in seed bed. Seedlings of 30 days old were uprooted from the nursery beds carefully. Seedlings were transplanted on January 11, 2007 in the well-puddled experimental plots. Spacing's were given 20 cm × 15 cm. 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 used 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.

All intercultural operations were done carefully. The first weeding was done at 15 DAT followed by second and third weeding were done at 15 days interval after first and second weeding. 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. The crop of each plot was harvested separately on different dates at full maturity when 90% of the grains become golden yellow in color. Ten samples hills were collected from each plot for collection of data on plant characters and yield components. 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. The data was analyzed using MSTAT-C [8] programme. The mean differences among the treatments were compared by multiple comparison tests using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effective and Non-effective Tillers: Significant differences in effective tiller $hill^{-1}$ were observed among the varieties (Fig. 1). 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). Effective tillers $hill^{-1}$ of rice varieties also varied significantly due to P fertilizer application (Fig. 1). 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. Similar results of applied P fertilizer to was reported by Katyal [9]. Matsuo *et al.* [10] also reported that it is necessary to apply much P fertilizers to help rice plants to accelerate the phosphate absorption for increased tillering.

Significant variation in number of effective tillers $hill^{-1}$was observed due to variation of P fertilizer and variety (Fig. 2). 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). This might be due to the increase in tiller fertility with increased P doses.

Panicle Length: Varieties did not show any significant variation in respect of panicle length (Table 1). However, numerically the longest panicle was observed from Hira-2 (25.50 cm) and the shortest from Aloron (24.17 cm). Phosphorus had significant role in increasing the panicle length (Table 1). 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

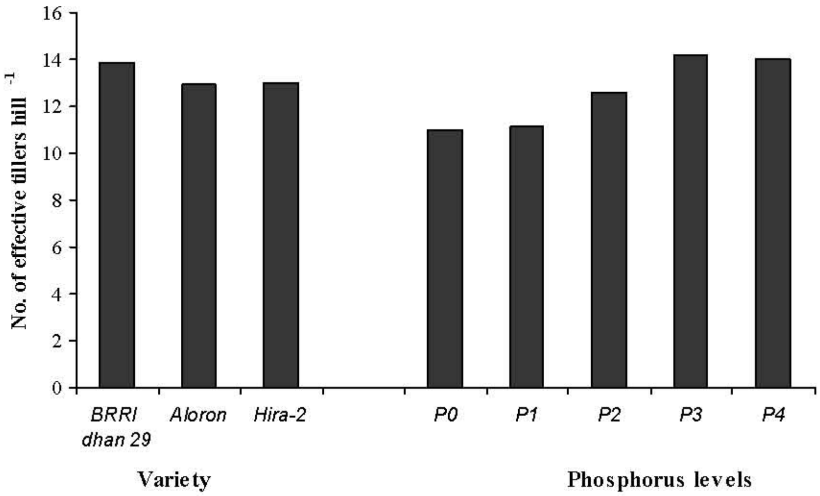

Fig. 1: Effective tillers of boro rice at harvest as affected by variety and phosphorus levels
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

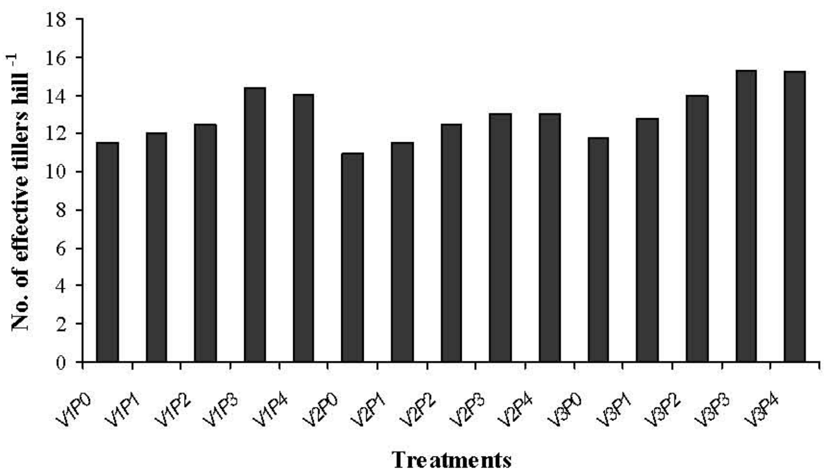

Fig. 2: Effective tillers $hill^{-1}$ of boro rice at harvest affected by variety and phosphorus
V_1= BRRI dhan 29, V_2= Aloron (HB-8), V_3= Hira-2 (HS-273)
P_0= No phosphorus (control), P_1= 24 Kg P_2O_5 ha^{-1}, P_2= 48 Kg P_2O_5 ha^{-1}, P_3= 72 Kg P_2O_5 ha^{-1} and P_4= 96 Kg P_2O_5 ha^{-1}

which was similar 24 kg P_2O_5 ha^{-1} (P_1).similar results were reported for low land rice by Sahar and Burbey [11]. The interaction of variety and phosphorus levels had also significant effect on the panicle length (Table 2). 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).

Filled Grain and Un-filled Grains per Panicle: Variations exerted significant influence on the filled grains $panicale^{-1}$(Table 1). 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 [12] reported that there were varietal differences in number of filled grains $panicle^{-1}$. Filled as well as unfilled grains $panicles^{-1}$ was also significantly affected by different phosphorus levels (Table 1). 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

Table 1: 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 2: 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}

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 [13]. Sahar and Burbey [11] showed that increasing the rate the panicles^{-1} of P compound significantly affected the grain number panicles^{-1}. Interaction of variety and phosphorus significantly affected the number of filled and unfilled grains panicle^{-1} (Table 2). 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).

Spikelet Sterility: Spikelet sterility varied significantly among the by varieties (Table 1). 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 [12]. The effect of phosphorus levels on the spikelet sterility was significant (Table 1). 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.* [14] observed similar findings. Ortega and Rojas [15] also reported that P application decreased floret sterility. Interaction of variety and P fertilizer affected significant difference in spikelet sterility percentage (Table 2). 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.

1000-Grain Weight: Varieties did not show any significant response on 1000-grain weight (Table 1). 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 [16]. Grain weight of rice varieties also varied significantly due to phosphorus fertilizer application (Table 1). Weight of 1000-grain 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 [16] reported that application of 30 kg P ha^{-1} gave the highest 1000-grain yield which was different from all other doses. Interactive effect of variety and phosphorus had a significant effect on the weight of 1000-grain (Table 2). 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).

Grain Yield: The rice varieties different significantly in respect of grin yield ha^{-1}(Table 3). 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 [12] in hybrid rice and Main [17] in T. aman rice. The impact of P application on grain yield ha^{-1} was significant (Table 3). 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. Shah [16] also reported the similar response of P on grain yield. Zaman *et al.* [18] found significant increase in grain yield with P application over P control. Tandon [19] 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.*** [20] reported that highest grain yield with the application of 80 kg P_2O_5 ha^{-1}. The interaction effect

Table 3: 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})	Harvest Index (%)
BRRI dhan29	6.86 b	7.90	46.47
Aloron	7.41 a	8.51	46.54
Hira-2	7.50 a	8.60	46.58
$S\bar{x}$	0.03	NS	NS
CV (%)	3.64	7.98	6.49
P_0	4.99 c	5.83 b	46.12
P_1	5.85 bc	6.78 b	46.31
P_2	6.89 ab	7.90 a	46.58
P_3	7.23 a	8.23 a	46.76
P_4	6.98 a	8.05 a	46.44
$S\bar{x}$	0.36	0.37	NS
CV (%)	6.56	8.53	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 4: 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})	Harvest Index (%)
V_1P_0	5.05 e	6.50 c	43.72 bc
V_1P_1	5.55 de	7.11 a-c	43.83 bc
V_1P_2	6.56 a-e	7.50 a-c	46.65 a-c
V_1P_3	6.99 a-c	7.87 a-c	47.03 a
V_1P_4	6.72 a-d	7.70 a-c	46.60 a-c
V_2P_0	5.19 e	6.70 bc	43.65 c
V_2P_1	6.05 b-e	7.23 a-c	45.55 a-c
V_2P_2	6.76 a-d	7.89 a-c	46.14 a-c
V_2P_3	7.34 ab	8.13 ab	47.70 a
V_2P_4	7.01 a-c	8.03 a-c	46.60 a-c
V_3P_0	5.85 cde	7.02 a-c	44.93 a-c
V_3P_1	6.76 a-d	7.87 a-c	46.20 a-c
V_3P_2	7.42 a	8.45 a	46.75 ab
V_3P_3	7.68 a	8.60 a	47.17 a
V_3P_4	7.49 a	8.55 a	46.69 a-c
$S\bar{x}$	0.3873	0.4726	0.90
CV (%)	6.56	8.53	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}

of variety and phosphorus exerted significant influence on the grain yield (Table 4). 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.* [10] also found differences in grain yield of rice varieties with variable P levels.

Straw Yield: Straw yield remained unaltered due to variety (Table 3). 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 [16] and Xie *et al.* [21] reported that biomass production varied with variety which rendering different straw yield. Significant difference on straw yield of boro rice was observed when P was applied (Table 3). 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 [22] also reported similar effect of phosphorus. Interaction effect of variety and phosphorus levels was also observed significant on straw yield (Table 4). 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.

Harvest Index: The difference in harvest index due to variety was not significant (Table 3). However, numerically the maximum harvest index was obtained from the variety Hira-2 and the lowest harvest index was obtained from BRRI dhan 29. There was no significant effect of phosphorus was found on the harvest index of boro rice (Table 3). 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 [23]. The interactive effect of variety and phosphorus had significant effect on the harvest index (HI) of boro rice (Table 4). 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.

REFERENCES

1. Anonymous, 1999. Feeding the world, Facts and Figures. http//www.riceweb.org.
2. Rotshield, G.H.L., 1996. Perspectives for rice production in Asia. Crop research in Asia: Achievements and perspectives. Proceedings of the 2nd Asian crop science conference. Asian Crop Sci. Assoc., Fukui., pp: 12-17.
3. IRRI (International Rice Research Institute), 2006. World Rice Statistics. Intl. Rice Res. Inst. http://www.irri.org/science/wrs. Accessed in July, 2006.
4. BRRI (Bangladesh Rice Research Institute), 2007. Bangladesh Rice Knowledge Bank. http://riceknowledgebank.brri.org. Accessed on January, 2007.
5. Yoshida, S., 1981. Fundamental of rice crop science. Intl. rice res. Inst., Los Banos, Philippines.
6. Aide, M. and J. Picker, 1996. Potassium and Phosphorus Nutrition in Rice. Information from 1996 Missouri Rice Research Update.
7. Sahrawat, K.L., M.K. Abekoe, S. Diatta, G. Tian, F. Ishida, D. Keatinge, R. Carsky and J. Wendt, 2001. Application of inorganic phosphorus fertilizer. In: Proc. Symp. Sponsored by the American Soc. Agron. USA. 5-9 November 2000, pp: 225-246.
8. Russell, O.F., 1994. MSTAT-C v.2.1 (a computer based data analysis software). Crop and Soil cience Department, Michigan State University, USA.
9. Katyal, J.C., 1978. Management of P in lowland rice. Phosphorus in Agric., 73: 21-34.
10. Matsuo, T., K. Kumazawa, R. Ishii, K. Ishihara and H. Hirata, 1995. Science of the plant. Volume Two physiology. Food and Agriculture Policy Research Centre, Tokyo. Japan, pp: 1240.
11. Sahar, A. and N. Burbey, 2003. Effect of nitrogen, phosphorus and potassium (NPK) compound dosages on the growth and yield of lowland rice. J. Stigma (Indonesia), 11(1): 26-29.
12. Obaidullah, M., 2007. Influence of clonal tillers age on growth and yield of inbred and hybrid rice. M.S. Thesis Dept. Agron., Sher-e-Bangla Agricultural University. Dhaka-1207.
13. Fageria, N.K. and M.P. Barabosa-Filho, 1982. Screening rice cultivars for tolerance to low levels of available soil phosphorus. Revista-Brasileira-de-Ciencia-do-solo, 6(2): 146-151.
14. Raju, R.N., K.M.N. Reddy and K.A. Reddy, 1997. Performance of phophorus-carries in wetland rice (*Oryza sativa*) on reverie alluvials. Indian J. Agron., 42(2): 272-274.
15. Ortega, B.R. and W.C. Rojas, 1999. Agronomic assessment of the effects of phosphorus sources on flooded rice. Agricultura Tecnica Santiago., 58(1): 23-31.
16. Shah, M.A.L., 2002. Phosphorus nutrition of rice varieties in relation to phosphorus sources and rates on a phosphorus deficit soil. Ph.D. Thesis Dept. Soil Sci., Banghabandhu Seikh Mujibur Rahman Agricultural University, Gazipur.

17. Main, M.A., 2006. Influence of planting technique on growth and yield of aman rice. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agril. Univ., Dhaka.
18. Zaman, S.K., M.A. Razzaque, S.M.R. Karim and N.I. Bhuiyan, 1995. Rice response to phosphorus in wetland soil. Pakistan J. Sci. Ind. Res., 38(11-12): 438-440.
19. Tandon, H.L.S., 1987. Phophorus Research and Agricultural Production in India. Fertilizer Development and Consultation Organization, New Delhi, pp: 160 + xii.
20. Mahajan, J.P., R.P. Singh and A.K. Dwivedi, 1995. Phosphorus utilization by rice varieties in "Vertisol". J. Nucl. Agric. and Biol., 24(3): 154-157.
21. Xie, W., G. Wang and Q. Zhang, 2007. Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. J. Zhejiang Univ. Sci., 8(7): 486-492.
22. Gupta, P.K., 1999. Handbook of Soils, Fertilizers and manure. Agro Botanica, New Delhi, India.
23. IRRI (International Rice Research Institute), 1973. Annual report for 1972. Los Banos, Philippnes.