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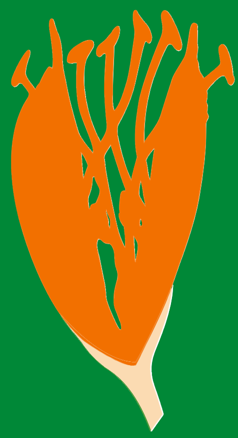

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## CONTENTS

# Comparative Factors and Income Share of Power Tiller and Draught Animal Power in Rice Production

M A Quayum[1] and Amin Muhammad Ali[2]

ABSTRACT

This study takes an attempt to assess the differences in income distribution among the participants in modern rice (MV) production using power tiller (PT) and draught animal power (DAP) in 2003 in some selected areas of Bogra, Comilla, Chuadanga and Manikganj districts in Bangladesh. The highest share (43%) was accrued by the current inputs of Boro rice followed by human labour (32%) under PT users. In case of DAP users higher shares were attributed to current inputs (46%) followed by human labour (35%) for Boro rice cultivation. Human labour earned the largest share of output in case of both PT users and DAP users for MV T. Aman and T. Aus cultivation but the share accrued to the human labour was always lower in mechanized farms (PT users) largely as a result of the decline in use of family labour. The larger shares were attributed to residual on PT users' farm compared to DAP users' farms for all types of rice such as MV Boro (8%), MV T. Aman (24%), and MV T. Aus (17%). The income share analysis indicates that hired human labour earned higher income share under PT users (both owner-users and hirer-users taken together) than that of DAP users (both owner-users and hirer-users taken together). Similar results were found in case of pure owner-users and pure hirer-users of both PT and DAP. The imputed total cost of a factor as a proportion of total value of the crop grown was the highest for human labour irrespective of cultivation method used. Share of farmer in total value added in the crop production was higher when DAP was used for rice production. Share of hired labour in total value added was greater for PT than for DAP in MV rice production.

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## INTRODUCTION

Traditionally a pair of bullock is used for land preparation in Bangladesh. In the 1960s power tillers were introduced from Japan and later on from China for land preparation due to shortage of draught animal power. In 1988, the government withdrew duties and sale taxes on power tillers. As a result, the number of power tillers increased and the farmers of Bangladesh are cultivating their land by it. The area cultivated by power tiller is increasing with the increase of power tiller. The percentage of area cultivated by PT was about 70% of the total cultivated land and the estimated number of power tillers was 1,94,460 in 2006 (Quayum 2009). The latest Livestock Census quoted the number of working animals as 11.2 million (BBS, 1996). There are many advantages of PTs over bullock power for land preparation. Draught animal power requires 147 hours and a PT requires only 22 hours for tilling one hectare of land saving 125 hours (Quayum, 2003). In spite of the advantages, farmers of Bangladesh use both draught power and power tiller for land preparation in rice production. These two methods of land preparation are not used by the owners only but by the hirer-users/hirer-farmers also.

Duff (1986) showed that in the Philippines, the largest share of output accrued to the residual representing the farmer's share under PT both in Boro and T. Aman rice cultivation. Residual means net return on full cost basis, which goes to the farmer as an entrepreneur. It may be either positive or negative. Residual is also called operator's surplus or farmer's surplus. The residual term is a balance term showing farm's profit if it is positive or farm's loss if it is negative. If some production resources such as management skill, are not included in the production function returns to those resources will be included in the residual (Kikuchi, 1991). Duff also showed that a factor share analysis for West Java in wet season indicated that labour had slightly higher share of total earnings on mechanized farms than on non-mechanized farms. He also showed that hired labour's share also increased while family labour's earnings declined under PT users compared to DAP users.

Human labour earned the highest share of output for MV and LIV T. Aman rice in both Noakhali and Chittagong districts (Quayum et al, 1992). The residual was found to be higher in case of MV rice compared to LIV rice in the coastal areas affected by salinity. The income share of the LIV farmers was lower than that of the MV farmers, because the higher portion of the income of the former was spent on hired labour.

In factor share analysis human labour earned the highest share of outputs for MV T. Aus (41%), MV T. Aman (27%) and MV Boro (36%) rice cultivation respectively (Quayum and Jabber, 2005). On the other hand, farmer earned 49, 73 and 61% of the value of the total product for the above mentioned three rice crops respectively.

There are many factors of crop production such as current inputs (seeds, insecticides, manure etc), irrigation, fertilizers, land, human labour and animal labour/power tiller etc. Proper use of these factors of rice production used by PT owner-users or PT hirer-users and DAP owner-users or DAP hirer-users increases the productivity and it is essential to know the contribution of each input used by different users/farmers in rice production to make the appropriate policy by the policy makers in agriculture particularly in rice production.

We tried to assess the contribution of factors of production and the differences in income distribution among the participants in crop production using PT or DAP. A simple way of analyzing this issue is to employ the concept of factors shares. Factor share of an input is the ratio of the input cost used in the production process to the total value of output produced by that input along with other inputs using a given technology. Income share is the income ratio received by a participant in production to the total value added.

The earlier studies analyzed factor share and income share only on MV Boro rice with a limited number of samples in a limited area. They analyzed power tiller users or DAP users. They did not analyze PT owner-users or PT hirer-users. Thus, in this study we tried to cover a larger areas for different MV rice crops with a larger samples.

Therefore, the present study was conducted to-

- Examine the factor share of different rice crop production by PT users and DAP users (both owner-users and hirer-users as well);
- Assess the differences in income distribution among the participants in crop production using PT and DAP (both owner-users and hirer-users as well).

## METHODOLOGY

### Sampling procedure and data collection

Four upazilas namely Chandina, Nandigram, Chuadanga sadar and Singair were randomly selected from Comilla, Bogra, Chuadanga and Manikganj districts of Bangladesh respectively. Two villages were randomly selected from one agricultural block of the selected upazilas. Selected villages were Rushulpur and Lona of Chandina, Nandigram and Chakalma of Nandigram, Shangkarchandra and Manikdihi of Chuadanga sadar, and Luxmipur and Beguntahary of Singair. A sample frame was developed from the comprehensive farmers list of the Department of Agriculture Extension (DAE) for each village. Sample farmers were stratified into four strata by the help of DAE and key informant farmers of the respective villages. The strata were- (i) PT owner farmers (those who both own and use PT), (ii) PT hirer- user farmers (those who hire and use PT), (iii) Draught animal power owner farmers (those who both own and use DAP) and (iv) Draught animal power hirer- user farmers (those who hire and use DAP). Farmers those who used both power tiller and draught animal power in the same plot for land preparation were identified and not considered as sample. Stratified random sampling technique was followed for selecting sample farms proportionately from each stratum. Structure questionnaires were used for collecting data from the farmers of the developed stratum (eg, PT owner- users, PT hirer- users, bullock power owner- users, and bullock power hirer-users). Sample size was 267. Among those 180 were power tiller users (41 PT owners and 139 PT hirers) and 87 were bullock power users (58 DAP owners and 29 DAP hirers) shown in Table 1. Survey was done during April 2003 to December 2003.

### Method of measuring factor share and income share

There are two general measures of income distribution: (i) functional income distribution and (ii) personal income distribution. Functional income distribution measures the distribution of income to factors of production, such as land, labour, capital and current inputs. Income distribution determined in this way is called functional distribution of income. This link in basic economic theory that makes factors share an important concept in analyzing economic issues such as resource allocation efficiency and income distribution (Hayami and Kikuchi, 1981). Factor share and income share are analyzed to examine the comparative factor share and income share of different production participants under power tiller and bullock power cultivation.

**Estimation of factor shares of inputs.** Factor shares are defined as the ratio of costs of factor inputs used in the production process to the total value of output (Shahid, 1982; Kikuchi, 1991; Quayum *et al*, 2004). In case of production of paddy, for instance,

Factor share for ith input = $(P_i X_i) / (P_1Q_1+P_2Q_2)$ or cost of ith input/GR (Gross Revenue)

$P_i$ = price of $i^{th}$ input

$X_i$ = Quantity of $i^{th}$ input

$Q_1$ = quantity of output (paddy)

$P_1$ = price of output (paddy)

$Q_2$ = quantity of output (straw)

$P_2$ = price of output (straw)

Factor shares were estimated for current inputs, animal labour, human labour, power tiller, and land for each stratam. Current inputs include cost of seeds, seedling raising, manure, insecticides and interest on operating capital etc. Interest on operating capital was calculated at the rate of 10% for four months (assumed length of crop season). The numerators are the farms' factor costs and the common denominator is total revenue (paddy price multiplied by output quantity plus price of straw multiplied by quantity of straw). Factors cost are payments for inputs purchased and are also called factor payments.

**Estimation of income shares by the participants of crop production**. Income share is defined as the ratio of income received by the production participant to the total value added in the production process (Shahid, 1982). That is,

Income share, I = $I_i/V$

Where, $I_i$ = income received by a production participant, V = total value added.

Total value added = Total value of output-current input costs. In fact, the difference between total revenue and current input cost is the value that is added to an economy by a production process, and is called value added. Value added by a farm is equal to the total revenue earned by the farm minus total cost of intermediate goods purchased and used by the farm. It should be noted that a partcipant (like the owner or owner operator) may provide more than one factor of production while a group of participants (like hired workers) may provide one factor (labour service) (Shahid, 1982).

## RESULTS AND DISCUSSION

### Factor share analysis in production of MV rice crops

Factor share and income share analyses were done by taking PT owner-users or PT hirer-users separately and also by taking them together as PT users. Table 2 shows that PT users accrued the biggest share (43%) to the current inputs of Boro rice followed by human labour (32%). DAP users for Boro rice cultivation were higher share to current inputs (46%) followed by human labour (35%). It might be due to less number of family labour used by PT users. The result is consistent with the findings of Duff (1986). The higher share is attributed to animal labour in case of DAP users compared to land preparation by PTusers (Duff, 1986).

Human labour earned the largest share of output in case of both the PT users and DAP users for MV T. Aman and T. Aus cultivation but share accrued to the human labour was always lower in mechanized farms (PT users) largely as a result of the decline in use of family labour. The second largest share was'; attributed to current inputs for both the MV T. Aman and MV T. Aus whereas the larger share was attributed to DAP users' farms compared to PT users' farms for MV T. Aman rice cultivation. It happened due to higher cost of current inputs spent by DAP users. The higher share was attributed to the residual on PT users' farm compared to DAP users' farms for MV Boro (8%), MV T. Aman (24%), and MV T. Aus (17%) (Table 2). Similar findings were reported by Qauyum *et al,* (2004). Residual is the net return on full cost basis and it was more in case of PT users' farm for all rice crops. This is why the PT users' farm was found more profitable. Conversely, the residual share found negative for MV Boro rice (-5%) under DAP users because the net return was found negative in case of DAP users' farm. A factor share analysis indicated that share of human labour was higher for DAP users' farms than that of PT users' farms. Similar findings were observed between PT owner –users and DAP owner-users (Table 3). The shares of most of the factors were found higher for DAP owner-users' farm than those of PT owner-users' farm for MV Boro, MV T. Aman and MV T. Aus rice cultivation. It was due to the higher cost of most of the input factors in case of DAP users' farm. Only the share of residual was higher for PT owner-users' farm than that of DAP owner-users' farm for MV Boro (10%), MV T. Aman (31%) and MV T. Aus (21%). It also indicated that the PT owner-users' farm was more profitable than DAP owner-users' farm. Table 4 shows shares of factors in the production of different MV rice crops by PT hirer-users and DAP hirer-users where the percentages of shares attributed to different factors such as current inputs, human labour, PT/animal labour and land were higher for DAP hirer-users compared to PT hirer-users for MV Boro, MV T. Aman and MV T. Aus rice cultivation. In this case it was also found that only the share of residual was higher for PT hirer-users'farm than that of DAP hirer-users' farm. Therefore, it indicated that PT hirer-users were more benefited than DAP hirer-users for growing MV rice in all three seasons.

### Income share analysis in production of MV rice crops

Production participants sharing the income include the farmer and the hired labour both in case of human and PT/DAP users (Table 5). The farmer earned 57% of the total income of which 32% generated by land (land owned by the farmer), 42% by family labour (both human and PT), and 26% as residual for MV Boro rice cultivation under PT users while in case of DAP users, the farmer earned 71% of the total income of which 28% generated by land, 85% by family labour (both human and animal labour) and the residual was found to be negative (-12%). The residual was negative because the total cost of MV Boro rice production was found more than the total return in case of DAP users and residual means net return on full cost basis or profit.

On the other hand, the farmer earned 72% income of the total income of which 24% generated by land, 33% by family labour (both human and PT) and 43% as residual for MV T. Aman rice under PT users while in case of DAP the corresponding figures were 78, 26, 70 and 5%.

However, for MV T. Aus rice, the farmer earned 69% income of the total income of which 31% generated by land, 36% by family labour (both human and PT), and 33% as residual under PT users but under DAP the corresponding figures were 81, 24, 63 and 13%. The income share analysis indicated that hired human labour earned higher income share under PT users (both owner-users and hirer-users taken together) than that of DAP users (both owner-users and hirer-users taken together) due to more hired labour was needed and more money was spent for hired labour for PT users farm. It indicated that more employment opportunities for hired human labour was created and hired labour would be more benefited if PT was used. Table 6 shows similar results found in case of pure owner-users. The farmer earned higher income of the total income than that of hired labour for MV Boro, MV T. Aman, and MV T. Aus for both PT owner-users' farm and DAP owner-users' farm. Hired human labour earned higher share of income in case of PT owner-users than that of DAP owner-users because PT owner-users spent more cost for hired labour. The income share generated by residual was found higher for PT owner-users' farm than that of DAP owner-users' farm for MV rice production in all three seasons. It indicated that PT owner-users' farm were more benefited. The farmer earned higher income of the total income than that of hired labour for MV Boro, MV T. Aman and MV T. Aus for both PT hirer-users' farm and DAP hirer-users' farm but for MV T. Aman PT hirer-users' farm obtained higher income share (69%) than that of DAP hirer-users' farm (60%) (Table 7). The income share generated by residual was found higher for PT hirer-users' farm than that of DAP hirer-users'farm for MV rice production in all three seasons. It indicated that PT hirer-users' farm was more benefited compared to DAP hirer-users' farm.

## CONCLUSION

Factor share analysis revealed that share of human labour was higher in case of DAP used for rice cultivation than that of PT. It indicated that hired labour's share increased and family labour earnings declined on mechanized farms. Thus farmers would be in a better position for growing crops under PT compared to DAP. Though the shares of different production factors were higher in non-mechanized farms than those of mechanized farms share attributed to residual was higher in case of mechanized farms than that of non-mechanized farms. An income share analysis indicated that farmer earned higher share of the total income as PT owner-users and hirer-users than that of DAP owner-users and hirer-users for cultivation of all types of rice. Similar results were found in case of both family human labour and family animal labour. The income share of the farmers' generated by residual was higher for PT users (both owner and hirer) than that for DAP users (both owner and hirer) for cultivation of all types of rice. Hired labour earned higher share of income of the total income when PT was used than that of DAP. Thus, factor share and income share analyses indicated that crop production was more profitable under PT from the view- point of farmers and hired labour.

**Table 1. Distribution of sample farmers in the selected villages.**

| Location | PT owner-user | PT hirer-user | PT user | DAP owner-user | DAP hirer-user | DAP user | Total |
|---|---|---|---|---|---|---|---|
| Chandina (Rashulpur and Lona), Comilla | 7 | 33 | 40 | 8 | 5 | 13 | 53 |
| Nandigram (Nandigram and Chakalma), Bogra | 18 | 37 | 55 | 21 | 7 | 28 | 83 |
| Chuadanga sadar (Sangkarchandra and Manikdihi), Chuadanga | 8 | 38 | 46 | 16 | 9 | 25 | 71 |
| Singair (Luxmipur and Beguntahary), Manikganj | 8 | 31 | 39 | 13 | 8 | 21 | 60 |
| All/total | 41 | 139 | 180 | 58 | 29 | 87 | 267 |

**Table 2. Factor share of different MV rice crop production under power tiller and draught animal power in the study areas, 2003.**

| Factor | Value (Tk/ha) | | Factor share (%) | |
|---|---|---|---|---|
| | Power tiller user | Draught animal user | Power tiller user | Draught animal user |
| **MV Boro rice** | | | | |
| Current inputs | 17698 | 16716 | 43 | 46 |
| a. Fertilizer | 4196 | 3997 | 10 | 11 |
| b. Irrigation | 9449 | 9231 | 23 | 25 |
| c. Other inputs[a] | 4053 | 3488 | 10 | 10 |
| Human labour | 13088 | 12996 | 32 | 35 |
| PT/Animal labour | 2401 | 4703 | 6 | 13 |
| Land[c] | 4279 | 3958 | 11 | 11 |
| Residual[b] | 3437 | -1638 | 8 | -5 |
| Total value of output | 40903 | 36735 | 100 | 100 |
| **MV T. Aman** | | | | |
| Current inputs | 6720 | 7786 | 22 | 27 |
| a. Fertilizer | 2937 | 3643 | 9 | 13 |
| b. Irrigation | 1009 | 958 | 3 | 3 |
| c. Other inputs[a] | 2774 | 3185 | 10 | 11 |
| Human labour | 10469 | 11423 | 34 | 40 |
| PT/Animal labour | 2297 | 4505 | 7 | 16 |
| Land[c] | 4242 | 4143 | 14 | 15 |
| Residual[b] | 7506 | 813 | 24 | 3 |
| Total value of output | 31234 | 28670 | 100 | 100 |
| **MV T. Aus** | | | | |
| Current inputs | 7172 | 5772 | 26 | 21 |
| a. Fertilizer | 2922 | 2113 | 11 | 8 |
| b. Irrigation | 1160 | 240 | 4 | 1 |
| c. Other inputs[a] | 3090 | 3419 | 11 | 12 |
| Human labour | 9041 | 10761 | 33 | 39 |
| PT/Animal labour | 2385 | 4740 | 9 | 17 |
| Land[c] | 4316 | 4208 | 16 | 15 |

| | | | | |
|---|---|---|---|---|
| Residual[b] | 4567 | 2346 | 17 | 8 |
| Total value of output | 27481 | 27828 | 100 | 100 |

Source: Field survey, 2003

[a]Includes cost of seeds, seedbed, insecticides, manure and interest.

[b]Residual = Total value product- amount (Taka) paid to current inputs, human labour, animal labour/power tiller, and land. [c]Average land rent for the season.

**Table 3. Factor share of different MV rice crop production by PT owner-users and DAP owner-users in the study areas, 2003.**

| Factor share | Value (Tk/ha) | | Factor share (%) | |
|---|---|---|---|---|
| | Power tiller owner-user | Draught animal power owner-user | Power tiller owner-user | Draught animal power owner-user |
| **MV Boro rice** | | | | |
| Current inputs | 17183 | 16416 | 42 | 44 |
| a. Fertilizer | 3965 | 3906 | 10 | 11 |
| b. Irrigation | 9472 | 9106 | 23 | 24 |
| c. Other inputs[a] | 3746 | 3404 | 9 | 9 |
| Human labour | 13547 | 13072 | 33 | 35 |
| PT/Animal labour | 2325 | 4865 | 6 | 13 |
| Land[c] | 4273 | 3951 | 10 | 11 |
| Residual[b] | 3989 | -994 | 10 | -3 |
| Total value of output | 41317 | 37310 | 100 | 100 |
| **MV T. Aman** | | | | |
| Current inputs | 6432 | 7708 | 20 | 27 |
| a. Fertilizer | 2632 | 3643 | 8 | 13 |
| b. Irrigation | 1152 | 849 | 4 | 3 |
| c. Other inputs[a] | 2648 | 3216 | 8 | 11 |
| Human labour | 9494 | 11716 | 30 | 41 |
| PT/Animal labour | 2003 | 4628 | 6 | 16 |
| Land[c] | 4276 | 4222 | 13 | 15 |
| Residual[b] | 9979 | 643 | 31 | 2 |
| Total value of output | 32184 | 28917 | 100 | 100 |
| **MV T. Aus** | | | | |
| Current inputs | 6837 | 5898 | 24 | 21 |
| a. Fertilizer | 2598 | 2056 | 9 | 7 |
| b. Irrigation | 1105 | 296 | 4 | 1 |
| c. Other inputs[a] | 3134 | 3546 | 11 | 13 |
| Human labour | 9108 | 10958 | 32 | 39 |
| PT/Animal labour | 2139 | 4913 | 7 | 17 |
| Land[c] | 4567 | 4080 | 16 | 15 |
| Residual[b] | 6077 | 2372 | 21 | 8 |
| Total value of output | 28728 | 28221 | 100 | 100 |

*Source:* Field survey, 2003. [a]Includes cost of seeds, seedbed, insecticides, manure and interest. [b]Residual = Total value product- amount (Taka) paid to current inputs, human labour, animal labour/power tiller, and land. [c]Average land rent for the season.

**Table 4. Factor share of different MV rice crop production by PT hirer-users and DAP hirer-users in the study areas, 2003.**

| Factor share | Value (Tk/ha) | | Factor share (%) | |
|---|---|---|---|---|
| | Power tiller hirer-user | Draught animal power hirer-user | Power tiller hirer-user | Draught animal power hirer-user |
| **MV Boro rice** | | | | |
| Current inputs | 17823 | 16657 | 44 | 47 |
| a. Fertilizer | 4264 | 4177 | 11 | 12 |
| b. Irrigation | 9442 | 9183 | 23 | 27 |
| c. Other inputs[a] | 4117 | 2997 | 10 | 8 |
| Human labour | 12952 | 12845 | 32 | 36 |
| PT/Animal labour | 2423 | 4379 | 6 | 12 |
| Land[c] | 4282 | 4630 | 11 | 13 |
| Residual[b] | 3301 | -2925 | 8 | -8 |
| Total value of output | 40781 | 35586 | 100 | 100 |
| MV T. Aman | | | | |
| Current inputs | 6829 | 8092 | 22 | 29 |
| a. Fertilizer | 3053 | 3643 | 10 | 13 |
| b. Irrigation | 955 | 1206 | 3 | 4 |
| c. Other inputs[a] | 2821 | 3243 | 9 | 12 |
| Human labour | 10840 | 10757 | 35 | 38 |
| PT /Animal labour | 2410 | 4225 | 8 | 15 |
| Land[c] | 4229 | 3963 | 14 | 14 |
| Residual[b] | 6565 | 1070 | 21 | 4 |
| Total value of output | 30873 | 28107 | 100 | 100 |
| **MV T. Aus** | | | | |
| Current inputs | 7315 | 5485 | 27 | 20 |

| | | | | |
|---|---|---|---|---|
| a. Fertilizer<br>b. Irrigation<br>c. Other inputs[a] | 3060<br>1184<br>3071 | 2246<br>111<br>3128 | 11<br>4<br>12 | 8<br>1<br>11 |
| Human labour | 9012 | 10305 | 33 | 38 |
| PT/Animal labour | 2491 | 4341 | 9 | 16 |
| Land[c] | 4209 | 4505 | 16 | 17 |
| Residual[b] | 3920 | 2286 | 15 | 9 |
| Total value of output | 26947 | 26922 | 100 | 100 |

*Source:* Field survey, 2003. [a]Includes cost of seeds, seedbed, insecticides, manure and interest. [b]Residual = Total value product- amount (Tk) paid to current inputs, human labour, animal labour/power tiller, and land. [c]Average land rent for the season.

**Table 5. Income shares of different participants in the production of MV rice under alternative methods (PT or DAP ) of cultivation in the study areas, 2003.**

| Production participants and value added[a] | Value (Tk/ha) | | Income share (%) | |
|---|---|---|---|---|
| | Power tiller user | Draught animal power user | Power tiller user | Draught animal power user |
| **MV Boro** | | | | |
| Value added[a] | 23205 | 20019 | 100 | 100 |
| Farmer[b] | 13271 | 14281 | 57 | 71 |
| Hired labour | 8063 | 4278 | 35 | 21 |
| Hired PT/DAP | 1871 | 1460 | 9 | 7 |
| **Farmer[b]** | 13271 | 14281 | 100 | 100 |
| a. Land | 4279 | 3958 | 32 | 28 |
| b. Family labour | 5025 | 8718 | 38 | 62 |
| c. Family PT/animal labour | | | | |
| d. Residual | 530 | 3243 | 4 | 22 |
| | 3437 | -1638 | 26 | -12 |
| **MV T. Aman** | | | | |
| Value added[a] | 24514 | 20884 | 100 | 100 |
| Farmer[b] | 17597 | 16262 | 72 | 78 |
| Hired labour | 5171 | 3334 | 21 | 16 |
| Hired PT/DAP | 1746 | 1288 | 7 | 6 |
| **Farmer[b]** | 17597 | 16262 | 100 | 100 |
| a. Land | 4242 | 4143 | 24 | 25 |
| b. Family labour | 5298 | 8089 | 30 | 50 |
| c. Family PT/ animal labour | | | | |
| d. Residual | 552 | 3217 | 3 | 20 |
| | 7505 | 813 | 43 | 5 |
| **MV T. Aus** | | | | |
| Value added[a] | 20309 | 22056 | 100 | 100 |
| Farmer[b] | 13915 | 17863 | 68 | 81 |
| Hired labour | 4650 | 2881 | 23 | 13 |
| Hired PT/DAP | 1744 | 1312 | 9 | 6 |
| **Farmer[b]** | 13915 | 17863 | 100 | 100 |
| a. Land | 4316 | 4208 | 31 | 24 |
| b. Family labour | 4391 | 7880 | 32 | 44 |
| c. Family PT/animal labour | | | | |
| d. Residual | 642 | 3428 | 4 | 19 |
| | 4567 | 2346 | 33 | 13 |

*Source:* Field survey, 2003. [a]Value added= Total value of output- Cost of current inputs. [b]Farmer = value added- hired labour (both human and animal/PT labour).

**Table 6. Income shares of participants in the production of different MV rice crops by PT owner-users and DAP owner-users in the study areas, 2003.**

| Production participants and value added[a] | Value (Tk/ha) | | Income share (%) | |
|---|---|---|---|---|
| | Power tiller owner-user | Draught animal power owner-user | Power tiller owner-user | Draught animal power owner-user |
| **MV Boro** | | | | |
| Value added[a] | 24134 | 20894 | 100 | 100 |
| Farmer[b] | 15653 | 16471 | 65 | 79 |
| Hired labour | 8481 | 4423 | 35 | 21 |
| **Farmer[b]** | 15653 | 16471 | 100 | 100 |
| a. Land | 4273 | 3951 | 27 | 24 |
| b. Family labour | 5066 | 8648 | 32 | 52 |
| c. Family PT/animal labour | | | | |
| d. Residual | 2325 | 4865 | 15 | 30 |
| | 3989 | -994 | 26 | -6 |
| **MV T. Aman** | | | | |
| Value added[a] | 25752 | 21209 | 100 | 100 |
| Farmer[b] | 20243 | 18107 | 77 | 85 |
| Hired labor | 5509 | 3102 | 21 | 15 |
| **Farmer[b]** | 20243 | 18107 | 100 | 100 |
| a. Land | 4276 | 4222 | 21 | 23 |
| b. Family labour | 3985 | 8613 | 20 | 48 |
| c. Family PT/animal labour | | | | |
| d. Residual | 2003 | 4628 | 10 | 25 |

| | | | | |
|---|---|---|---|---|
| | 9979 | 643 | 49 | 4 |
| **MV T. Aus** | | | | |
| Value added[a] | 21891 | 22323 | 100 | 100 |
| Farmer[b] | 16831 | 19466 | 77 | 87 |
| Hired labour | 5060 | 2857 | 23 | 13 |
| **Farmer[b]** | 16831 | 19466 | 100 | 100 |
| a. Land | 4567 | 4080 | 27 | 21 |
| b. Family labour | 4048 | 8101 | 24 | 42 |
| c. Family PT/ animal labour | | | | |
| d. Residual | 2139 | 4913 | 13 | 25 |
| | 6077 | 2372 | 36 | 12 |

*Source:* Field survey, 2003. [a]Value added= Total value of output- Cost of current inputs. [b]Farmer = value added- hired human labour (in case of owner-user).

**Table 7. Income shares of participants in the production of different MV rice crops by PT hirer-users and DAP hirer-users in the study areas, 2003.**

| Production participants and value added[a] | Value (Tk/ha) | | Income share (%) | |
|---|---|---|---|---|
| | Power tiller hirer-user | Draught animal power hirer-user | Power tiller hirer-user | Draught animal power hirer-user |
| **MV Boro** | | | | |
| Value added[a] | 22958 | 18929 | 100 | 100 |
| Farmer[b] | 12595 | 10563 | 55 | 56 |
| Hired labour | 7940 | 3987 | 34 | 21 |
| Hired PT/ animal labour | 2423 | 4379 | 11 | 23 |
| **Farmer[b]** | 12595 | 10563 | 100 | 100 |
| a. Land | 4282 | 4630 | 34 | 44 |
| b. Family labour | 5013 | 8858 | 40 | 84 |
| c. Residual | 3301 | -2925 | 26 | -28 |
| **MV T. Aman** | | | | |
| Value added[a] | 24044 | 20015 | 100 | 100 |
| Farmer[b] | 16592 | 11926 | 69 | 60 |
| Hired labour | 5042 | 3864 | 21 | 19 |
| Hired PT/animal labour | 2410 | 4225 | 10 | 21 |
| **Farmer[b]** | 16592 | 11926 | 100 | 100 |
| a. Land | 4229 | 3963 | 25 | 33 |
| b. Family labour | 5798 | 6893 | 35 | 58 |
| c. Residual | 6565 | 1070 | 40 | 9 |
| **MV T. Aus** | | | | |
| Value added[a] | 19632 | 21437 | 100 | 100 |
| Farmer[b] | 12667 | 14159 | 64 | 66 |
| Hired labour | 4474 | 2937 | 23 | 14 |
| Hired PT/animal labour | 2491 | 4341 | 13 | 20 |
| **Farmer[b]** | 12667 | 14159 | 100 | 100 |
| a. Land | 4209 | 4505 | 33 | 32 |
| b. Family labour | 4538 | 7368 | 36 | 52 |
| c. Residual | 3920 | 2286 | 31 | 16 |

*Source:* Field survey, 2003. [a]Value added= Total value of output- Cost of current inputs. [b]Farmer = value added- hired human labour and hired animal labour/PT(in case of hirer-user).

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# Effect of Post-anthesis Drought on Photosynthesis, Respiration and Associated Parameters of Modern and Traditional Rice Varieties

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ABSTRACT

This study evaluates one modern (BR22) and two traditional rice varieties (Lalmota and Matichal) in pots at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh, during T. Aman 2000 to measure photosynthesis (Pn), respiration and associated parameters such as leaf water potential, leaf water content, stomatal conductance, mesophyll conductance under post-anthesis drought at milky and dough stages. Portable photosynthesis measuring system (LiCOR-6200) was used in laboratory. Yield and yield attributes were recorded. Water stress markedly reduced Pn. BR22 displayed larger Pn than two traditional varieties under both optimal irrigated and post-anthesis drought conditions. Mesophyll conductance was also drastically reduced due to drought and paralleled Pn. However, stomatal conductance was slightly affected by drought. Leaf intercellular $CO_2$ concentration became higher under post-anthesis drought because of less utilization of $CO_2$ for Pn and hence diffusion pressure deficit from air to leaf intercellular spaces was decreased. However, BR22 maintained higher diffusion pressure deficit than traditional varieties, because it was able to run its Pn more actively than the traditional varieties by maintaining its better mesophyll conductance even at drought. Drought did not alter leaf respiration rate appreciably and were inconsistent among the varieties. Leaf water potential (ψ) in three varieties were significantly decreased due to drought. BR22 maintained relatively higher ψ than Lalmota and Matichal. Leaf water content (%) paralleled ψ. Pn had positive and linear association with leaf water potential ($R^2$=0.91-0.98). Mesophyll conductance also had positive and linear association with Pn ($R^2$=0.97-0.99). But the relationship between stomatal conductance and Pn was weak and inconsistent ($R^2$=0.04-0.45). Averaged over the varieties, drought caused a grain yield reduction of 57.50%. Drought significantly reduced the number of filled grains per panicle, increased sterility percentage, reduced the grain size (1000 grain weight), straw yield and HI.

## INTRODUCTION

Drought is considered to be a major environmental factor limiting plant growth and productivity of many crops worldwide (Chaves, 2002; Ober and Luterbacher, 2002). Rice yield is often substantially reduced due to periodic drought in the rainfed lowland ecosystem in South and Southeast Asia (Cabuslay *et al*, 2002). Drought induces many physiological, biochemical and molecular responses in which photosynthesis is one of the primary physiological targets (Chaves, 1991; Lawlor, 1995). Basically stomatal closure in response to drought stress restricts $CO_2$ entry into leaves thereby decreasing $CO_2$ assimilation. There is evidence that the decrease in $CO_2$ assimilation rates found in drought-stressed leaves cannot be simply reversed by increasing the external $CO_2$ supply, showing that drought stress must also affect mesophyll metabolism (Lawlor, 1995, 2002; Cornic and Fresneau, 2002).

The debate as to whether drought mainly limits photosynthesis through stomatal closure or through metabolic impairment has been running since the earliest reports (Chaves, 1991; Lawlor and Uprety, 1993; Lawlor, 1995; Cornic, 2000; Flexas and Medrano, 2002). During the last decade, stomatal closure was generally accepted to be the main determinant for decreased photosynthesis under mild to moderate drought (Chaves, 1991; Cornic 2000). Recently variations in mesophyll conductance due to drought have been identified and proposed that drought limits photosynthesis through reduced mesophyll conductance (Massacci and Loreto, 2001; Centritto *et al*, 2003; Ethier and Livingston, 2004; Manter and Kerrigan, 2004; Flexas *et al*, 2004). The inhibition of Pn under water stressed conditions was due mainly to reduced mesophyll conductance (non-stomatal factor) rather than stomatal factors. (Siosemardeh *et al*, 2004; Jin *et al*, 2004).

Under water stress, a good correlation is often observed between leaf water potential and stomatal conductance (Flexas *et al*, 1999). The complex regulation of stomatal conductance is related to important differences among species and genotypes in the response of stomata to leaf water potential, relative water content, ABA and other parameters, making it difficult to define a pattern of photosynthetic responses to drought (Chone *et al*, 2001).

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Generally, leaf rolling is an adaptive mechanism in tissue water conservation and resulted benefits to plant *in situ* under depleting soil moisture conditions (Sing and Jain, 2000; Sing and Sing, 2000a). In addition, the ability of maintaining higher leaf water potential during drought stress is one of the mechanisms of drought tolerance (Fukai and Cooper, 1995; Fukai *et al*, 1999). Drought at flowering stage is more detrimental than at tillering stage (Saxena *et al*, 1996). Genotypic variation in photosynthetic efficiency under post-flowering water stress was evident in rice (Raissac and Raissac, 1992).

In Bangladesh the rainfed lowland rice usually suffers from water stress at their reproductive and ripening stages when rainfall is minimal or none during October and November. Increasing photosynthetic rate (Pn) under post-anthesis drought, especially of flag leaf should be one of the most vital issues in our present breeding programme while developing varieties for drought prone rainfed lowland environments. Because, the flag leaf plays the most vital role in post-anthesis growth and grain development processes (Regina *et al*, 1994) and contributes about 73.4% of the total amount of grains mass (Qiu *et al*, 1993). On the other hand, the lesser will be the maintenance respiration for the amount of biomass produced, the higher will be the net increase in grain dry matter accumulation after flowering (Saitoh *et al*, 1998; Saitoh *et al*; 2000 and Swain *et al*, 2000).

Hence, investigation of stomatal and nonstomatal parameters limiting photosynthesis (Pn) under water stressed conditions may provide a means to understand the physiological basis of drought resistance. In spite of numerous reports about the effects of water deficit on dryland plants, drought tolerance and responses of rice as a wetland plant remain poorly understood.

Therefore, the present study evaluated the photosynthesis and respiration along with their associated parameters of modern and traditional rice varieties under post-anthesis drought to identify potential attributes controlling photosynthesis and respiration. It would be a scope to be considered in the breeding programme to develop varieties that would increase grain yield at the drought prone environments.

## MATERIALS AND METHODS

The experiment was conducted in pots with five replications at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur (24° 09' N latitude and 90° 26' E longitude with an elevation of 8.4 m from the mean sea level), Bangladesh, during wet season 2000. The soil used in the pots was silty clay of shallow red brown terrace soil under Madhupur Tract (AEZ 28), Salna series (Haider *et al*, 1991). The chemical properties of soil were: soil pH 6.34, organic matter 1.2%, total N 0.09%, total P 0.157 mg/100 g soil and exchangeable K 0.136 meq/100 g soil. Each pot contained about 15 kg soils. Fertilizers were applied in the soil of the pots @ 80:60:40:10:3 kg N, $P_2O_5$, $K_2O$, S Zn $ha^{-1}$ (1 ha soils = $2 \times 10^6$ kg) respectively, as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphat ($ZnSO_4$). Except urea, all the fertilizers were uniformly mixed in the soil before filling the pots. The urea was uniformly top-dressed in four equal splits up to panicle initiation stage.

We evaluated two traditional varieties, Lalmota (BSMRAU germplasm Acc no. IPK3001) and Matichal (BSMRAU germplasm Acc no. 3003) and one modern variety, BR22, developed by BRRI, Gazipur. All three varieties were late maturing and selected to represent the varieties those usually encounter water stress during post-anthesis period. Two seedlings per pot were grown under uniform management and cultural conditions. At heading stage pots were grouped into two. For measuring photosynthesis, one group of plants comprising five pots for each variety (5 × 3 varieties=15 pots) was continued with irrigation water, while irrigation was withheld in another group having same number of pots after heading and excess water was removed. In addition, four extra pots for each variety under each group were treated alike and used for destructive sampling to measure leaf water content, leaf water potential and soil moisture content over time.

Within few days of withdrawing irrigation the hills showed the leaf-rolling symptom. The hills showing the leaf-rolling symptom during the day were keenly observed in the next morning whether the leaf rolling was stable or not. If the leaf rolling was existed over night till the next morning, it indicated the existence of severe drought stress in the soil (Asana *et al*, 1955). At that condition, if life saving water were not applied, the plant would run to permanent wilting point and ultimately die. Therefore, it needed life saving water and the amount of life saving water was calculated as follows:

Amount of life saving water (ml) = $\pi r^2 h$

Where,

$\pi$= (Constant) = 3.14

r = 15 cm (the radius of the circumference of pot at the base of the hill)

h = 0.5 cm/day (the approximate evapo-transpiration at the period of Nov-Dec).

The amount of evapo-transpiration (ET) of wet season rice at greater Dhaka areas (the experimental area is situated under that area) in November was suggested as 3.31 mm/day (Karim and Akhand, 1982). However, during calculating the life saving water for the pot experiment at BSMRAU, Salna, Gazipur, ET was taken as approximately 5 mm/day, because the ET at drought imposed pots, supposed to be higher than that of the optimal field soil condition. Accordingly, the calculated life saving water that applied to each of drought treated pots was ($3.14 \times 15^2 \times 0.5$) = 353.25 ml.

At milky and dough stages, soil water content at drought imposed pots was measured (after appearance of leaf rolling symptom). Soil moisture in the drought-imposed pots was kept at about 14-15% (dry weight basis) (Fig. 9). Leaf water content was measured at dough stage. Leaf water content was calculated as follows:

$$\text{Leaf water content (wet basis) \%} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

$W_1$ = Fresh weight of five leaves

$W_2$ = Oven dried weight of five leaves.

Leaf water potential (ψ) was measured at dough stage by pressure bomb machine. Photosynthesis and respiration rates of flag leaves were measured at milky and dough stages using portable photosynthesis measuring system (LiCOR-6200) between 11.00 and 14.00 hrs. at a uniform light intensity (around 1550 quantum) provided artificially in laboratory. Respiration rate (µ mol $m^{-2}$ $s^{-1}$) was measured at zero light intensity. During measurement period the maximum air temperature ranged 29.71° -31.69°c and the minimum ranged 19.20°-23.91°c and the relative humidity ranged 77.26-80.16% at 9:00 hrs and 53.90-70.38% at 14:00 hrs (Plant Physiology Division, BRRI, Gazipur, about five km away from BSMRAU lab).

The data recorded were net photosynthetic rate (µ mol $m^{-2}$ $s^{-1}$), stomatal conductance (mol $m^{-2}$ $s^{-1}$), leaf intercellular $CO_2$ concentration (CINT) (ppm), mesophyll conductance (mol $m^{-2}$ $s^{-1}$), as Pn/CINT (Kubota and Hamid, 1992), $CO_2$ concentation gradient or diffusion pressure deficit (DPD) (the driving force from air to leaf intercellular spaces) was calculated as $CO_2$ concentration in air-CINT, and the Respiration rate (µ mol $m^{-2}$ $s^{-1}$). Grain weight $hill^{-1}$ (g), straw weight $hill^{-1}$ (g), filled grains $panicle^{-1}$, sterility %, 1000-grain weight and harvest index were recorded following the standard methodologies.

Analysis of variance (ANOVA) of concerned variables was performed using IRRISTAT windows version 4.0 (1998) and means separated by LSD.

## RESULTS

### Photosynthetic rate

Water stress markedly affected Pn both at milky and dough stages although the magnitude of variation in Pn among the varieties narrowed down dramatically at post-anthesis drought (Fig. 1). BR22 displayed larger leaf Pn than the other two traditional varieties at both milky and dough stages under both optimal irrigated and post-anthesis drought conditions. Irrespective of soil moisture regime, Matichal had consistently lower Pn rates at both the stages.

### Stomatal conductance (mol $m^{-2}$ $s^{-1}$)

Rate of entrance of $CO_2$ from air to leaf intercellular spaces (stomatal conductance) was decreased from milky to dough stage irrespective of varieties under optimal irrigated condition and it was much higher in Matichal (Fig. 2). Under post-anthesis drought the trend was similar in the varieties except for Matichal that displayed similar rate in both milky and dough stages. Stomatal conductance was reduced due to affect of post-anthesis drought irrespective of varieties at both milky and dough stages and the reduction was much in Matichal irrespective of the stages.

### Leaf intercellular $CO_2$ concentration (CINT) (ppm)

CINT became higher under post-anthesis drought irrespective of varieties in both milky and dough stages (Fig. 3). The modern variety BR22 displayed lesser CINT than those of traditional varieties at both optimal irrigated and drought conditions.

### Mesophyll conductance (mol $m^{-2}$ $s^{-1}$)

Rate of entrance of $CO_2$ from leaf intercellular spaces to mesophyll cells (mesophyll conductance) drastically reduced under drought. BR22 displayed higher rate than those of traditional varieties at both milky and dough stages. Mesophyll conductance paralleled the photosynthesis rate. (Fig. 1 and Fig. 4).

**$CO_2$ concentration gradient (the diffusion pressure deficit from air to leaf intercellular spaces) (ppm)**

The diffusion pressure deficit from air to leaf intercellular spaces was decreased under post-anthesis drought in all varieties (Fig. 5). BR22 was able to maintain higher diffusion pressure deficit at both milky and dough stages than those of Matichal and Lalmota irrespective of moisture regime.

**Respiration rate (μ mol $m^{-2}$ $s^{-1}$)**

It is discernible from Fig. 6 that drought did not alter respiration rate appreciably except for the variety, Lalmota that showed much higher respiration rate than the other varieties at dough stage. The changes in respiration rates among the varieties were inconsistent. BR22 exhibited higher respiration rate at dough stage under both optimal irrigated and drought conditions than that of milky stage. But it was reverse in case of Matichal and Lalmota.

**Leaf water potential (MPa) and leaf water content (%)**

Drought stress imposed at post-anthesis stage caused enormous variation in leaf water potential ($\psi$). All three varieties were severely affected by drought showing significantly lower $\psi$ (Fig. 7). BR22 maintained relatively higher $\psi$ than Lalmota and Matichal under both optimal irrigated and drought conditions at dough stage. Matichal showed lowest $\psi$ and Lalmota being intermediate. The leaf water content was reduced under drought stress irrespective of varieties. Leaf water content (%) paralleled leaf water potential (Fig. 8).

**Relationship among parameters associated with Pn**

Pn had positive and linear association with leaf water potential at optimal irrigated ($R^2$=0.91) (Fig. 10) and post-anthesis drought ($R^2$=0.98) (Fig. 11). Mesophyll conductance also had positive and linear association with Pn at both milky stage ($R^2$=0.99) (Fig. 12a, b) and dough stage ($R^2$=0.97-0.99) (Fig. 13a, b). But the relationship between stomatal conductance and Pn was weak and inconsistent ($R^2$=0.04-0.45) (Figures not given) at both milky and dough stages irrespective of moisture regimes.

**Yield and yield components**

There was marked reduction in grain yield due to drought (Table 1). Yield reduction ranged between 50.96% (in BR22) and 62.41% (in Matichal). Averaged over the varieties, drought caused a yield reduction of 57.50%. Table 1 presents water stress induced changes in the yield components and agronomic traits. Drought tended to reduce the number of panicles $hill^{-1}$ but the reduction was not statistically significant. This was rather expected because panicles had been formed and developed prior to the imposition of water stress. It might be possible that severe drought impeded panicle exertion or caused death of some of the panicles that eventually reduced the number of panicles $hill^{-1}$. Most pronounced effect of drought was on the number of filled grains per panicle. The affect of drought was further amplified in the dramatic increase in unfilled grains per panicle or sterility percentage. Drought seems to reduce the grain size (1000-grain weight), traditional varieties markedly reduced straw yield and HI. Traditional varieties had lower HI than BR22.

DISCUSSION

Photosynthesis is a complex and inter-related process and very much sensitive to water stress especially at flowering stage. As a result, Pn was drastically reduced at post-anthesis drought (Fig. 1). The results were in agreement with the findings of Machado *et al*, 1996; Wang *et al*, 1996 and Scartazza *et al*, 1998.

Generally rice plants try to adapt with the water stress by leaf rolling and closing of stomata. Leaf rolling is an adaptive mechanism in tissue water conservation and resulted benefits to plant in situ under depleting soil moisture conditions (Tanimoto *et al*, 1999; Choi *et al*, 1999; Sing and Jain, 2000; Sing and Sing, 2000a). As a result of leaf rolling and stomatal closure, stomatal conductance was decreased in all varieties at post-anthesis drought (Fig. 2). The rate of reduction was higher in Matichal than those of other varieties that indicated its more sensitivity to water stress. Stomatal conductance is a determinant of how much $CO_2$ is entering into the leaf intercellular spaces.

The lower stomatal conductance at drought indicated the less entrance of $CO_2$ inside the leaf but at the same time CINT was increased that indicated the less utilization of $CO_2$ from leaf inter cellular spaces. Due to less Pn, mesophyll conductance (mol $m^{-2}$ $s^{-1}$) was reduced by feedback inhibition. Therefore, mesophyll conductance paralleled Pn (Fig. 4). It seems that mesophyll conductance was one of the major determinants in the variation of photosynthesis (Scartazza *et al*, 1998). However, at drought, stomatal conductnce of BR22 was not varied much with other traditional varieties but its higher utilization of intercelluar $CO_2$ increased the mesophyll conductance and theirby higher Pn. Although leaf water potential was decreased due to affect of drought irrespective of varieties (Fig. 7), BR22 exhibited relatively higher Pn irrespective of moisture regime (Fig. 1), which was contributed by its ability to maintain higher leaf water potential and leaf water content (Fig. 8) than those of traditional varieties. These results were in agreement with the findings of Machado *et al*, 1996; Fukai and Cooper, 1995; Gomes *et al*, 1997; Fukai *et al*, 1999.

The reduction of the diffusion pressure deficit from air to leaf intercellular spaces at drought (Fig. 5) in all varieties was due to increase of CINT that resulted from the decrease of mesophyll conductance. BR22 maintained higher diffusion pressure deficit than traditional varieties, because it was able to run its Pn more actively than the traditional varieties by maintaining its better mesophyll conductance even at drought. But the higher diffusion pressure deficit in BR22 could not enhance the stomatal conductance because stomatal conductance was perhaps associated with other several factors. Thus stomatal conductance exhibited very weak association with Pn, while mesophyll conductance showed a very strong linear positive relationship with Pn (Fig. 12a, b and Fig. 13a, b). Similarly, leaf water potential showed positive linear association with Pn indicating its influence on Pn (Fig. 10 and 11). At drought the reduction of respiratory losses is an adaptive mechanism of a rice genotype. However, in the present study none of the genotypes was found potential in this regards. Because, after flowering, the lesser will be the maintenance respiration for the amount of biomass produced, the higher will be the net increase in dry matter accumulation in grains (Saitoh *et al*, 1998; Saitoh *et al*, 2000 and Swain *et al*, 2000).

Photosynthetic production in flag leaves after heading contributed about 73.4% of the total amount of grains mass (Qiu *et al*, 1993; Regina *et al*, 1994)). Due to drought, the flag leaf Pn was disrupted and drastically reduced and resulted in marked reduction in grain yield. Drought affected Pn more severely than any other traits. Hence post-anthesis Pn contributed little to grain development. As a result number of filled grains decreased, sterility % increased, grain size (1000-grain weight) decreased. The results were in agreement with the findings of Saxena *et a*l., 1996; Islam *et al*, 1997; Chauhan *et al*, 1999 and Park *et al*, 1999. The extent of difference in optimally irrigated and drought-imposed plants in terms of straw yield was perhaps due to higher rate of remobilization of pre-heading shoot reserve (dry mass) under drought stress (Chauhan *et al*, 1999).

## CONCLUSION

Post-anthesis drought markedly reduced grain yield irrespective of modern and traditional varieties. Reduction of photosynthesis rate due to drought is one of the vital causes for lower grain yield at terminal drought. Stomatal conductance was slightly affected but mesophyll conductance was severely affected and hence mesophyll conductance was found as the major determinant for reduction in photosynthesis rate under drought. Both modern and traditional varieties were not able to minimize their respiration rates. However, BR22 has some genetic potential to maintain relatively higher mesophyll conductance than traditional varieties even under drought. So, more studies should be conducted using more late maturing modern and traditional varieties to identify potential genotypes having capability of maintaining higher mesophyll conductance at post-anthesis drought in order to use in the breeding programne for developing drought resistant varieties.

**Table 1. Yield and yield components of three rice varieties evaluated for photosynthesis under optimal irrigated and post-anthesis drought during wet season 2000.**

| Variety | No. of panicles $hill^{-1}$ | Filled grains $panicle^{-1}$ | Sterility (%) | 1000-grain wt (g) | Grain weight (g $hill^{-1}$) | Straw wt (g $hill^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|
| | | | | *Optimal irrigated* | | | |
| R22 | 28.6 | 84.0 | 17.55 | 19.66 | 47.15 | 53.40 | 42.60 |
| Matichal | 26.6 | 45.3 | 22.84 | 27.42 | 32.65 | 80.19 | 29.02 |
| Kamargachikon | 25.8 | 50.8 | 21.05 | 28.16 | 36.90 | 89.73 | 29.29 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Post-anthesis drought* | | | | |
| BR22 | 25.6 | 52.8 | 48.45 | 17.24 | 23.12 | 52.66 | 30.56 |
| Matichal | 21.2 | 24.9 | 54.77 | 23.33 | 12.27 | 65.36 | 15.86 |
| Kamargachikon | 23.2 | 27.5 | 52.74 | 24.05 | 15.07 | 78.64 | 16.12 |
| LSD (5%) | 3.92 | 7.27 | 4.51 | 0.48 | 4.18 | 12.05 | 2.99 |
| CV% | 11.6 | 11.4 | 9.3 | 1.6 | 11.2 | 12.5 | 8.2 |

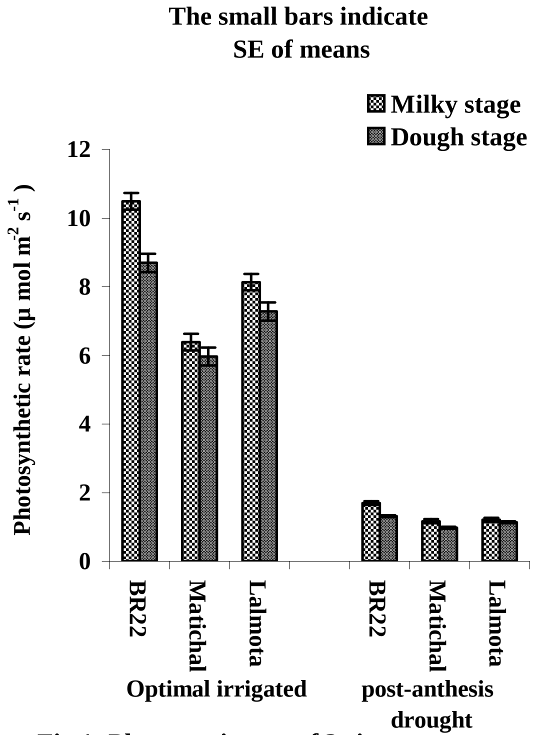


Fig.1: Photosyntic rate of 3 rice varieties

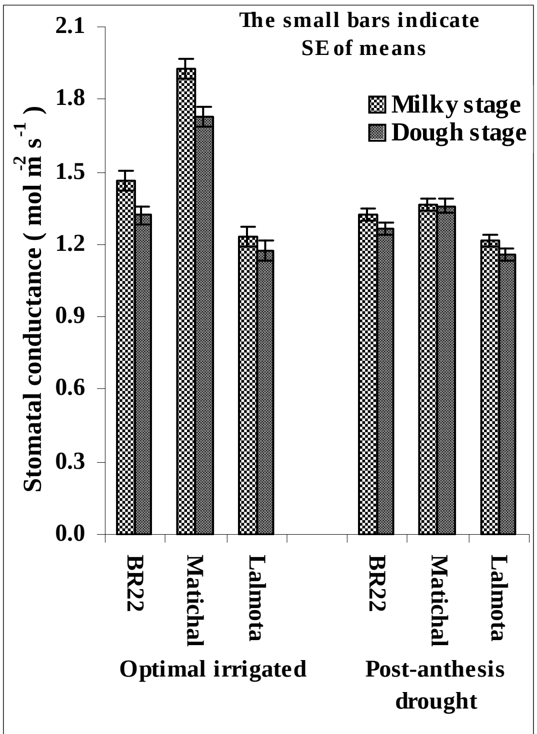


Fig.2: Stomatal Conductance of 3 rice varieties

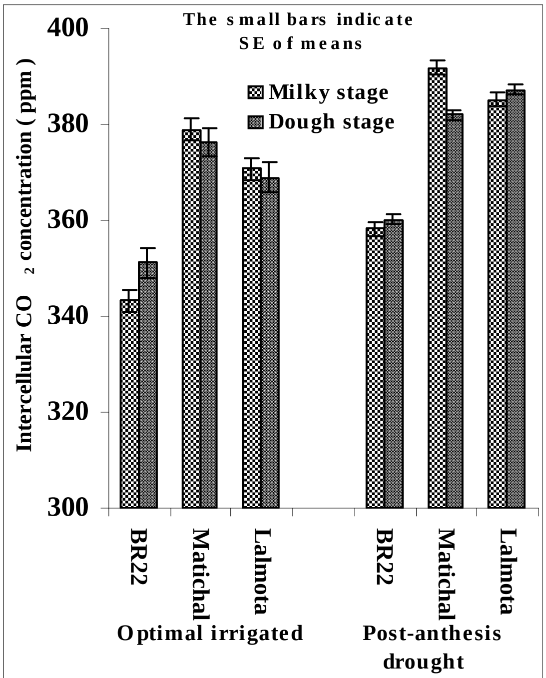


Fig.3: Intercellular $CO_2$ concentration of 3 rice varieties

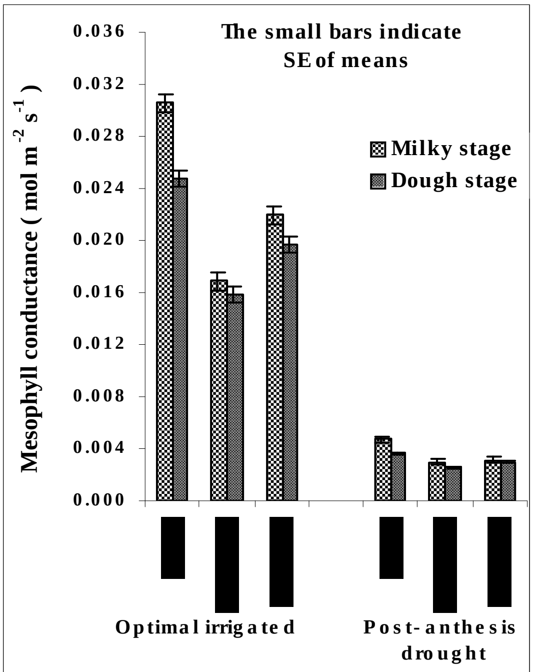


Fig.4: Mesophyll conductance of 3 rice varieties

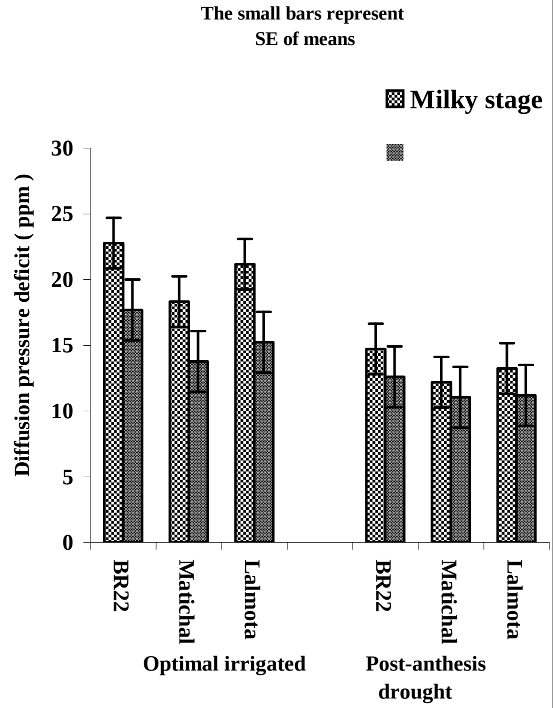


Fig.5: Diffusion pressure deficit of 3 rice varieties

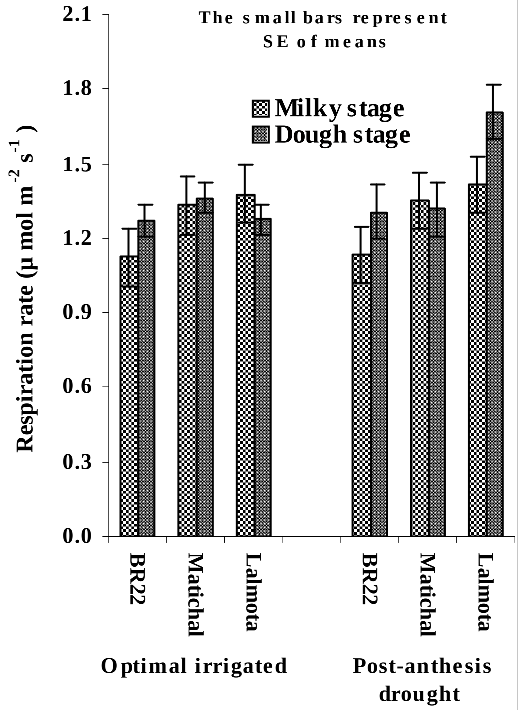


Fig.6: Respiration rate of 3 rice varieties

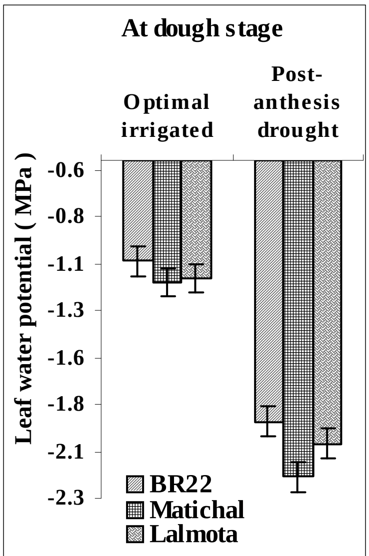


Fig. 7: Leaf water potential of 3 rice varieties

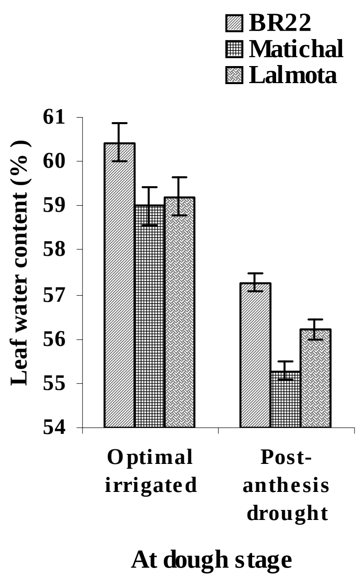


Fig. 8: Leaf water content of 3 rice varieties

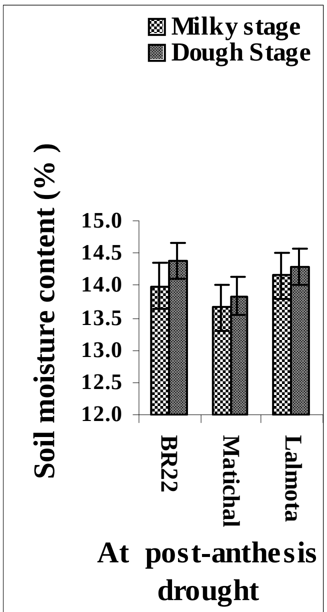


Fig.9: Soil moisture content at drought

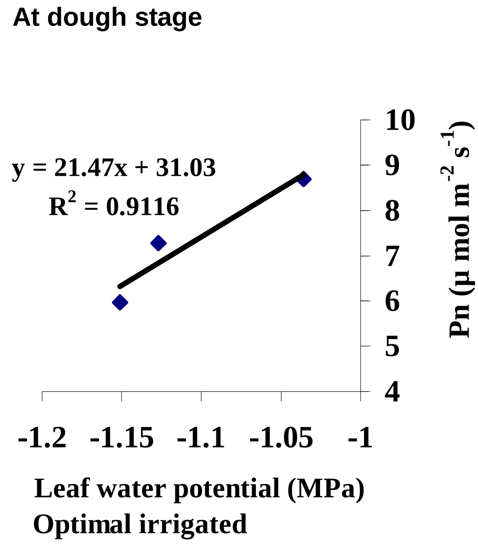


Fig. 10: Relationship between Pn and LWP at optimal irrigated condition

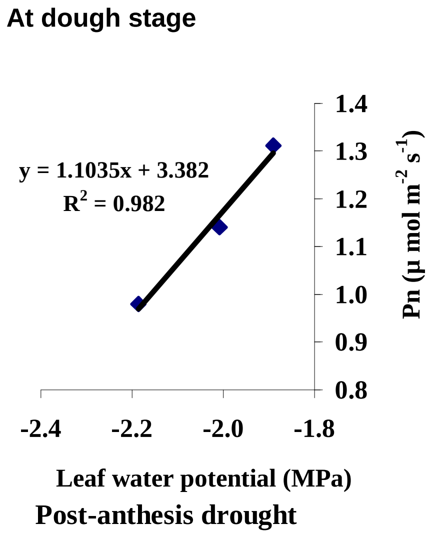


Fig. 11: Relationship between Pn and LWP at post-anthesis drought

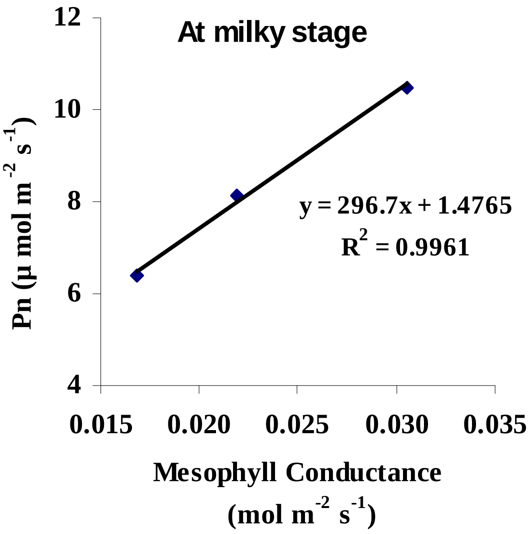


Fig.12a: Relationship between Pn and mesophyll conductance at optimal irrigated condition

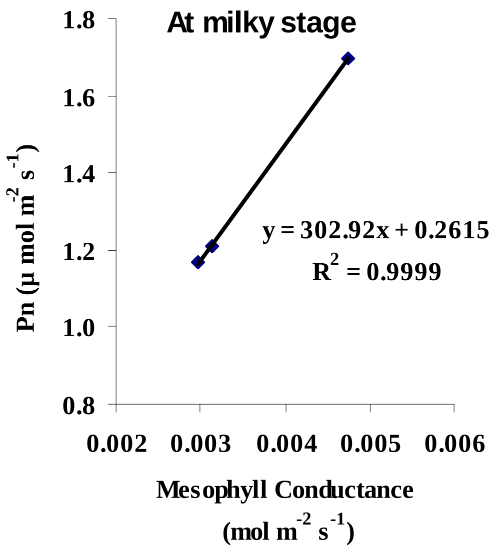


Fig. 12b: Relationship between Pn and mesophyll conductance at post-anthesis drought

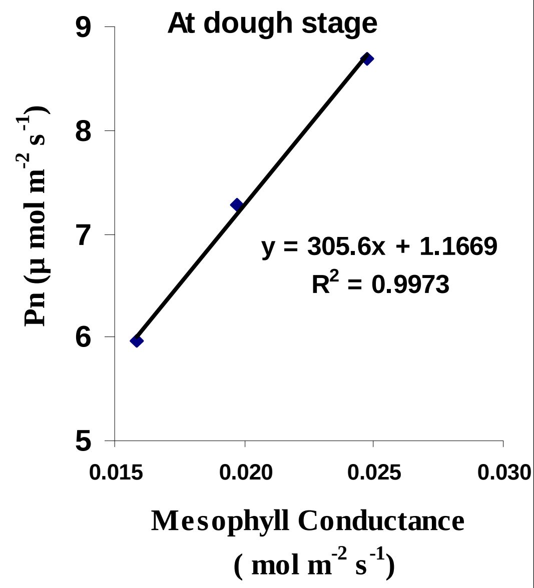


**Fig. 13a: Relationship between Pn and mesophyll conductance at optimal irrigated condition**

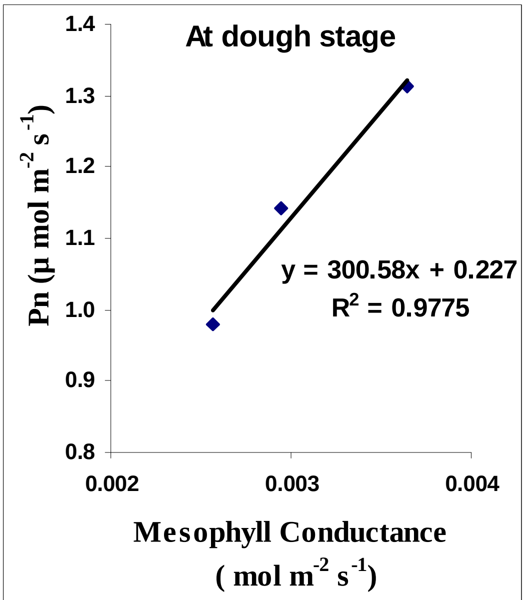


**Fig.13b: relationship between Pn and mesophyll conductance at post-anthesis drought**

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# Leaf Photosynthesis, Respiration and Associated Parameters of some Modern and Traditional Rice Varieties

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ABSTRACT

This study evaluates four modern and four traditional rice varieties in pots at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh, during wet season 2000 to compare some modern and traditional varieties in relation to photosynthesis (Pn), respiration and specific potential leaf characteristics such as stomatal conductance, mesophyll conductance, specific leaf weight (SLW), leaf chlorophyll and leaf nitrogen content. Photosynthesis and respiration rates with associated parameters were measured at panicle initiation (PI), booting, flowering and dough stages using portable photosynthesis measuring system (LiCOR-6200). Yield and yield attributes were recorded. The modern variety (MV), BRRI dhan32 exhibited the highest flag leaf Pn among all the varieties at booting and flowering stages. But BRRI dhan32 showed lower Pn than other varieties at PI stage (on fully expanded top leaf) which might be attributed to the differences in characteristics of the leaves selected at PI and reproductive stages (flag leaf) in relation to leaf chlorophyll and nitrogen contents. The traditional variety, Bunsha exhibited better Pn at all the measuring stages than the other traditionals except Kamargachikon only at booting stage. Mesophyll conductance paralleled leaf Pn and BRRI dhan32 displayed much higher rate than those of the others from booting to flowering. Very strong linear positive relationship was observed between Pn and mesophyll conductance at different growth stages ($R^2$=0.95-0.99). Varieties highly differed in stomatal conductance and the respiration rates were quite inconsistent at different successive growth stages. However, the respiration rates of three MVs such as BR10, BR11 and BRRI dhan32 declined sharply after booting, which is a good character of those varieties, contributing their maximum dry mass to grains. Among eight varieties BRRI dhan32 provided the highest grain yield and harvest index. The relationships between flag leaf N % at flowering and Pn at booting, flowering and dough stages were linear but gradually became weaker ($R^2$=0.6, 0.5 and 0.3 respectively). Similar trends were observed in relationship between flag chlorophyll-a and Pn ($R^2$=0.68, 0.65 and 0.40 respectively) and between flag chlorophyll-b and Pn ($R^2$=0.71, 0.62 and 0.41 respectively) at booting, flowering and dough stages. The linear relationship between Pn at flowering and grain yield ($R^2$=0.62) and filled grains hill$^{-1}$ ($R^2$=0.52) reveals that the greater was the Pn, the higher was the grain weight and filled grains hill$^{-1}$. Among the tested varieties, flag leaf of BRRI dhan32 was found more potential in respect of chlorophyll and nitrogen content and photosynthetic capacity. Mesophyll conductance might be one of the most potential attributes controlling the photosynthetic rate.

## INTRODUCTION

The yield of rice has been doubled in the last century through genetic improvement, management practice, control of pests and diseases, and a greatly increased fertilizer application rate (Evans, 1993; Kush, 2000). However, it is predicted that further improvements will be required to meet the demand of growing populations (Sheehy, 2000). Evidence suggests that many of the mechanisms used to improve rice yield in the past, such as canopy architecture and harvest index (HI), are now close to optimization and that future improvements will arise from an improvement in total biomass production (Cassman, 1994; Ying *et al*, 1998, Mann, 1999, 1999a; Horton, 2000; Sheehy, 2000; Long *et al*, 2006). A useful parameter is radiation use efficiency (RUE), which is the amount of biomass produced per unit of radiation intercepted. Comparison of different $C_3$ crop species showed that rice has one of the lowest RUE (Mitchell *et al*, 1998). It is strongly predicted that raising the leaf photosynthetic rate in rice will raise the RUE, biomass production and yield. Evidence exists that an increased photosynthetic rate forms the basis for an increase in canopy $CO_2$ fixation rate and productivity; for example, growth of crops in elevated $CO_2$ levels often results in a higher biomass production and yield (Ainsworth *et al*, 2004; Long *et al*, 2006). It seems likely that leaf photosynthetic rate will exert a higher degree of control on grain yield only when the effect of other factors such as partitioning, nutrient responsiveness and LAI have been minimized (Long *et al*, 2006). Since LAI is generally high in most crops, the increased assimilate production must come from improved photosynthesis.

However, still there is a question, whether the source or the sink is the yield-limiting factor (Egli, 1998), and it is incorrect to consider that source and sink operating independently. Indeed, the concepts of source and sink are redundant terms in the context of considering regulation and limitation of the biochemical processes that determine crop yield. For rice, there is clearly great promise in manipulation of the pathways leading to starch deposition in the developing grain. Photosynthesis in rice plants during the grain-filling period contributes 60-100% of the final grain carbon content (Yoshida, 1981). To achieve yield potential, metabolic activity within the grain must coincide with maximum activity of source leaves, especially the flag leaf (Murchie *et al*, 1999). Because, the flag leaf plays the most vital role in post-anthesis growth rate and grain development process (Regina *et al*, 1994). Photosynthetic production in flag leaves after heading contributed to 73.4% of the total grains mass in rice (Qiu *et al*, 1993).

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Yang *et al*, (2000) identified different patterns of grain filling among rice cultivars. The increase in sink activity may permit a greater export of carbohydrate from the leaves and relieve any end-product inhibition of photosynthesis (Winder *et al*, 1998). However, there is disagreement as to whether improving sink size alone in rice crops will also result in an increase in leaf or whole plant photosynthesis (Horton, 2000; Reynolds *et al*, 2000; Richards, 2000).

Besides, an adequate supply of N stimulates leaf growth via cell growth and division and $CO_2$ assimilation and related processes (Lawlor, 2002). Higher photosynthetic rate is achieved by higher leaf chlorophyll content, stomatal conductance and N concentration in leaf blades (Miah *et al*, 1997). Stomatal conductance can be used as a trait in breeding programme (Richards *et al*, 2000). Recently, variations in mesophyll conductance, have also been proposed (Ethier and Livingston, 2004; Manter and Kerrigan, 2004). Therefore, more understanding of the factors regulating grain filling and photosynthetic activities is important for improving rice yield potential. On the other hand, after flowering, the lesser the maintenance respiration, the higher the net increases in dry matter accumulation (Saitoh *et al*, 1998; Saitoh *et al*, 2000 and Swain *et al*, 2000). Therefore, the pattern of respiration during grain filling is important. But still the regulation of photosynthesis and respiration during the grain-filling period in rice is poorly understood. A recent study (Masumoto *et al*, 2004) suggested that *O. rufipogon* can be used as a source of germplasm to enhance the photosynthetic capacity of *O. sativa*. It is therefore, needed to study whether traditional rice cultivars have the traits that may be used potentially to increase photosynthetic capacities of modern rice varieties. The present study compared photosynthesis and respiration characteristics of some modern and traditional rice varieties along with their associated parameters in relation to grain yield and biomass production. If there is any potential attribute that may be considered in the breeding programme to break the yield ceiling.

## MATERIALS AND METHODS

The experiment was conducted in pots following CRD with 4 replications at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur (24° 09' N latitude and 90° 26' E longitude with an elevation of 8.4 m from the mean sea level), Bangladesh, during wet season, 2000. The soil used in the pots was silty clay of shallow red brown terrace soil under Madhupur Tract (AEZ 28), Salna series (Haider *et al*, 1991). The chemical properties of soil were: soil pH 6.34, organic matter 1.2%, total N 0.09%, total P 0.157 mg/100g soil and exchangeable K 0.136 meq/100g soil. Each pot contained about 15 kg soils. Fertilizers were applied in the soil of the pots @ 80:60:40:10:3 kg N, $P_2O_5$, $K_2O$, S Zn $ha^{-1}$ (1 ha soil = $2 \times 10^6$ kg) respectively, as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphat ($ZnSO_4$). Except urea, all the fertilizers were uniformly mixed in the soil before filling in the pots. The urea was uniformly top-dressed in four equal splits up to panicle initiation stage.

Four modern varieties (MVs) (BR10, BR11, BR22 and BRRI dhan32) developed by Bangladesh Rice Research Institute (BRRI) and four traditional varieties, BSMRAU germplasm code no. IPK3001 (Lalmota), IPK10002 (Bunsha), IPK1021 (Kamargachikon) and IPK3011 (Bashfulchikon) collected from Jhalakathi, Khulna and Chittagong districts of the country having diverse agro-ecological environments, were evaluated. The traditional varieties were selected mainly based on their wide cultivation in those areas during wet season. Thirty-six-day old seedlings were transplanted on 30 July 2000 at the rate of two seedlings per pot. Irrigation and other intercultural operations were uniformly done.

Specific leaf weight (SLW) was determined as leaf weight/leaf area (mg $cm^{-2}$) and chlorophyll a and chlorophyll b were determined as per Arnon (1949) and leaf nitrogen was determined as per Cataldo *et al*, 1974. Photosynthesis and respiration rates together with associated parameters were measured using the fully expanded upper most leaves at panicle initiation (PI) while the flag leaves at booting, flowering and dough stages using portable photosynthesis measuring system (LiCOR-6200) between 11.00 and 14.00 hrs at a uniform light intensity (around 1550 quantum) provided artificially in laboratory. At the time of measurement the maximum temperature ranged 29.71°-31.69°c and the minimum temperature ranged 19.20°-23.91°c and the relative humidity ranged 77.26-80.16% at 9.00 hrs and 53.90-70.38% at 14.00 hrs (Plant Physiology Division, BRRI, Gazipur, about five km from BSMRAU lab).

The data recorded were net photosynthetic rate (μ mol $m^{-2}$ $s^{-1}$), stomatal conductance (mol $m^{-2}$ $S^{-1}$), leaf intercellular $CO_2$ concentration (CINT) (ppm), mesophyll conductance (mol $m^{-2}$ $s^{-1}$) as Pn/CINT (Kubota and Hamid, 1992). $CO_2$ concentation gradient or diffusion pressure deficit (DPD) (the driving force from air to leaf intercellular space) was calculated as $CO_2$ concentration in air - CINT and respiration rate (μ mol $m^{-2}$ $s^{-1}$) was recorded. Grain weight $hill^{-1}$ (g) and yield attributes were recorded. ANOVA and LSD were employed by statistical package IRRISTAT windows version 4.0, 1998.

## RESULTS AND DISCUSSION

### Photosynthetic rate

At PI stage, Pn of traditional varieties (Bunsha and Kamergachikon) were found better than the modern varieties except for BR22 (Fig. 1). The lesser Pn was recorded in BR11 and BRRI dhan32 at PI stage. At booting stage BRRI dhan32 exhibited the highest Pn followed by Kamargachikon while the other varieties showed drastic reduction of Pn. Although BRRI dhan32 registered lower Pn at flowering than earlier booting stage, the reduction was rather minimal in BRRI dhan32 maintaining much higher Pn than the other varieties. At flowering, in general the MVs found better than traditional varieties and BRRI dhan32 showed the highest Pn followed by Bunsha. At dough stage the differences in Pn among varieties were reduced but Bunsha registered the highest Pn followed by BRRI dhan32.

The sharp differences in Pn of BRRI dhan32 at PI and booting might be attributed because of differences in the characteristics of selected leaves (fully expanded upper most leaves at PI and flag leaves at booting, flowering and dough stages) in relation to leaf chlorophyll and N contents (Table 1). The flag leaf of BRRI dhan32 attributed with higher chlorophyll and N contents than those of fully expanded uppermost leaf at PI stage. In other studies, changes in photosynthesis, SLW, chlorophyll and N contents were observed in rice due to positional changes of leaves (Sarkar *et al*, 1998; Chen *et al*, 2000). Varietal difference in flag leaf photosynthesis was also reported by other workers (Saitoh *et al*, 2002).

### Stomatal conductance

Varieties also differed in stomatal conductance at PI and booting stages but the differences narrowed down at subsequent flowering and dough stages (Fig. 2). Kamargachikon and Bashfulchikon both showed much higher rate of stomatal conductance at PI stage. At booting stage, Kamargachikon showed the highest stomatal conductance and then reduced drastically at flowering and dough stage. Bashfulchikon reduced stomatal conductance drastically at booting, flowering and dough stages. The trend of the changes in stomatal conductance in Kamargachikon paralleled the changes in Pn over time from PI to flowering (Fig. 1 and 2) but in other varieties, changes in Pn apparently were not related with the changes in stomatal conductance. So, stomatal conductance was not the major determinant for higher Pn.

### Intercellular $CO_2$ concentration

The changes in intercellular $CO_2$ concentration (CINT) among the varieties at the subsequent PI, booting, flowering and dough stages were highly inconsistent (Fig. 3). CINT was found the highest in BR11, BR22, BR10 and Kamargachikon respectively, at PI, booting, flowering and dough stages. But the higher CINT was not related with higher Pn.

### Diffusion pressure deficit (DPD)

The DPD among the varieties were also highly inconsistent at PI, booting, flowering and dough stages. Although, DPD sharply varied among the varieties at PI stage, the variations narrowed down over time. However, the trend indicated that BRRI dhan32 was able to maintain a steady higher DPD in all measuring stages (Fig. 4). Also Bunsha had the ability to maintain a moderate level of DPD in all stages. So, maintaining a higher DPD may be one of the vital factors for maintaining higher Pn.

### Mesophyll conductance

Mesophyll conductance paralleled the leaf photosynthesis rates. BRRI dhan32 displayed much higher rate of mesophyll conductance from booting to flowering stages followed by Kamargachikon at booting and Bunsha at flowering stage (Fig. 5). Lalmota and Bansfulchikon showed the lower rate of mesophyll conductance from booting to dough stages. It was observed that maintaining a higher rate of mesophyll conductance of leaf is the genetic ability of a particular variety and appeared as the major determinant governing Pn.

**Respiration rate**

Change in respiration rates in respect of growth stages or varietal differences was also highly inconsistent. Respiration rates of BR10, BR11 and BRRI dhan32 tended to increase reaching a peak at booting stage. It declined sharply thereafter reaching a minimum at dough stage. However in BR22 a large degree of fluctuation in respiration rates was observed. Kamargachikon and Lalmota from PI to dough stages (Fig. 6). All four traditional varieties showed higher respiration rates compared to MVs at post-anthesis period (dough stage). At post-anthesis period if a genotype has the ability to reduce its respiratory losses; its maximum current photosynthesis will be transferred to the grains. BRRI dhan32 has the genetic ability to reduce the post-anthesis respiratory losses in flag leaf.

**Physioco-chemical properties of the leaves**

Leaf chlorophyll and leaf N contents were higher in BR22 and Kamargachikon at PI stage while it was higher in flag leaf of BRRI dhan32 at flowering (Table 1). The higher Pn of BR22 and Kamargachikon at PI and higher Pn of flag leaf of BRRI dhan32 at flowering thus can be related with their higher leaf chlorophyll and N contents. SLW of flag leaf ranged 3.99 - 5.19 mg $cm^{-2}$ at flowering stage while the lowest and the highest being recorded for penultimate leaf were 4.17 and 5.68 mg $cm^{-2}$ respectively. Among the varieties BR22 and Bunsha exhibited higher SLW for both flag and penultimate leaves.

**Relationship among parameters**

Pn is plotted against mesophyll conductance at different growth stages (Fig. 7) and very strong linear positive relationship ($R^2$=0.95-0.99) was observed. It seems that mesophyll conductance was the major determinant in the variation of leaf photosynthesis across the varieties. These results were in conformity with the findings of Saitoh *et al*, 1991 and Scartazza *et al*, 1998. On the other hand, Pn is plotted against stomatal conductance at different growth stages (figures were not given)) and virtually no relationship was observed ($R^2$=0.005-0.29). It indicates that with higher stomatal conductance the CINT may be higher but higher CINT could not increase Pn without higher mesophyll conductance. Leaf N was determined at PI (fully expanded upper leaf) and flag leaf at booting, flowering and dough stages. The relationship between flag leaf N % and Pn reveals that leaf N regulated Pn at all the growth stages. However, the relationship becomes gradually weaker from booting to dough stages ($R^2$=0.60, 0.50 and 0.32 respectively) (Fig. 8). Similar trends were observed in relationship between flag chlorophyll-a and Pn ($R^2$=0.68, 0.65 and 0.40 respectively) (Fig. 9) and between flag chlorophyll-b and Pn ($R^2$=0.71, 0.62 and 0.41 respectively) (Fig. 10) at booting to dough stages. Influence of leaf N concentration on Pn has also been reported by other workers and was relevant with the present study (Hasegawa and Hori, 1996; Miah *et al*, 1997). So, higher mesophyll conductance and higher leaf N and chlorophyll contents are the major determinants for higher Pn.

**Yield and yield attributes**

MVs outyielded the traditional varieties, with the highest as recorded for BRRI dhan32. MVs produced 56.63-64.51 g $hill^{-1}$, nearly 37% higher grain yield than the traditional varieties (27.79-51.84 g $hill^{-1}$). Bunsha had relatively higher yield than the other traditional varieties but significantly lower than the MVs (Table 2). In contrast, the traditional varieties produced much higher straw yield than the MVs. Stem plus grain yields together made up the aboveground total biomass. The traditional varieties produced significantly higher biomass than MVs. That higher biomass might be attributed from higher Pn of traditional varieties at vegetative stage. But later on at reproductive phase the Pn of traditional varieties reduced and because of higher respiration rate and lower partitioning capacity their grain yields become lower. That was further observed in the varietal differences for harvest index (HI). HI ranged 15.92-45.09, the highest being recorded for BRRI dhan32 and the lowest for Banshfulchikon. Magnitude of difference in HI was low among the MVs, but there was wide variation in HI among the traditional varieties that ranged 15.92-27.92, a variation of 75%.

The sterility in traditional varieties ranged 16.23-48.96% with an average of 35.87% while it differed from 20.77 to 29.35% among the MVs with an average of 25.09%. Striking difference between traditional and modern varieties was observed in filled grains panicle$^{-1}$ and it was somewhat influenced by their respective grain size (1000-grain weight or TGW). Among the varieties Kamargachikon, a traditional variety exhibited the smallest grain size (TGW was only 9.58g). Except Kamargachikon, TGW in three other traditional varieties ranged 22.33-29.14 g and in 4 MVs 19.65-24.17 g with their corresponding filled grains panicle$^{-1}$ were 43.27-62.59 and 71.23-85.65 respectively. Magnitude of variation in the number of panicles hill$^{-1}$ between the modern (34.50-39.75) and traditional (31.75-38.50) was rather small. It appears that the difference in grain yield between the modern and traditional varieties was mainly caused by the difference in sterility percentage or the number of filled grains hill$^{-1}$ (Table 2).

The closer association of grain yield and filled grains per hill with flag leaf Pn at flowering reveals that the greater was the Pn at flowering, the higher was the grain yield and filled grains hill$^{-1}$ (Fig. 11). The results were in agreement with the findings of Reddy *et al*. (1994) and Sharma *et al*. (1997). The flag leaf of BRRI dhan32 exhibited very potential physioco-chemical properties such as higher leaf chlorophyll and leaf N contents, mesophyll conductance those attributed to its higher Pn. In addition, its post-anthesis respiratory loss was also lower. These all-potential characteristics of BRRI dhan32 thus contributed to its higher post-anthesis Pn and grain yield. Lower yield of traditional varieties could be largely attributed to high degree of sterility and less amount of current photosynthesis (flag leaf Pn). Among the traditional varieties Bunsha was more potential in post-anthesis Pn and thus contributed to its higher grain weight than those of other traditionals.

## CONCLUSION

Among the Pn contributing parameters, the mesophyll conductance of the leaf might be one of the most potential attributes controlling the photosynthetic rate. The higher was the mesophyll conductance of leaf, the higher would be the Pn. The flag leaf of BRRI dhan32 appeared as the best among eight varieties in relation to mesophyll conductance, chlorophyll a, chlorophyll b and N contents enhancing post-anthesis photosynthesis rate that ultimately contributed to higher grain weight (64.51g/hill) than those of other varieties (27.79-63.97g hill$^{-1}$).

**Table 1. Leaf characteristics of traditional and modern rice varieties evaluated for photosynthesis during T. Aman, 2000.**

| | PI stage | | | Flowering stae | | | | |
|---|---|---|---|---|---|---|---|---|
| | Top leaf | | | Flag leaf | | | Penultimate leaf | Flag leaf |
| Variety | chlor a (mg g$^{-1}$) | chlor b (mg g$^{-1}$) | N (%) | chlor a (mg g$^{-1}$) | chlor b (mg g$^{-1}$) | N (%) | SLW (mg cm$^{-2}$) | SLW (mg cm$^{-2}$) |
| | | | | *Modern* | | | | |
| BR10 | 0.98 | 0.33 | 1.39 | 0.84 | 0.29 | 1.27 | 5.06 | 4.84 |
| BR11 | 0.94 | 0.32 | 1.36 | 0.89 | 0.30 | 1.31 | 4.17 | 4.08 |
| BR22 | 1.02 | 0.34 | 1.42 | 0.98 | 0.33 | 1.38 | 5.07 | 5.19 |
| BRRI dhan32 | 0.99 | 0.33 | 1.39 | 1.13 | 0.38 | 1.51 | 4.42 | 4.54 |
| | | | | *Traditional* | | | | |
| Bunsha | 0.94 | 0.32 | 1.35 | 1.00 | 0.34 | 1.40 | 5.68 | 5.16 |
| Lalmota | 0.85 | 0.29 | 1.28 | 0.86 | 0.30 | 1.29 | 4.90 | 3.99 |
| Kamargachikon | 1.05 | 0.35 | 1.44 | 1.01 | 0.34 | 1.41 | 5.35 | 4.34 |
| Bashfulchikon | 0.89 | 0.30 | 1.31 | 0.83 | 0.29 | 1.26 | 4.67 | 4.39 |
| LSD (5%) | 0.0461 | 0.0138 | 0.04 | 0.0398 | 0.0119 | 0.033 | 0.00021 | 0.0000 |
| CV% | 3.3 | 2.9 | 1.90 | 2.9 | 2.6 | 1.7 | 0.00000 | 0.0000 |

**Table 2. Yield and yield components of traditional and modern rice varieties evaluated for photosynthesis during T. Aman, 2000.**

| Variety | No. of panicles hill$^{-1}$ | Filled grains panicle$^{-1}$ | Sterility (%) | 1000-grain wt (g) | Grain wt (g hill$^{-1}$) | Total biological wt (g) | Harvest index (%) |
|---|---|---|---|---|---|---|---|
| | | | | *Modern* | | | |
| BR10 | 37.25 | 71.23 | 27.81 | 22.58 | 56.63 | 137.09 | 41.32 |
| BR11 | 34.50 | 73.15 | 29.35 | 24.17 | 60.24 | 143.35 | 42.04 |
| BR22 | 39.75 | 78.89 | 20.77 | 19.65 | 63.97 | 157.57 | 40.62 |
| BRRI dhan32 | 36.75 | 85.65 | 22.43 | 21.48 | 64.51 | 143.14 | 45.09 |
| | | | | *Traditional* | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bunsha | 34.00 | 62.59 | 16.23 | 26.00 | 51.84 | 185.74 | 27.92 |
| Lalmota | 38.50 | 43.68 | 31.57 | 29.14 | 46.78 | 204.74 | 22.89 |
| Kamargachikon | 33.25 | 87.36 | 48.96 | 9.58 | 28.39 | 157.87 | 17.97 |
| Bashfulchikon | 31.75 | 43.27 | 46.73 | 22.33 | 27.79 | 174.54 | 15.92 |
| LSD (5%) | 4.812 | 4.643 | 3.904 | 0.296 | 4.86 | 20.822 | 1.355 |
| CV% | 9.2 | 4.6 | 8.7 | 0.9 | 6.6 | 8.7 | 2.9 |

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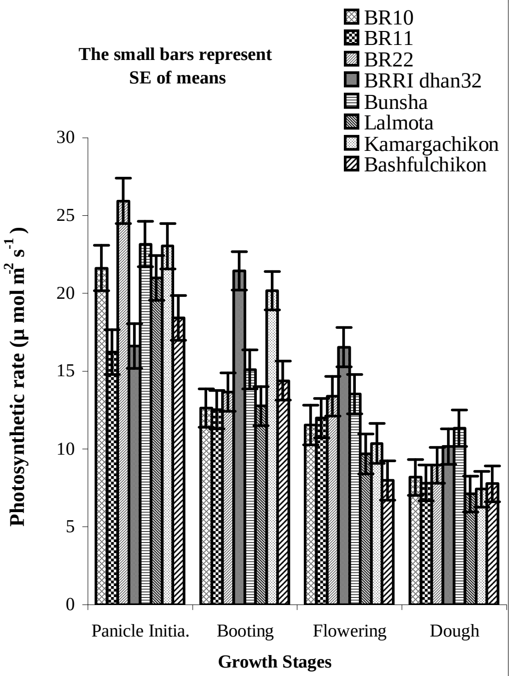


**Fig.1: Photosynthetic rate of traditional and modern rice varieties**

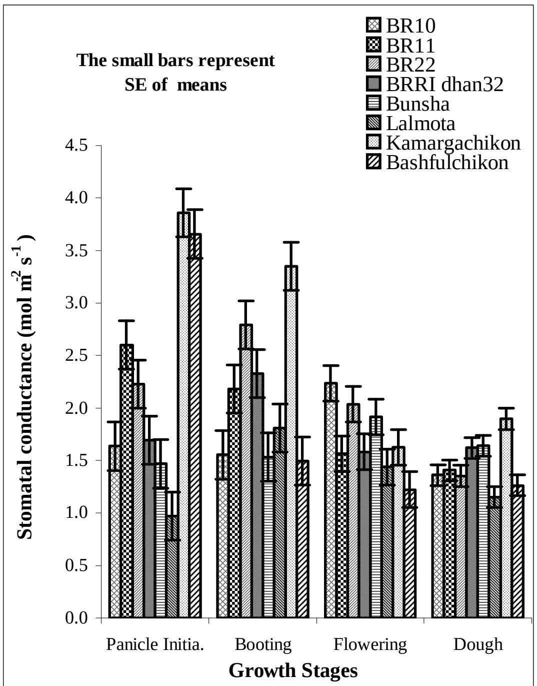


**Fig.2: Stomatal conductance of traditional and modern rice varieties**

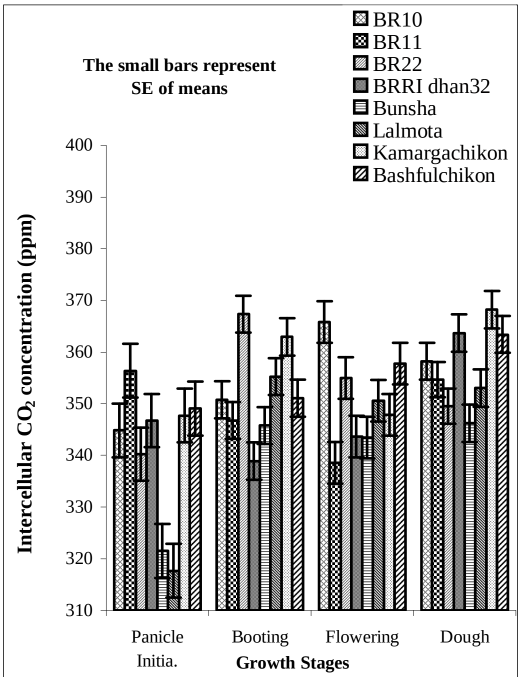


**Fig.3: Intercellular CO2 concentration of traditional and modern rice varieties**

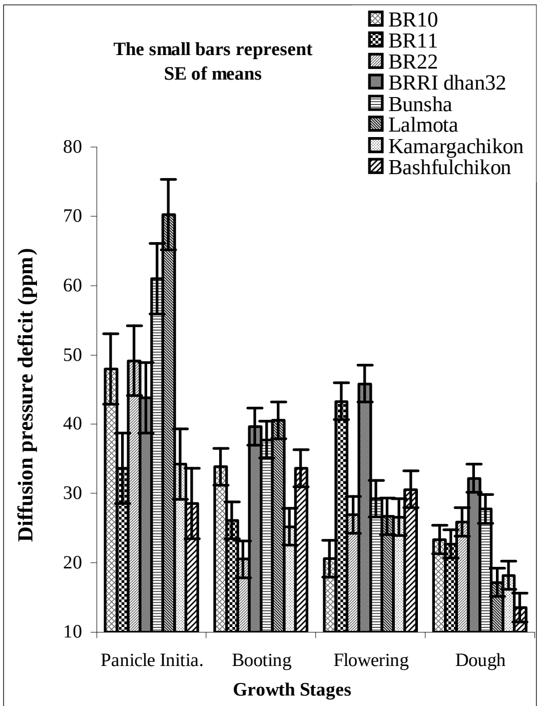


**Fig.4: Diffusion pressure deficit of traditional and modern rice varieties**

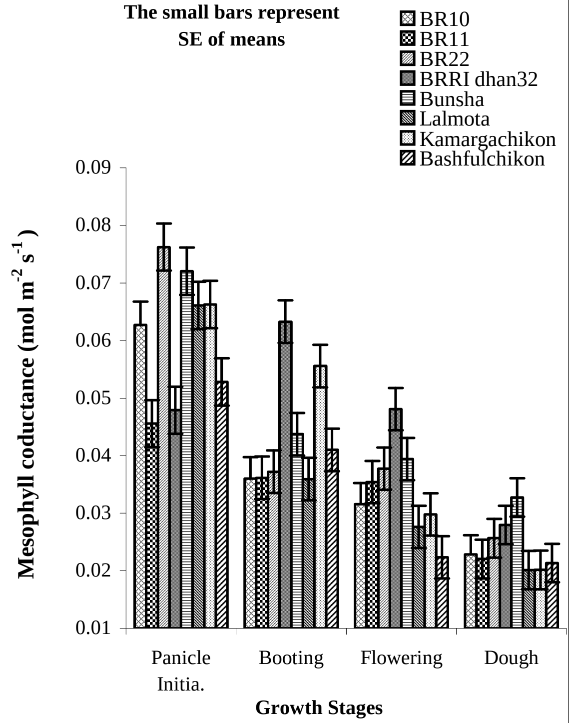


**Fig.5: Mesophyll conductance of traditional and modern rice varieties**

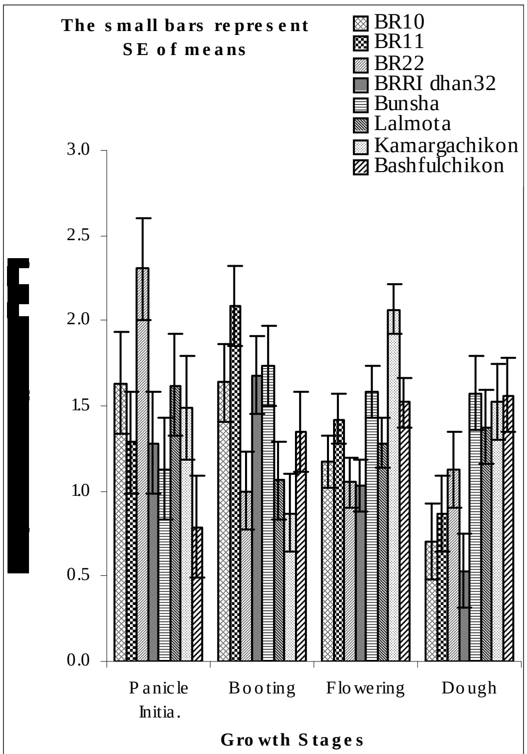


**Fig. 6: Respiration rates of traditional and modern rice varieties**

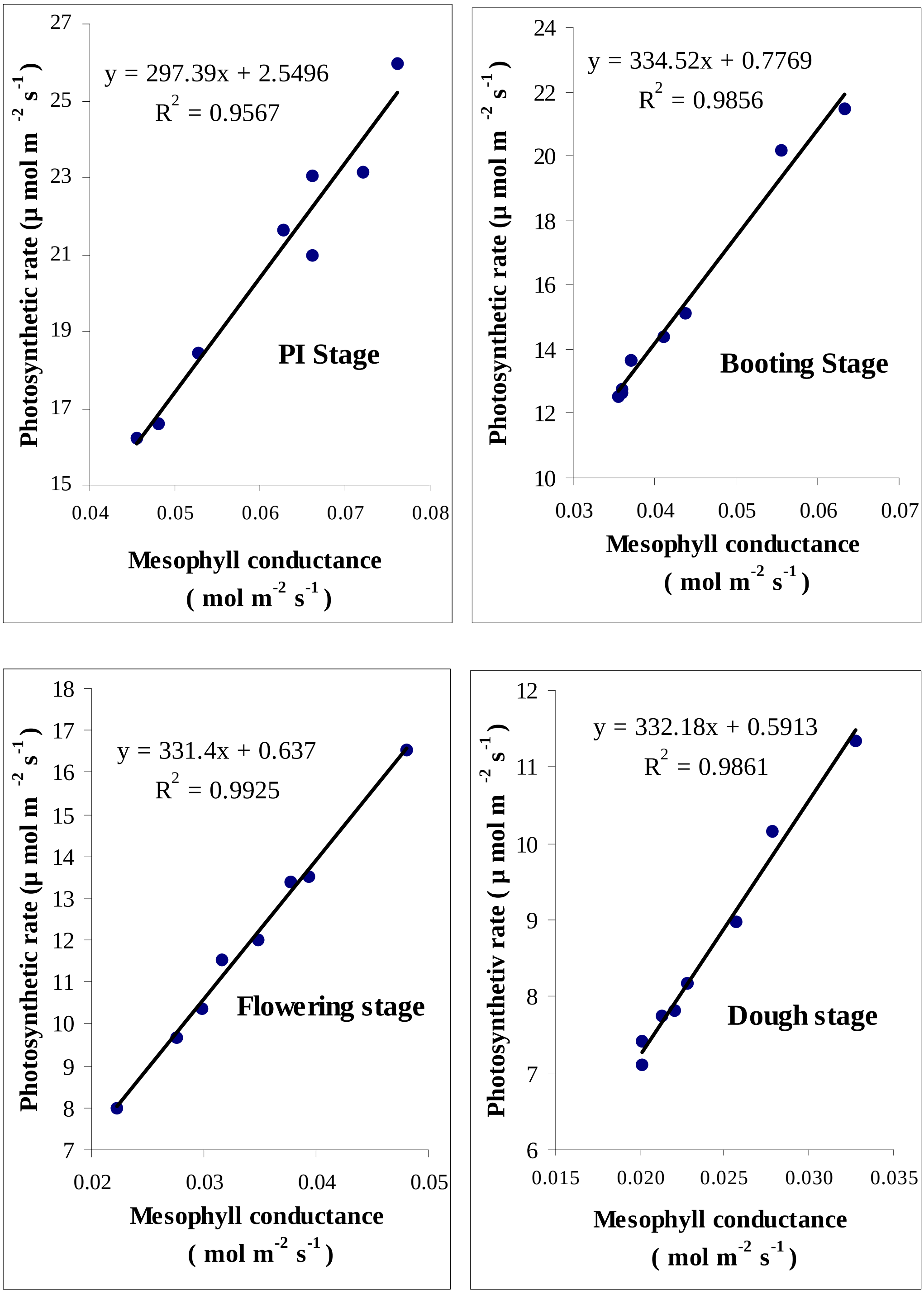


Fig.7: Relationship between Pn amd mseophyll conductance at PI, booting, flowering and dough stages.

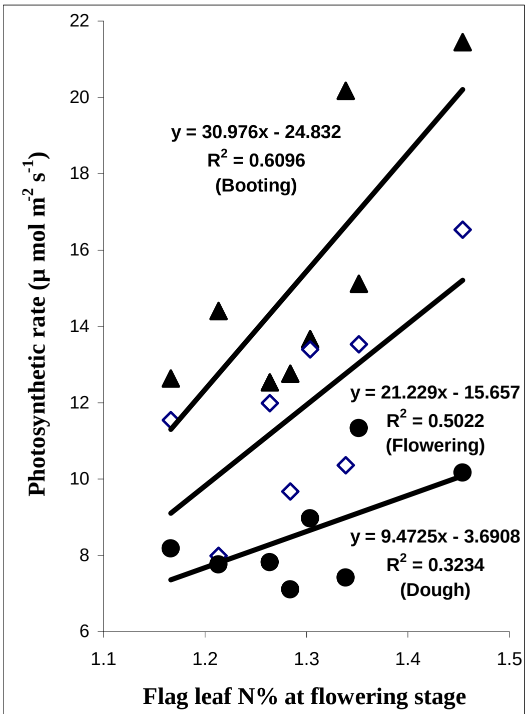


**Fig.8: Relationship between flag leaf N and Pn**

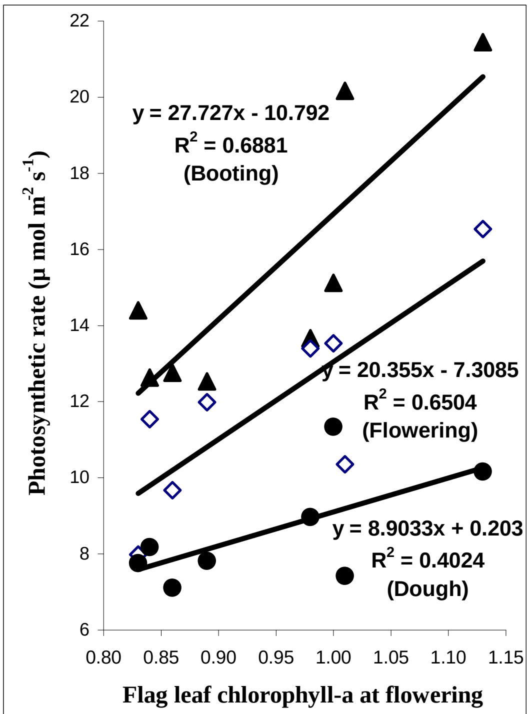


**Fig.9: Relationship between flag leaf chlorophyll-a and Pn**

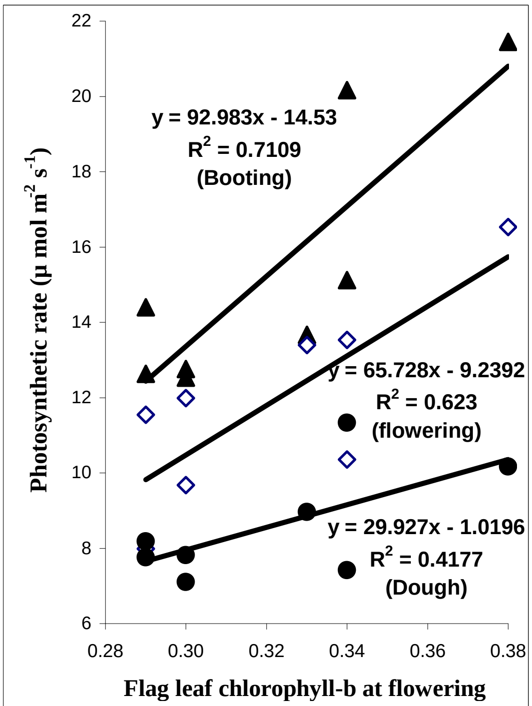


**Fig.10: Relationship between flag leaf chlorophyll-b and Pn**

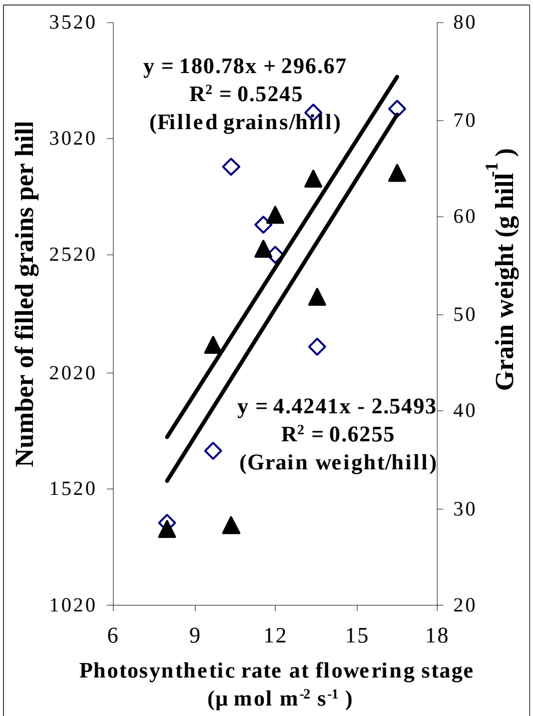


**Fig.11: Relationship between filled grains and grain weight per hill**

# Phosphorus Response and Use Efficiency of Lowland Rice at Different Soil Phosphorus Levels

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ABSTRACT

We conducted a field experiment during three consecutive years at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, Bangladesh (AEZ 28) on an aeric haplaquept soil with different levels of soil available P (modified Olsen) under Boro-Fallow-T. Aman cropping pattern. In this study, we wanted to know the response behaviour of wet land rice (cv. BRRI dhan29 (Boro) and BR11 (T. Aman)) to rates of added P fertilizers under different levels of soil available P and to determine P use efficiency and P nutrient accumulation during maturity stage. Results showed that P fertilizer @ 15 kg P $ha^{-1}$ for each season (Boro and T. Aman) produced 8-9 t $ha^{-1}$ $yr^{-1}$ grain yield, where soil available P is less than 7 mg $kg^{-1}$ (modified Olsen). Amount of P fertilizer application can be reduced to a variable extent for the same level of grain yield, where the soil P is more than 7 mg $kg^{-1}$ with similar soil characteristics. Phosphorus use efficiencies were significantly decreased with increasing the levels of soil available P and added P rates.

## INTRODUCTION

The cultivation of modern rice varieties increased the removal of P, K, S and other plant nutrients, and more rice soils are becoming P and K deficient than before. Inappropriate P fertilizer management coupled with increasing cropping intensity with modern high yielding variety (HYV) led P deficiency in many alluvial soils of Bangladesh. Acute P deficiency in soil caused a yield reduction in lowland rice by 50% or more (Saleque *et al,* 1998). In Bangladesh agriculture among the chemical fertilizers, phosphatic fertilizers rank the second position after nitrogen. Phosphorus requirement of rice is about 2.5 to 3.0 kg P per ton of rough rice, which is much less than that of N and K (Dobermann and Fairhust, 2000). About 25 kg P $ha^{-1}$ are generally recommended for MV rice cultivation under wetland rice culture, irrespective of P fertility status in Bangladesh (BARC, 1987). But the response of wetland rice to P fertilization is generally lacking in many soils of Bangladesh. This is perhaps due to the build up of P fertility in soil because of the repeated P fertilizer application. The apparent first season recovery of the added phosphorus from the inorganic fertilizer is usually in the range of 15-25% (Dobermann and Fairhaust, 2000), but direct measurements are rare. Considerable residual effect of the P fertilizer on the succeeding crop has also been reported by many workers (Saha, 1985; Meelu and Rekhi, 1981; Singh and Brar, 1986 and Dobermann et al, 1998). On the other hand, an emerging slogan of the world today is to minimize the use of agrochemicals for higher profit and safer environment. In Bangladesh a huge amount of phosphatic fertilizer is imported in every rice growing season. As a result, the country spends a lot of money on P fertilizer. In view of the above considerations, we conducted a study to determine a realistic P fertilizer recommendation for wetland rice cultivation. For this purpose, it is essential to know the response behaviour of wetland rice to rates of added P fertilizers under different levels of soil available P and to determine P use efficiency, and P nutrient accumulation during the maturity stage.

## MATERIALS AND METHODS

The experiment was carried out in the long-term P frequency experimental plots under Boro-Fallow-T. Aman cropping pattern at the BRRI farm, Gazipur (AEZ-28). The soil was an aeric haplaquept. Initial surface soil was a clay loam in texture, neutral in reaction (pH 7.1) and had organic C 1.0% and soil available P 8.5 mg $kg^{-1}$ (modified Olsen). Over the previous six years 300, 150, 100, 75 and 0 kg P $ha^{-1}$ were applied using TSP in five treatments depending on variations in frequencies of P fertilizer application. At the end of six years of cropping, these variable amounts of added P had resulted in five different levels of soil available P (modified Olsen), which were 13.5, 9.2, 6.6, 6.3 and 4.8 mg $kg^{-1}$ respectively. In Boro 1993, a P response trial was initiated on the same layout to evaluate P response of rice under each level of soil available P, so that a rational P fertilizer recommendation based on soil available P could be made. This study was continued up to 1995. The experiment was laid out in a split-plot design with three replications. Each plot was divided in to three sub-plots. In main plots were the soil available P levels. In the sub-plots three rates of P fertilizer (0, 15 and 30 kg P $ha^{-1}$) from TSP were applied randomly under each level of soil available P. In Boro and T.Aman seasons two MV rice BRRI dhan29 and BR11 were tested respectively. All P fertilizer as per treatment was applied as basal and thoroughly incorporated with soil before planting. A blanket dose of NKS @ 140-35-20 and 120-35-20 kg $ha^{-1}$ was applied for Boro and T. Aman respectively. Appropriate management practices were followed during each growing season. At maturity, grain (14% moisture) and straw (oven dry) yields were also recorded from each treatment

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following the standard procedures. Data on grain yield parameters were statistically analyzed following the IRRI STAT version 4.1 (IRRI, 1998). A portion of grain and straw samples was oven dried at 70 °C for three days and then ground in a Willey mill. These samples were analyzed for determination of P content by digesting with tri-acid mixture (Yoshida *et al*, 1972). Total P uptake was calculated. Agronomic efficiency (AE) (kg $kg^{-1}$) and apparent P recovery (%) were calculated following the formula described by Dobermann, A and Fairhurst, T H (2000). The formulas are as follows:

- **Agronomic efficiency (AE):** Agronomic efficiency of an added nutrient. Grain yield increase per unit nutrient added. It is expressed in kg $kg^{-1}$.
- **Recovery efficiency (RE):** Apparent recovery efficiency (%) of an added nutrient = increase in nutrient uptake per unit nutrient added × 100. Also sometimes it is referred to as uptake efficiency. It is expressed in percent.

## RESULTS AND DISCUSSION

### Grain yield (Boro rice)

In the first year (1993), grain yield increased significantly with increasing rates of P fertilizer application only where soil available P was 4.8 mg $kg^{-1}$ (Fig. 1). But at higher levels of soil available P (6.3 mg $kg^{-1}$ and above), application of P fertilizer at any rate did not increase grain yield. It is surprising to note that at the highest level of soil available P (13.5 mg $kg^{-1}$), P fertilizer application gradually decreased the grain yield and the yield decrease was significant at higher rate (Fig. 1 and Table 1). This might be the reason that due to higher P concentration in soil as well as higher rates of P application. Saha et al, 2006 reported that higher P absorption by rice plant was not utilized for higher grain production and this can be considered as luxury consumption of P due to its higher availability.

In the second year (1994), up to 9.2 mg $kg^{-1}$ soil available P level, application of P @ 15 kg P $ha^{-1}$ significantly increased the grain yield. However, the benefit from P application was not observed in rice grown on the soil with 13.5 mg $kg^{-1}$ soil available P; rather there was a negative effect. In the plot with 4.8 mg $kg^{-1}$ soil available P, increase in grain yield was dramatic, grain yield in P control ($P_0$) plot was only 1.34 t $ha^{-1}$, while application of P @ 15 kg P $ha^{-1}$ increased the grain yield to 5.12 t $ha^{-1}$. But further addition of P ie P @ 30 kg P $ha^{-1}$ did not increase the grain yield. In other responsive plots (soil available P content 6.3 to 9.2 mg $kg^{-1}$) application of 15 kg P $ha^{-1}$ increased grain yield by 27 to 41%.

In the third year (1995), the application of P fertilizer increased the grain yield in all soils containing 4.8 to 13.5 mg $kg^{-1}$ available P initially (Fig. 1). Like the second year, in the plot with 4.8 mg $kg^{-1}$ soil available P, grain yield increased dramatically. The yield of control ($P_0$) plot was only 1.67 t $ha^{-1}$, which increased significantly to 4.32 t $ha^{-1}$ with the application of 15 kg P $ha^{-1}$. But further addition of P i e P @ 30 kg P $ha^{-1}$ did not increase the grain yield. In other plots (soil available P 6.3 to 9.2 mg $kg^{-1}$) application of 15 kg P $ha^{-1}$ also significantly increased the grain yield but in case of 30 kg P $ha^{-1}$ application the grain yield was unchanged. Although not significant, a consistent yield increase was observed by P application of 15 kg P $ha^{-1}$ in soil with initial available P content of 13.5 mg $kg^{-1}$. The yield level of $P_0$ sub-plots of the plots containing 4.8 and 6.6 mg $kg^{-1}$ P were significantly lower than those obtained from plots containing 9.2 or 13.5 mg $kg^{-1}$ (LSD $_{0.05}$ for two soil means at P each level was 0.84).

### Grain yield (T. Aman rice)

In the first year (1993), the grain yield was increased significantly with 15 kg P $ha^{-1}$ application only where soil available P was 4.8 mg $kg^{-1}$. At the higher levels of soil available P (6.3 mg $kg^{-1}$ and above) application of P fertilizer at any rate did not increase grain yield. Moreover, P fertilizer application @ 30 kg P $ha^{-1}$ slightly depressed the grain yield (Fig. 2). The grain yield of second year (1994) was increased significantly with 15 kg P $ha^{-1}$ application in the plots where soil test P were 4.8, 6.3 and 6.6 mg $kg^{-1}$ (Fig. 2). Phosphorus at 30 kg P $ha^{-1}$ produced lower grain yield than that of 15 kg P $ha^{-1}$ in those plots (Fig. 2). At the higher levels of soil available P (9.2 mg $kg^{-1}$or above), like the first year, added P showed a negative result. In the third year (1995) there was a similar trend like the previous Boro rice (1995). In plots with soil available P 4.8 to 9.2 mg $kg^{-1}$, the application of 15 kg P $ha^{-1}$ significantly increased the grain yield. The application of 30 kg P $ha^{-1}$ did not give any positive result, but in some instances it depressed the grain yield (Fig. 2). Like the previous Boro crop, a non-significant consistent yield increase was observed by P application of 15 kg P $ha^{-1}$ in soil with initial available P content of 13.5 mg $kg^{-1}$. It indicated that the soil P level in $P_0$ plots may have came down very close to the critical level after four to five crops.

From the above discussion it is observed that P fertilizer application @ 15 kg P $ha^{-1}$ for each season (Boro and T.Aman) produced 8- 9 t $ha^{-1}$ $yr^{-1}$ grain yield, where soil available P is less than 7 mg $kg^{-1}$ (modified Olsen) (Figs. 1 and 2).

### Phosphorus uptake and use efficiency

A relationship between P uptake and grain yield of lowland rice in both seasons was determined (Fig. 3). The relationship was significant and linear in both the season ($R^2$ = 0.60 and 0.65 for Boro and T.Aman, respectively).

Agronomic use efficiency (AE) (kg $kg^{-1}$) and apparent P recovery (%) were calculated (Tables 2 and 3). AE was significantly decreased with increasing the levels of soil available P and added P rates (Table 2). AE varied from 83 (mean of three years) at 30 kg P $ha^{-1}$ level to 150 (kg $kg^{-1}$) at 15 kg P $ha^{-1}$ level in Boro season and in T. Aman season it varied from 29 at 30 kg P $ha^{-1}$ level to 78 (kg $kg^{-1}$) at 15 kg P $ha^{-1}$ level in the plot where soil available P was 4.8 mg $kg^{-1}$ (Table 2). Comparable results were reported by Dobermann *et al* (1998). At higher levels of soil available P it decreased gradually in both levels of applied P. Similar trend was also found in case of apparent P recovery (Table 3). Apparent P recovery varied from -9 to 75 %.

## CONCLUSIONS

Based on three years experiment, it is concluded that P fertilizer application @ 15 kg P $ha^{-1}$ for each season (Boro and T. Aman) would be enough to produce 8-9 t $ha^{-1}$ $yr^{-1}$ grain yield, where soil available P is less than 7 mg $kg^{-1}$ (modified Olsen). An amount of P fertilizer application can be reduced to a variable extent for the same level of grain yield, where the soil available P is more than 7 mg $kg^{-1}$ with similar soil characteristics.

**Table 1. LSD $_{0.05}$ value for two P means at each soil level for grain yield ($tha^{-1}$).**

| Year | $LSD_{0.05}$ value | |
|---|---|---|
| | Boro | T. Aman |
| 1993 (Y1) | 0.32 | 0.66 |
| 1994 (Y2) | 0.68 | 0.21 |
| 1995 (Y3) | 0.67 | 0.58 |

**Table 2. Agronomic efficiency of BRRI dhan29 (Boro) and BR11 (T. Aman) as affected by rates of P fertilizer application in soil with different levels of available soil P contents in a Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur, 1993-95.**

| Soil P (mg $kg^{-1}$) | Agronomic efficiency (AE) (kg $kg^{-1}$) | | | |
|---|---|---|---|---|
| | Application P levels (kg $ha^{-1}$) | | | |
| | 15 | 30 | 15 | 30 |
| | Boro | | T. Aman | |
| | 1993 | | | |
| 4.8 | 21 | 32 | 53 | 28 |
| 6.3 | -2 | -7 | -1 | -8 |
| 6.6 | -13 | -3 | 7 | 4 |
| 9.2 | -15 | 0 | 5 | -12 |
| 13.5 | -15 | -13 | -28 | -15 |
| | 1994 | | | |
| 4.8 | 252 | 123 | 55 | 10 |
| 6.3 | 77 | 47 | 15 | 10 |
| 6.6 | 96 | 55 | 47 | 11 |
| 9.2 | 73 | 28 | 10 | 3 |
| 13.5 | -45 | -32 | -6 | -2 |
| 1995 | | | | |
| 4.8 | 177 | 93 | 125 | 50 |
| 6.3 | 51 | 35 | 45 | 40 |
| 6.6 | 110 | 71 | 114 | 56 |
| 9.2 | 69 | 30 | 63 | 38 |
| 13.5 | 41 | 19 | 25 | 18 |
| | Mean (3 yrs) | | | |
| 4.8 | 150 | 83 | 78 | 29 |
| 6.3 | 42 | 25 | 20 | 14 |
| 6.6 | 64 | 41 | 56 | 24 |
| 9.2 | 42 | 19 | 26 | 10 |
| 13.5 | -6 | -9 | -3 | 0 |

**Table 3. Apparent P recovery efficiency of BRRI dhan29 (Boro) and BR11(T. Aman) as affected by rates of P fertilizer application in soil with different levels of available soil P contents in a Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur, 1993-95.**

| Soil P (mg $kg^{-1}$) | Apparent P recovery efficiency (RE) (%) | | | |
|---|---|---|---|---|
| | Application P levels (kg $ha^{-1}$) | | | |
| | 15 | 30 | 15 | 30 |
| | Boro | | T. Aman | |
| | 1993 | | | |
| 4.8 | 31 | 32 | 35 | 25 |
| 6.3 | 7 | 6 | 19 | 8 |
| 6.6 | 13 | 12 | 21 | 19 |
| 9.2 | -9 | 4 | 11 | 7 |
| 13.5 | -6 | -6 | -3 | -1 |
| | 1994 | | | |
| 4.8 | 75 | 48 | 38 | 27 |

| | | | | |
|---|---|---|---|---|
| 6.3 | 41 | 42 | 20 | 15 |
| 6.6 | 57 | 38 | 21 | 21 |
| 9.2 | 56 | 32 | 17 | 13 |
| 13.5 | 11 | 6 | 12 | 13 |
| | | 1995 | | |
| 4.8 | 39 | 35 | 71 | 37 |
| 6.3 | 33 | 28 | 39 | 40 |
| 6.6 | 46 | 29 | 59 | 33 |
| 9.2 | 30 | 22 | 45 | 29 |
| 13.5 | 25 | 20 | 31 | 19 |
| | | Mean (3 yrs) | | |
| 4.8 | 48 | 38 | 48 | 30 |
| 6.3 | 27 | 25 | 26 | 21 |
| 6.6 | 39 | 26 | 34 | 24 |
| 9.2 | 26 | 19 | 24 | 16 |
| 13.5 | 10 | 7 | 13 | 10 |

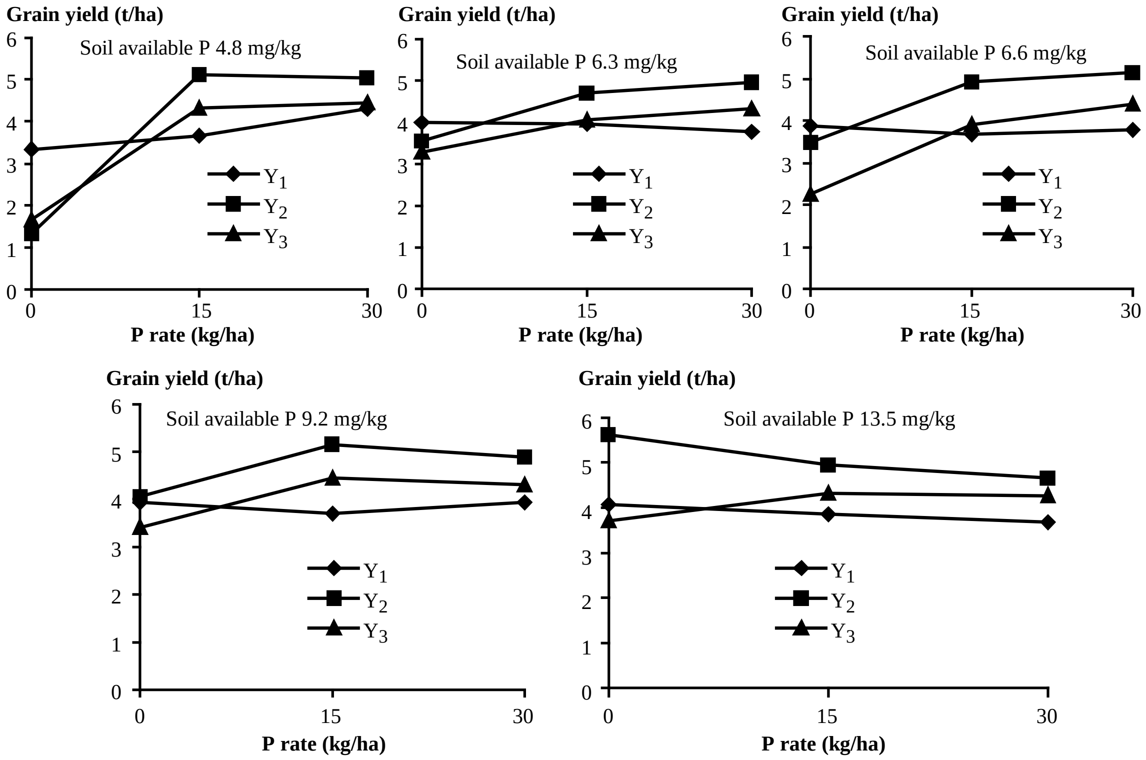


Fig. 1. Phosphorus respose curve of Boro rice at different levels of soil available P during 1993-95.

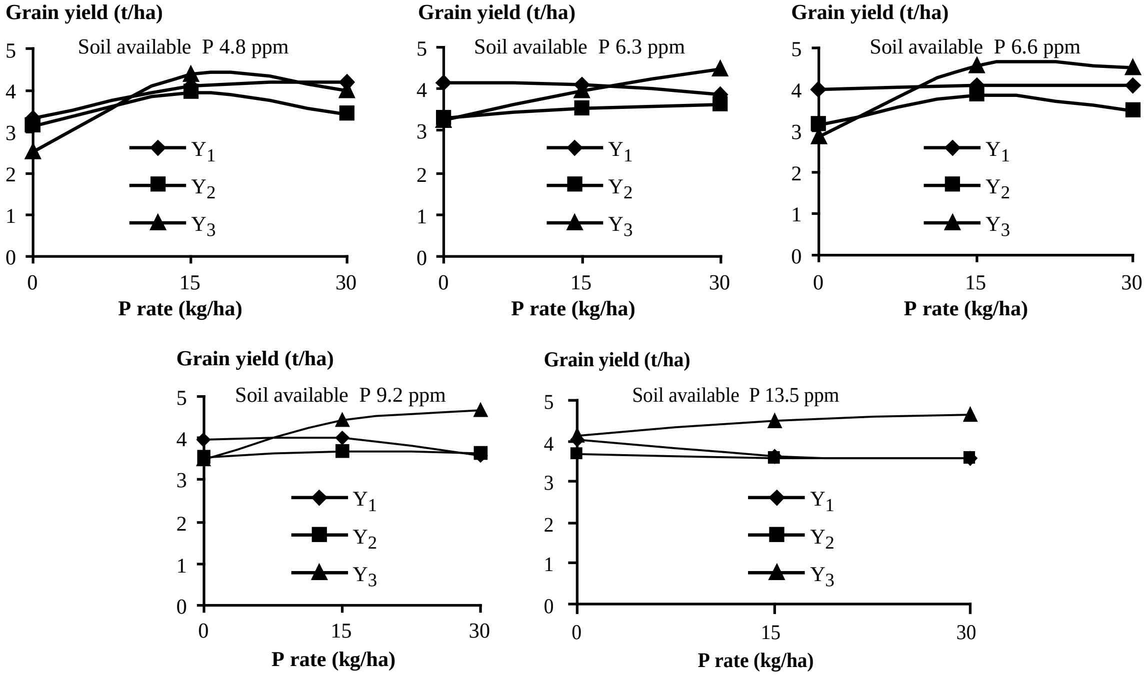

Fig. 2. Phosphorus respose curve of T. Aman rice at different levels of soil available P during 1993-95.

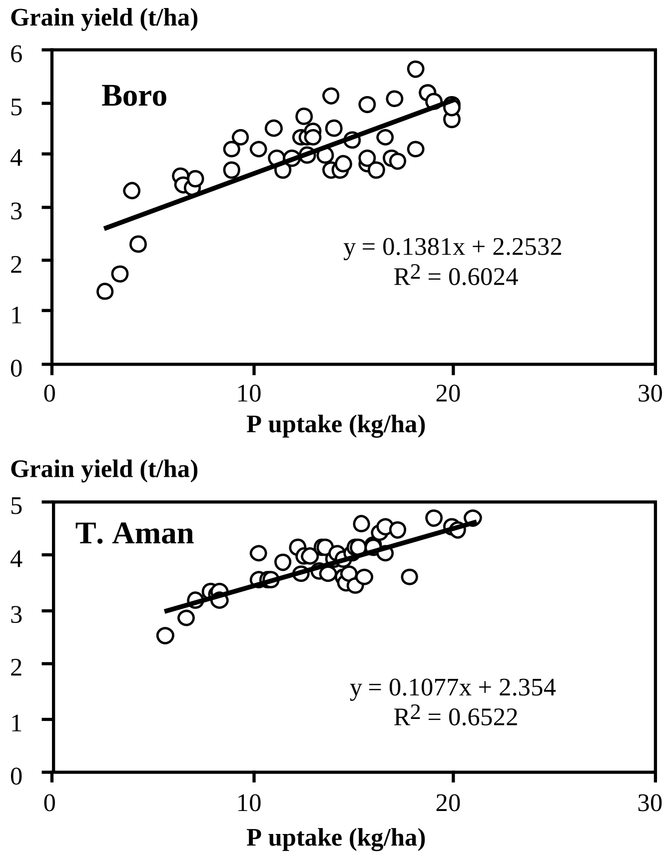


Fig. 3. Relationship between P uptake and grain yield of Boro and T. Aman rice across the three years.

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# Zinc and Nitrogen Interaction in HYV Rice Grown in Calcareous Soil

P K Saha[6], M Akter[7], M Hossain[8] and S K Zaman[9]

ABSTRACT

This study takes an attempt to assess the interaction effect of Zn and N on the yield of HYV rice grown in calcareous soil. For this we did a field experiment at the Bangladesh Rice Research Institute (BRRI) regional station farm, Rajshahi (AEZ-11, HL) during Boro and T. Aman seasons of 2008-09. In Boro season, four doses of N (0, 40, 80 and 120 kg $ha^{-1}$) and Zn (0, 2.5, 5.0 and 7.5 kg $ha^{-1}$) were used as treatments while in T. Aman season, doses of N were 0, 30, 60 and 90 kg $ha^{-1}$ and the residual effects of Zn were studied. A flat dose of P K S @15-50-10 kg $ha^{-1}$ was applied. The experiment was laid out in a RCB (2-factorial) design with three replications. The result showed that application of Zn and N significantly increased grain yield, Zn concentration in the grain and total Zn uptake of the rice varieties. In Boro season, the highest grain yield was obtained when 120 kg $ha^{-1}$ N was applied along with 7.5 kg $ha^{-1}$ Zn, where as in T. Aman season the highest grain yield was found in 90 kg $ha^{-1}$ N with 2.5 kg $ha^{-1}$ Zn treatment. In general, it may be concluded that application of Zn in calcareous soil along with N significantly increased yield of HYV rice.

## INTRODUCTION

The Zn content of agricultural soils and crops in Bangladesh has attracted attention at present time as a result of a growing awareness about environmental and food quality issues among the producers and consumers. Nutrient deficient agricultural soils in Bangladesh have been remedied especially through the application of fertilizers containing NPK. The demand of the use of Zn fertilizers in low land rice is increasing day by day. In Bangladesh, about 30% of rice soils are zinc deficient (BARC, 2005). Continuous use of high amount of nitrogenous fertilizers and intensive cultivation of high yielding cereal crop varieties during the last few decades have resulted in widespread Zn deficiency especially in calcareous soil in Bangladesh. Ozanne (1955) reported severe Zn deficiency in subterranean clover with increasing N supply due to formation of Zn-protein complex in the roots. Langin *et al*, 1962 observed that fertilizer N through $NH_4NO_3$ enhanced the Zn uptake despite substantial dilution caused by yield increase from N application. Conversely, Miller *et al*, 1964 reported that applied N at a lower dose did not affect the Zn content, but increased it at higher doses. However, there is scant information about the interactions between Zn and N on wet land rice. So, the present study was conducted to examine the nature of the interaction between Zn and N in rice crops as it is a major crop in Bangladesh.

## MATERIALS AND METHODS

The field experiment was conducted in Boro and T. Aman seasons during 2008-09 at the Bangladesh Rice Research Institute (BRRI) regional station farm, Rajshahi (AEZ-11, land type-high land (HL)). The soil of the experimental field was silty-clay-loam with pH=7.7. Organic C, total N, available P, exchangeable K and available S of the soil was 1.2 %, 0.13%, 15.0 mg $kg^{-1}$, 0.18 meq /100 g soil and 11.8 mg $kg^{-1}$, respectively. The available Zn (EDTA extracted) of the soil was 1.23 mg $kg^{-1}$. In Boro season, four doses of N ie 0, 40, 80, 120 kg $ha^{-1}$ and four doses of Zn ie 0, 2.5, 5.0, 7.5 kg $ha^{-1}$ were imposed as treatment. In T. Aman season, four doses of N ie 0, 30, 60, 90 kg $ha^{-1}$ and the residual effect of previous applied Zn doses were observed. The experiment was laid out in a RCB (2-factorial) design with three replications. Each plot received a blanket dose of P, K and S at the rate of 15-50-10 kg $ha^{-1}$, respectively. BRRI dhan45 and BRRI dhan49 were used as test variety in Boro and T. Aman season respectively. Forty-five-day-old (Boro) and 30-day-old (T. Aman) seedlings of each variety were transplanted at 20- × 20-cm spacing. Full doses of Zn as $ZnSO_4$. $7H_2O$ and other non-urea fertilizers were applied as basal during final land preparation. Nitrogen from urea was applied in three equal splits (1/3 as basal + 1/3 at active tillering stage + 1/3 at 5-7 days before panicle initiation stage). Necessary intercultural operations were done as required.

At maturity, the crop was harvested from 5 $m^2$ areas at the centre part of each plot and 16 hills were collected for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The

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plant samples (grain and straw) were digested with di-acid mixture (nitric and perchloric acid at the rate of 5:2) for the determination of Zn and with $H_2SO_4$ for the determination of N. The Zn was determined on an atomic absorption spectrophotometer and N by micro-Kjeldahl method (Yoshida *et al*, 1976). Data were analyzed as per standard statistical procedure (IRRI, 1998).

## RESULTS AND DISCUSSION

### Boro season

**Grain and straw yield.** In Boro season, the direct interaction effect of Zn and N on the yield of rice and some other parameters was studied. Application of Zn increased N fertilizer use efficiency. The interaction effect of N and Zn on the grain yield of Boro rice (BRRI dhan45) was highly significant ($p<0.01$). Fig. 1(a) shows that the result of the interaction effect of N and Zn on grain yield was inconclusive at 0 and lower level of N (even up to 80 kg N $ha^{-1}$). This may be due to the reason that the Zn availability in calcareous soil is low. Brummer *et al*, (1983) reported that Zn availability is reduced in $CaCO_3$ treated soils mainly because of adsorption of Zn either on the surfaces of $CaCO_3$ or on the surfaces of humic acid, amorphous Fe and Al-oxides, and $MnO_2$ compounds in the presence of $CaCO_3$. When nitrogen at the rate of 120 kg N $ha^{-1}$ was applied along with 7.5 kg Zn $ha^{-1}$ increased the grain yield of Boro rice (BRRI dhan45). Similar results were also obtained by Verma and Bhagat (1990). They reported that the response of added N was greater with applied Zn than without Zn. The interaction effect of N and Zn on the straw yield of Boro rice (BRRI dhan45) was not significant ($p= 0.257$) [Fig.1(b)].

**Zinc concentration and uptake.** The concentration of Zn in grain of Boro rice increased significantly with the increasing levels of Zn [Fig. 2(a)]. In the absence of added N, the Zn concentration in grain of Boro rice increased significantly with increasing levels of Zn [Fig. 2(a)]. Similar trend was also found in the presence of added N @ 80 kg N $ha^{-1}$. In case of added N @ 80 kg N $ha^{-1}$, it increased significantly up to 5 kg Zn $ha^{-1}$.

Application of N enhanced Zn concentration in grain and the magnitude of increase was more when N was applied in the absence of Zn. However, in the presence of Zn, a slight reverse trend was found in case of added N @ 40 and 120 kg N $ha^{-1}$. In the presence of added N @ 40 kg N $ha^{-1}$, with increasing levels of Zn, the concentration of Zn in grain gradually decreased [Fig. 2(a)]. In case of added N @ 120 kg N $ha^{-1}$, it was unchanged in all levels of Zn application. From the Figure 2(b) shows that significantly high Zn concentration in straw was obtained with the treatment $N_{120} \times Zn_{2.5}$. It also indicates that Zn concentration in straw got depressed after 2.5 kg Zn $ha^{-1}$ and the reduction was significant at 7.5 kg Zn $ha^{-1}$ when compared with other levels of Zn. Total Zn uptake (kg $ha^{-1}$) by BRRI dhan45 increased significantly up to $N_{120} \times Zn_{2.5}$ [Fig. 2(c)]. Addition of 5.0 and 7.5 kg Zn $ha^{-1}$ had a depressing effect while 2.5 kg Zn $ha^{-1}$ enhanced Zn uptake by rice plant at all levels of N added. Significantly the highest Zn uptake of 2.61 kg $ha^{-1}$ was obtained with the treatment $N_{120} \times Zn_{2.5}$ followed by the treatment $N_{120} \times Zn_{7.5}$ (2.45 kg $ha^{-1}$). These treatments were identical with each other [Fig. 2(c)]. The increase in Zn uptake may be attributed to the yield increase caused by increasing N rates.

**Nitrogen concentration and uptake.** The concentration of N in grain remained unchanged due to the addition of Zn. But there was a tendency of depression of N concentration in the presence of Zn. However, the application of Zn @ 5 kg Zn $ha^{-1}$ decreased the N concentration in grain significantly in the presence of added N 120 kg $ha^{-1}$ [Fig. 2(d)]. Similarly, the application of Zn @ 2.5 kg Zn $ha^{-1}$ decreased the N concentration in straw significantly in the presence of all levels of added N [Fig. 2(e)]. The results are in agreement with the findings of Verma and Bhagat (1990) for wheat crop. Conversely, the uptake of N by rice plant increased with Zn addition to 7.5 kg $ha^{-1}$ in the presence of $N_{120}$ [Fig. 2(f)]. This is mainly because of an increase in grain yield of Boro rice under 7.5 kg Zn $ha^{-1}$ addition in the presence of $N_{120}$ [Fig. 1(a)]. Thus, it can be concluded from the results of Boro rice that in the absence of added N, Zn concentration in grain increased [Fig. 2(a)] where as in the presence of added Zn, N concentration in grain decreased or remained unchanged [Fig. 2(d)].

### T. Aman season

**Grain and straw yield.** In T. Aman season, the interaction effect of residual Zn and direct N on the yield of rice and some other parameters were studied. The interaction effect of residual Zn and direct N on the grain and straw yield of T. Aman rice (BRRI dhan49) was highly significant ($p<0.05$). Fig. 3(a) shows that the significantly highest grain yield of 4.90 t $ha^{-1}$ was obtained with the treatment $N_{90} \times Zn_{2.5}$. Addition of 5.0 and 7.5 kg Zn $ha^{-1}$ had a depressing effect. However, significantly the highest straw yield of 7.17 t $ha^{-1}$ was produced with the treatment $N_{60} \times Zn_{2.5}$ [Fig.3(b)]. Like grain yield, addition of 5.0 and 7.5 kg Zn $ha^{-1}$ had a depressing effect on the straw yield.

**Zinc concentration and uptake.** The concentration of Zn in grain of T. Aman rice increased significantly with the increasing Zn levels both in the absence and presence of added N [Fig. 4(a)]. Like Boro season, in T. Aman season, application of N enhanced Zn concentration in grain and the magnitude of increase was more when N was applied in the absence of Zn. However, in the presence of Zn, this increasing trend was found in case of low doses of N ie up to 30 kg N $ha^{-1}$, where as increasing N level was not found to increase Zn concentration in grain up to 90 kg N $ha^{-1}$. There was no significant interaction effect of residual Zn and direct N application on straw Zn concentration of T. Aman rice [Fig. 4(b)]. The Zn uptake (kg $ha^{-1}$) of T. Aman rice (BRRI dhan49) increased significantly with the increasing levels of Zn both in the absence and presence of added N [Fig. 4(c)]. Application of N at different levels enhanced Zn uptake and magnitude of this was more prominent at 0 level of Zn. However, the increasing trend was similar those in grain Zn concentration [Fig. 4(c)].

**Nitrogen concentration and uptake.** The interaction effect of residual Zn and direct N application at different levels was non-significant on the grain and straw N concentration of T. Aman rice (BRRI dhan49) [Fig. 4(d) and 4(e)]. Total N uptake (kg $ha^{-1}$) of T. Aman rice (BRRI dhan49) showed a significant result due to the interaction of residual Zn @ 2.5 kg $ha^{-1}$ and N @ 90 kg $ha^{-1}$ [Fig. 4(f)]. This is mainly because of an increase in grain yield of T. Aman rice under residual Zn @ 2.5 kg Zn $ha^{-1}$ addition in the presence of $N_{90}$ and [Fig. 3(a)].

## CONCLUSIONS

It may be concluded that in calcareous soil the significant highest grain yield was obtained with the treatment $N_{120} \times Zn_{7.5}$ in Boro season and with the treatment $N_{90} \times Zn_{2.5}$ in T. Aman season. The application of N and increasing level of Zn had a synergistic effect on grain Zn concentration both in Boro and T. Aman seasons. The grain N concentration remained unchanged due to the application of Zn. The application of N and Zn had synergistic effect on both total Zn and N uptake.

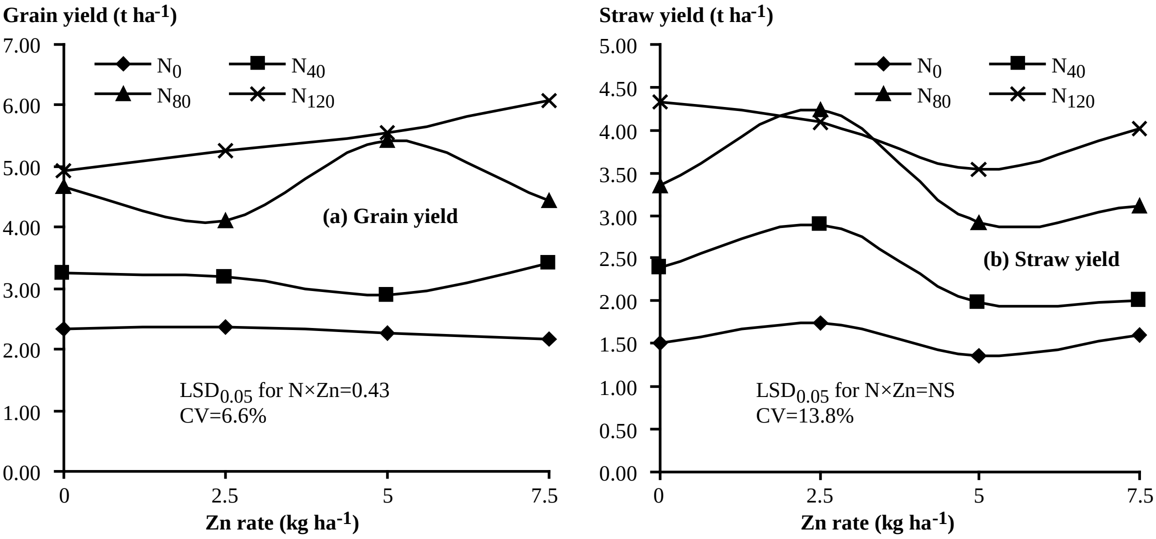


Fig. 1. Interaction effect of N and Zn on the (a) grain yield and (b) straw yield of BRRI dhan45.

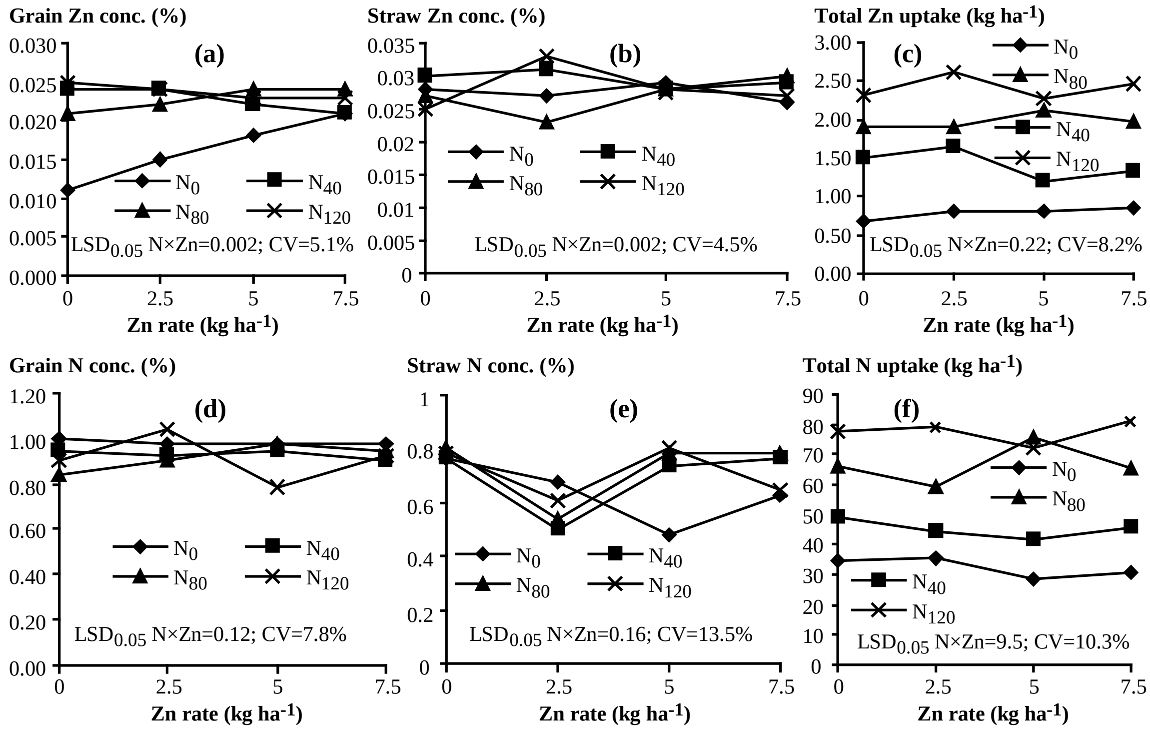

Fig. 2. Interaction effect of applied N and Zn on the grain Zn conc. (a), straw Zn conc. (b), total Zn uptake (c), grain N conc. (d), straw N conc. (e), and total N uptake (f) of BRRI dhan45.

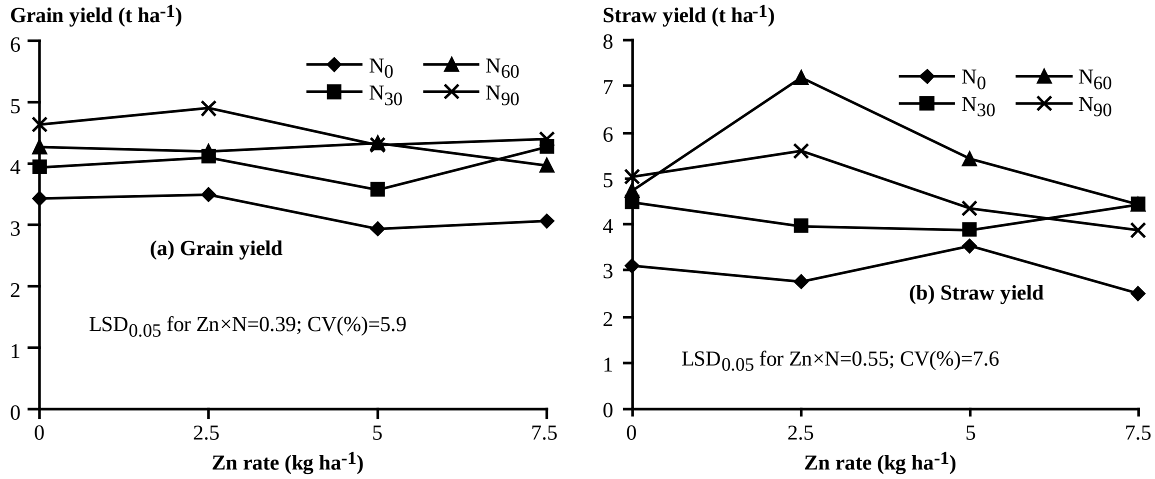

Fig. 3. Interaction effect of applied N and residual Zn on the (a) grain yield and (b) straw yield of BRRI dhan45.

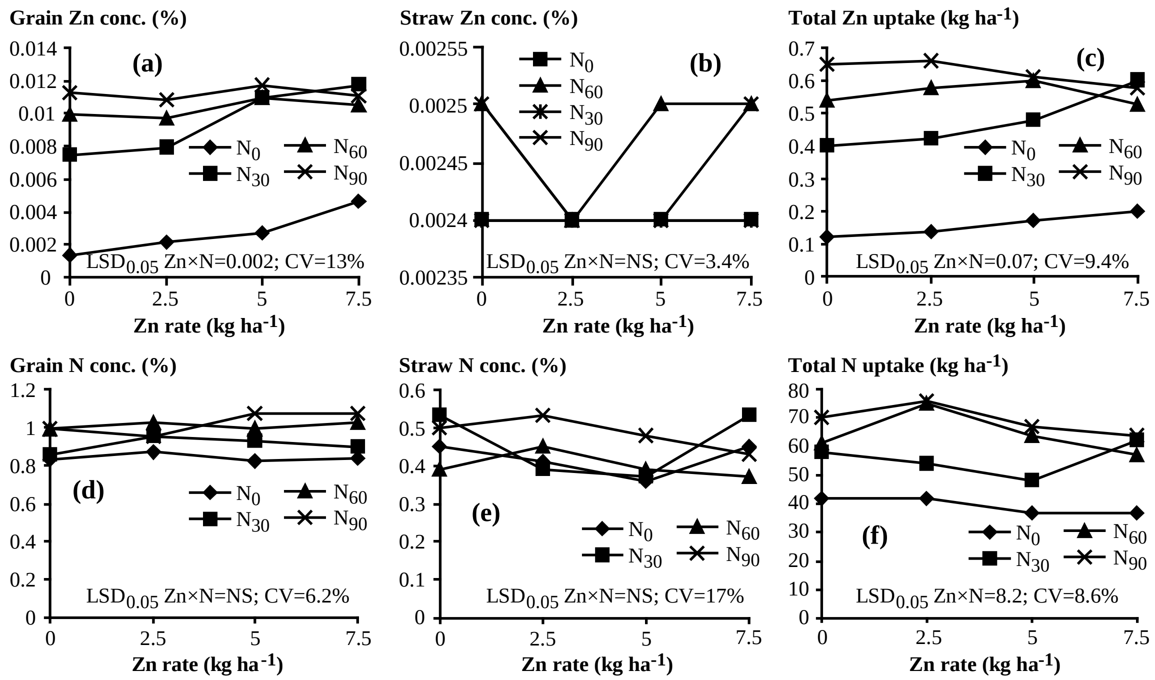

Fig. 4. Interaction effect of applied N and residual Zn on the grain Zn conc. (a), straw Zn conc. (b), total Zn uptake (c), grain N conc. (d), straw N conc. (e), and total N uptake (f) of BRRI dhan45.

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# Seed Priming and Seedling Establishment under Anaerobic Conditions

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ABSTRACT

Three different experiments were conducted to study better seedling establishment under oxygen depleted conditions through different seed priming methods at Plant Physiology Division, Bangladesh Rice Research Institute, Gazipur, from July to October 2007. The priming treatments were $KNO_3$ (ψ = -1.25MPa), NaCl (ψ = -1.25MPa), $CaCl_2$ (ψ = -1.25MPa) and hydropriming along with a control. The studies were conducted with six rice genotypes *viz*, BRRI dhan29, Jahmir, Bashful, Banajira, BRRI dhan28 and Boro 109/2. At first in an *in vitro* study, seedlings were allowed to grow under different aerobic and hypoxic condition. Strict anoxic condition was maintained for the second experiment. The third experiment was conducted under drained and lowland conditions. Under hypoxia most of the anoxia tolerant genotypes had their elongated coleoptiles. Therefore, the variety should withstand the lowland conditions. Accordingly Jahmir had elongated coleoptile as well as elongated leaves in some treatments under oxygen depleted conditions. With few exceptions, BRRI dhan28 and BRRI dhan29 were able to produce more or less elongated coleoptile under the oxygen depleted conditions. Therefore, these genotypes should have the ability to establish seedling under lowland conditions. But they were not able to establish seedlings under lowland conditions. However, BRRI dhan29 had good number of seedlings establishment when the seeds were treated with hydro-priming treatments. Under lowland conditions, $CaCl_2$ showed some interesting influence of seedling establishment for the designated anoxia-tolerant genotypes like Jahmir, Bashful and Banajira. In contrast, Boro 109/2 was enhanced by NaCl.

**Key words**: Seed priming, Seedling establishment, Anaerobic conditions.

## INTRODUCTION

Improved seed invigoration techniques are being used in many parts of the world to reduce the germination time, to get synchronized germination, improved germination rate and better seedling stand to achieve better seedling establishment in many horticultural (Jett *et al*, 1996) and field crops like wheat, maize (Farooq *et al*, 2004a). Furthermore, the invigouration persists under less than optimum field conditions, such as salinity (Muhyaddin and Weibe, 1989), high and low temperature (Ruan *et al*, 2002, and low soil moisture contents ( Du and Tuong, 2002) and drought (Du and Tuong, 2000). Even under extreme hypoxic condition, Lee *et al*, 1998 observed enhanced seedling establishment due to seed priming. This invigoration techniques or priming technique include traditional soaking (soaking in tap water up to radicle protrusion), hydropriming for 48 h, osmoconditioning, osmohardening with KCl or $CaCl_2$ (osmotic potential of -1.25 MPa) for 24 h, hardening and priming with growth regulators and vitamins etc. These treatments are also employed for easier and better nursery establishment, resulting in the improved performance of the traditional rice production system (Basra *et al*, 2005). Wet direct seeding method, a cost effective method for seedling establishment might not get any success until any suitable variety developed for direct seeding under anaerobic conditions. Therefore, we are in earnest need of an anaerobic tolerant rice variety. But it would take a long time to develop a variety like this. So, we could quantify the ability of primed seed to establish under lowland conditions. Accordingly, we could develop some relevant agronomic practices for easier and better seedling establishment methods. This study was considered to achieve the following objectives to:

- Achieve better seedling establishment under hypoxic (oxygen depleted) condition through different seed priming methods.
- Compare the eligibility of different seed priming methods.
- Observe the simple mechanism of seed priming in the enhancement of seedling establishment under hypoxic conditions.

## MATERIALS AND METHODS

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The research work was carried out from July to August 2007 at Plant Physiology Division, Bangladesh Rice Research Institute (BRRI), Gazipur. Seeds (BRRI dhan29, Jahmir, Bashful, Banajira, BRRI dhan28 and Boro109/2) were collected from Plant Physiology Division, BRRI. The genotypes were tolerant to anaerobic conditions except BRRI dhan28 and BRRI dhan29. The initial moisture content were in between 10-12.0%. Germination percentage of these seeds was more or less 99%.

METHODOLOGY

Osmopotential ($\psi$ = -1.25MPa), chemical solutions of KNO3 (30.0 g/L), NaCl (16.4 g/L) and $CaCl_2$ (22.2g/L) were prepared as per Ruan *et al.*, (2002) and Farooq *et al*., (2006). The seed priming treatments were $T_1$ = $KNO_3$, $T_2$ = NaCl, $T_3$ = $CaCl_2$, $T_4$ = Hydropriming, $T_5$ = No priming. Twenty-five gram of seeds were soaked in 50 ml of solutions (Chemical priming) or distilled water (hydropriming) at room temperature (27±2 °C). The seeds were soaked for 24 hours for chemical primimg and 48 hours for hydropriming. The ratio of seed weight to solution volume was 1:5 (g/mL). The seeds were then surface washed thrice, dried to the previous moisture level under forced air (Fan) under room condition and stored in a tightly fitted glass bottle at 5 °C for the study.

Study 1. Seedling growth as affected by seed priming treatments and growing conditions.

The growing conditions were **Aerobic** (Seedlings were allowed to grow in the petri dishes (9 cm dia) lined with moistened filter paper) and **Hypoxic:** Seedlings were grown in a 50 ml Erlenmeyer flask. Water column (distilled water) was 5 ml above the seeds. Five disinfectant seeds just after sprouting were put in to the Erlenmeyer flask having the hypoxic condition mentioned here. The flasks were then kept in a growth chamber (**growing condition**: dark and 30±2 °C with sufficient humidity). The sprouting was done by 24 hours soaking under the same growing conditions. The seedlings were grown for seven days.

The study contained five seed priming treatments, six genotypes and two growing conditions designed in a two replicated factorial randomized complete block design (Table1).

Study 2. Seedling growth as affected by seed priming treatments and strict anoxic conditions.

The treatments were the same as those with the study 1. However the growth conditions were completely anaerobic. Five sprouted (sprouting was done by the same method as in study 1) seeds were put into the test tubes (100 × 25-mm) having 18 ml of water, equivalent to a 50 mm water depth above the seeds. A thin layer of olive oil added above the water surface to maintain strict anoxia. The experimental design was the same as study 1.

Study 3. Seedling establishment and seedling growth as affected by seed priming treatments and lowland conditions.

The treatments were the same as the previous studies. But the growing conditions were as drained and lowland conditions. Plastic cups (size: 70 mm in diameter × 85 mm in height) were used as experimental unit. The cups were filled with powdered soil (soils were crushed and sieved through 40 mesh) from BRRI farm. The cups were arranged in two plastic trays (size: 1000 × 500 × 125-mm): one assigned for drained conditions and the other for lowland conditions. In the drained tray, the cups were provided with a whole at the bottom covered with tissue paper to facilitate water absorption from the tray. All the cups were maintained in more or less a field capacity conditions. The cups of the lowland conditions were submerged under water in the tray. The water depth over the cups was 25 mm. The treated sprouted seeds were seeded (5 seeds per cup) with the help of a forceps at a depth of 25 mm. The water depth was monitored every day.

There were six genotypes, five priming treatments and two growing conditions. Each treatment combination was repeated twice. This kind of treatment combination needs many trays. Due to shortage of trays, only two big trays were used. Statistically, this arrangement could not be considered as a perfect design as repetition of treatments combination did not satisfy conditions of replication. However, the data to interpret were analyzed a**s** a factorial randomized design experiment.

Seedling establishment and seedling organs were observed. Percent seedling establishment data were transformed to root square transformation. During transformation 0 data were considered as 0.005 with the proper consultation with a BRRI statistician.

The raw data were calculated with MS Excel. Statistical data were analyzed through MS windows based IRRISTAT (statistical package). Mean separation was shown as LSD at the 5% level of significance ($LSD_{0.05}$).

RESULTS AND DISCUSSION

**Study 1**

Interaction effect for coleoptile length, mesocotyl length, first leaf length, were significant (P<0.05). Therefore, only these attributes were discussed hereafter. CV% of these parameters ranged from 13.7 to 17.8 appeared to be quite reasonable.

**Coleoptile**. With a little exceptions in NaCl for BRRI dhan28, the other genotypes showed a little response of seed priming treatments (Table 1). Irrespective of genotype, enhanced coleoptile growth in hypoxia is quite expected. The land race genotypes showed a little variation of growth with respect to the control treatment. Some exceptions were observed in Jahmir. It had significant coleoptile growth (29.70 – 40.10 mm) compared to the control in priming treatments. Compared to the control treatments, BRRI dhan28 was affected to some extent by hydropriming treatment. Similarly BRRI dhan29 was affected when treated with $KNO_3$.

**Mesocotyl.** The priming treatments had no effect on mesocotyl growth in aerobic conditions (Table 2). Hypoxic conditions appeared to influence mesocotyl growth in some genotypes like BRRI dhan28 and Bashful. Growth enhancement was only observed in $KNO_3$ treated BRRI dhan29.

**First leaf.** Irrespective of genotype and priming treatment, some enhanced first leaf growth was observed in hypoxia (Table 3). Some exceptions were observed in BRRI dhan29 at $KNO_3$. There was no first leaf growth at all. BRRI dhan29 produced 28.70 mm and 26.60 mm under hypoxic and aerobic conditions respectively. The same treatment had significantly reduced first leaf growth (10.30 mm) in BRRI dhan28 in hypoxia compared to that of aerobic conditions (29.9 mm).Similar to coleoptile growth, significant first leaf growth was observed in Jahmir under NaCl and $CaCl_2$ primed seeds. BRRI dhan28 was able to produce significantly longer first leaf growth in $KNO_3$, NaCl, and $CaCl_2$ treated seeds under the same conditions. $KNO_3$, NaCl, and $CaCl_2$ had the leaf growth of 46.70, 56.50 and 45.30 mm respectively.

**Study 2**

Under strict anoxia the seedling experienced a severe stress. The growth of the seedling attributes was restricted severely. The CV% of most of the attributes were extremely high. One of the most important seedling organs, coleoptile showed only treatment effect (Fig. 1). Variety and treatment interaction was significant ($P<0.05$) only for mesocotyl growth. The seminal root and variety interaction was narrowly insignificant at $P_{0.05}$ ($P= 0.0588$). So the results of the main effect of coleoptile, and the interaction effect of mesocotyl were discussed.

**Coleoptile.** The enhanced coleoptile growth across the varieties was observed with respect to some of the treatments. $KNO_3$, NaCl and $CaCl_2$ produced significant coleoptile length of 40.38 mm, 41.31mm, and 41.63 mm respectively compared to those of the control and hydroprimed seeds. (Fig. 1).

**Mesocotyl.** Significantly enhanced mesocotyl length was observed in BRRI dhan28 and BRRI dhan29 when treated with $KNO_3$, NaCl and $CaCl_2$ . The hydropriming treatment had a little effect on the growth of the attribute. The genotypes Jahmir, Bashful, Banajira and Boro 109/2 were stimulated a little with the priming treatments (Table 4).

**First leaf.** The main effect of the treatments on first leaf and seminal root was significant. $KNO_3$, NaCl and $CaCl_2$ were able to produce more first leaf lengths than the controls (Fig. 1). $CaCl_2$ produced the highest leaf length (15.6 mm) followed by $KNO_3$, and NaCl which had the first leaf length of 7.71 and 7.31 mm respectively (Table 5).

**Study 3**

The genotype × Treatment × Growing conditions with respect to seedling establishment and the seedling attributes were highly significant for all the varieties. But under lowland conditions seedling establishment was significantly reduced for all the varieties (Table 6). BRRI dhan28 could not establish seedling in either of the treatments. BRRI dhan29 had the similar pattern with that of BRRI dhan28 with an exception in hydropriming. The hydropriming treatment significantly in seedling establishment (44.89%) compared to those of the control and other treatments. The anoxia tolerant Jahmir, Banajira and Boro 109/2 had better seedling establishment under this conditions. Bashful, an anoxia-tolerant genotype could not establish under the control and NaCl-primed conditions. The extremely poor performance under control conditions is quite strange for Bashful. $CaCl_2$ showed significantly the best seedling establishment performance under this conditions for Jahmir, Bashful and Banajira while Boro109/2 had its best performance when treated with NaCl.

**First leaf.** First leaf growth followed the similar pattern as observed in case of seedling establishment (Table 7). The drained conditions had little effect of seed priming. Despite similar seedling establishment, $KNO_3$ showed significantly quite elongated leaf length.

## DISCUSSION

More recently, seed invigoration techniques such as hydropriming, osmoconditioning, osmohardening etc have been successfully applied to accrue optimal seedling establihment in rice (Farooq *et al*, 2006). The invigoration thus achieved could be translated as better seedling establishment and crop performances under many of the extreme conditions like drought (Du and Tuong, 2002), hypoxia (Ruan *et al*, 2002) etc. Therefore, it was expected that some of the seed priming treatments would enhance seedling attributes under different in vitro conditions (aerobic, hypoxic and anoxic) considered in these studies. The enhance growth of an attribute with respect to treatment and genotypes was observed in some of the cases. But it is very hard to find a specific treatment effect with respect to certain seedling attribute. Elongated coleoptile produced under hypoxia should have the ability to produce better first leaf growth. Under hypoxia most of the genotypes had their elongated coleoptile but not elongated leaves. However, in hypoxia Jahmir had elongated leaves as well as elongated coleoptile in some treatments. Seed priming with $KNO_3$ showed some negative effect on some attributes. However, BRRI dhan28 and BRRI dhan29 showed the ability to produce elongated coleoptile under the oxygen depleted conditions. Accordingly, these genotypes should have the ability to establish seedlings under lowland conditions. But in reality, it is observed that BRRI dhan29 and BRRI dhan28 in most of the cases could not establish under lowland conditions. The exception was BRRI dhan29, which had a number of seedling establishment when the seeds were hydroprimed. In the same study, beside hydropriming effect on BRRI dhan29, $CaCl_2$ showed very significant effect of seedling establishment for the anoxia-tolerant genotypes like Jahmir, Bashful and Banajira. In contrast, Boro 109/2 was enhanced by NaCl. Thus it appears that the priming treatment needed to enhance seedling establishment under lowland conditions is very specific.

Primed seeds usually exhibit increased and uniform germination rate (Basra *et al*., 2005) which are attributed to metabolic repair during imbibition (Bray *et al*., 1989) to build up of germination enhancing metabolites (Basra *et al*., 2005), osmotic adjustment (Bradford, 1986), and for seeds that are not redried after treatment, a simple reduction in the lag time of imbibition (Bradford, 1986). Seed priming ensured the proper hydration, which resulted in enhanced activity of a-amylase activity that hydrolysed the macro starch molecules into smaller and simple sugars (Farooq *et al*, 2006). When the seedling has to come up from the anaerobic conditions, the biochemistry from the aerobic condition must be different. One of the primary effects of anaerobic conditions is the reduction in respiratory activity resulting in reduction in levels of ATP and accumulation of NADH. Ethanolic fermentation enables the pyruvate to be routed through an alternative pathway causing lower levels of ATP production and concomitantly, regeneration of NAD for the continuation of respiration, of course in low level (Grover *et al*, 1995). There is, of course, genotype variation of ethanolic fermentation to compensate energy under the stress. Some of the priming treatment having better seedling establishment might accumulate the ability to synthesise more energy through alcoholic fermentation. Biochemical aspects of seedling prime with respect to the treatments might satisfy many of the interesting queries. From the above results and discussion the conclusions are as follows:

- Seedling establishment of some of the genotypes having no tolerance to anoxia could be improved.
- The ability of seedling establishment of some anoxia-tolerant genotypes could also be improved.
- The priming agent and its matching partner genotypes appeared to be very specific.

These were the very preliminary studies of this kind in Bangladesh. More study is needed to explain the mechanism and to find more matching seed-priming agents.

**Table 1. Coleoptiles as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| | *Aerobic (Growing condition)* | | | | |
| BRRI dhan29 | 11.50 | 12.70 | 11.10 | 10.20 | 12.70 |
| Jahmir | 15.80 | 15.0 | 16.60 | 9.10 | 15.50 |
| Bashful | 17.90 | 20.10 | 20.60 | 11.40 | 20.10 |
| Banajira | 11.50 | 14.30 | 15.40 | 10.80 | 14.80 |
| BRRI dhan28 | 15.0 | 28.50 | 17.30 | 10.50 | 15.80 |
| Boro 109/2 | 14.30 | 12.70 | 15.0 | 13.0 | 15.50 |
| | *Hypoxia (Growing condition)* | | | | |
| BRRI dhan29 | 17.30 | 32.10 | 32.20 | 26.30 | 33.70 |
| Jahmir | 3.80 | 34.80 | 40.10 | 29.70 | 21.0 |
| Bashful | 30.0 | 36.90 | 35.60 | 26.40 | 40.10 |
| Banajira | 29.40 | LSD $_{0.05}$ | 33.20 | 28.40 | 33.30 |
| BRRI dhan28 | 34.70 | | 32.20 | 29.0 | 36.70 |
| Boro 109/2 | 40.50 | 42.10 | 39.90 | 33.0 | 40.0 |

LSD $_{0.05}$ – 6.55

LSD $_{0.05}$

**Table 2. Mesocotyls as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| | *Aerobic (Growing condition)* | | | | |
| BRRI dhan29 | 0.95 | 1.50 | 1.50 | 1.10 | 1.30 |
| Jahmir | 2.0 | 1.60 | 1.80 | 1.30 | 1.50 |
| Bashful | 2.0 | 2.10 | 2.0 | 1.40 | 2.30 |
| Banajira | 1.50 | 2.0 | 2.0 | 1.20 | 1.50 |
| BRRI dhan28 | 2.30 | 3.40 | 4.60 | 1.70 | 2.0 |
| Boro 109/2 | 1.40 | 1.40 | 2.10 | 1.20 | 1.40 |
| | *Hypoxia (Growing condition)* | | | | |
| BRRI dhan29 | 5.40 | 2.90 | 2.60 | 1.90 | 1.80 |
| Jahmir | 1.80 | 2.70 | 2.70 | 1.40 | 2.30 |
| Bashful | 3.0 | 3.60 | 4.20 | 2.10 | 5.30 |

| | | | | | |
|---|---|---|---|---|---|
| Banajira | 2.10 | 2.30 | 2.90 | 2.60 | 5.0 |
| BRRI dhan28 | 4.50 | 4.0 | 4.0 | 4.0 | 4.50 |
| Boro 109/2 | 2.30 | 3.0 | 2.90 | 1.90 | 2.40 |

LSD $_{0.05}$ – 1.12

**Table 3. First leaves as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| | *Aerobic (Growing condition)* | | | | |
| BRRI dhan29 | 14.20 | 23.90 | 25.20 | 23.0 | 26.60 |
| Jahmir | 34.20 | 30.90 | 30.70 | 26.50 | 31.70 |
| Bashful | 26.0 | 28.40 | 27.90 | 22.60 | 20.0 |
| Banajira | 32.60 | 33.70 | 37.20 | 30.90 | 32.70 |
| BRRI dhan28 | 34.50 | 33.40 | 28.0 | 27.40 | 29.90 |
| Boro 109/2 | 32.60 | 29.40 | 32.60 | 30.70 | 32.60 |
| | *Hypoxia (Growing condition)* | | | | |
| BRRI dhan29 | 0.0 | 34.40 | 36.70 | 31.30 | 28.70 |
| Jahmir | 36.50 | 45.30 | 56.0 | 26.20 | 32.30 |
| Bashful | 17.20 | 36.10 | 40.50 | 43.10 | 37.0 |
| Banajira | 33.40 | 37.70 | 43.80 | 26.10 | 44.90 |
| BRRI dhan28 | 46.70 | 38.40 | 27.20 | 29.50 | 10.30 |
| Boro 109/2 | 54.10 | 56.50 | 45.30 | 47.20 | 42.20 |

LSD $_{0.05}$ - 12.94

**Table 4. Mesocotyls as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| BRRI dhan29 | 4.60 | 4.50 | 3.10 | 2.40 | 2.60 |
| Jahmir | 2.40 | 2.30 | 3.10 | 1.70 | 3.80 |
| Bashful | 2.70 | 4.0 | 3.60 | 2.70 | 4.10 |
| Banajira | 2.80 | 3.30 | 4.0 | 1.90 | 5.60 |
| BRRI dhan28 | 5.40 | 7.30 | 6.30 | 4.10 | 4.40 |
| Boro 109/2 | 3.0 | 3.0 | 2.60 | 2.30 | 2.60 |

LSD $_{0.05}$ – 1.5

**Table 5. First leaves as affected by seed priming and strict anoxic conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| BRRI dhan29 | 12.10 | 0.0 | 0.0 | 9.80 | 3.20 |
| Jahmir | 6.80 | 24.30 | 16.50 | 6.60 | 0.0 |
| Bashful | 3.60 | 0.0 | 0.0 | 0.0 | 0.0 |
| Banajira | 3.40 | 2.80 | 12.50 | 0.0 | 4.50 |
| BRRI dhan28 | 10.20 | 4.20 | 4.0 | 0.0 | 0.0 |
| Boro 109/2 | 10.20 | 12.60 | 60.60 | 0.0 | 0.0 |

LSD $_{0.05}$ - 36.50

**Table 6. Percent seedling establishment as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| | *Lowland (Growing condition)* | | | | |
| BRRI dhan29 | 0.04 | 0.04 | 0.04 | 44.89 | 0.04 |
| Jahmir | 49.42 | 49.42 | 58.21 | 44.89 | 58.21 |
| Bashful | 29.05 | 0.04 | 58.21 | 19.98 | 0.04 |
| Banajira | 89.68 | 78.67 | 89.68 | 69.55 | 79.92 |
| BRRI dhan28 | 5.47 | 0.04 | 5.47 | 15.84 | 5.47 |

| | | | | | |
|---|---|---|---|---|---|
| Boro 109/2 | 69.55 | 100 | 59.90 | 49.42 | 59.90 |
| | *Drained (Growing condition)* | | | | |
| BRRI dhan29 | 100 | 100 | 100 | 100 | 100 |
| Jahmir | 100 | 100 | 100 | 100 | 100 |
| Bashful | 100 | 100 | 100 | 100 | 100 |
| Banajira | 100 | 100 | 100 | 100 | 100 |
| BRRI dhan28 | 100 | 100 | 100 | 100 | 100 |
| Boro 109/2 | 100 | 100 | 100 | 100 | 100 |
| LSD $_{0.05}$ - 6.56 | | | | | |

**Table 7. First leaves as affected by seed priming and growing conditions.**

| Genotype | Priming treatment | | | | |
|---|---|---|---|---|---|
| | $KNO_3$ | NaCl | $CaCl_2$ | Hydropriming | Control |
| | *Lowland (Growing condition)* | | | | |
| BRRI dhan29 | 0.0 | 0.0 | 0.0 | 39.40 | 0.0 |
| Jahmir | 72.90 | 20.0 | 26.90 | 21.40 | 24.70 |
| Bashful | 7.40 | 0.0 | 17.10 | 8.20 | 0.0 |
| Banajira | 34.80 | 29.20 | 39.0 | 28.40 | 27.20 |
| BRRI dhan28 | 3.50 | 0.0 | 2.80 | 6.0 | 0.0 |
| Boro 109/2 | 35.50 | 36.50 | 31.80 | 25.60 | 41.10 |
| | *Drained (Growing condition)* | | | | |
| BRRI dhan29 | 26.90 | 26.20 | 24.90 | 2.80 | 25.20 |
| Jahmir | 42.40 | 42.30 | 35.0 | 27.10 | 36.10 |
| Bashful | 31.0 | 34.20 | 28.60 | 25.20 | 30.80 |
| Banajira | 3.70 | 32.0 | 31.90 | 28.60 | 29.80 |
| BRRI dhan28 | 32.60 | 26.30 | 28.50 | 2.10 | 25.50 |
| Boro 109/2 | 35.50 | 36.50 | 31.80 | 25.60 | 41.10 |
| LSD $_{0.05}$ - 18.11 | | | | | |

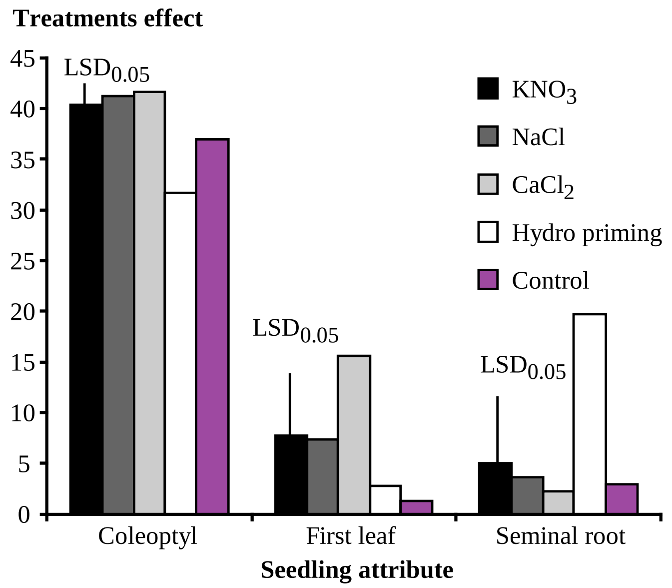


Fig. 1. Seedlings atributes as affected by priming treatments.

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# Evaluation of Alternative Direct-Seeded Aus Rice Based Cropping Pattern in Upland Ecosystem

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ABSTRACT

We conducted an experiment at the experimental farm of Bangladesh Rice Research Institute, Gazipur during Kharif-1 season to identify alternative direct seeded Aus rice based cropping pattern for upland ecosystem. Single direct seeded Aus rice pattern produced the lowest REY (2.45 t/ha) than the rest of the tested patterns. The direct seeded Aus rice-Edible podded pea pattern produced the highest rice equivalent yield (13.05 t/ha) followed by Aus rice-Bushbean (10.15 t/ha) and DS Aus rice-Chickpea patterns (9.5 t/ha). Moreover, edible podded pea, bushbean and chickpea produced 2.25 t/ha, 0.91 t/ha and 3.33 t/ha crop residues respectively. Results of the study suggested that the upland ecosystem could be diversified and its productivity could be increased by growing edible podded pea, bushbean and chickpea.
**Key words:** Direct seeded Aus rice, cropping pattern and upland ecosystems

## INTRODUCTION

Upland rice are grown annually in about 17 million ha worldwide with 10.5 million ha in Asia, 3.7 million ha in Latin America and 2.8 million ha in Africa (De Datta, 1975). In Bangladesh, estimated area of upland rice ecosystems is about 0.7 million ha (Huke and Huke, 1997) where farmers traditionally grow single crop of direct seeded Aus rice with yield potential of about 0.8 to 1.2 t/ha. Drought, weeds, blast and insect pests are the major constraints to upland rice production (Bernier, *et al,* 2008). These adverse factors cause many farmers to limit upland rice production to subsistence levels (Mercado, *et al,* 1993). It is critical to the food security of impoverish communities that do not produce enough lowland rice to meet their needs. Some authors indicated that it was used to bridge farmer through the 'hungry month'- a period before lowland crops could be harvested (Cruz Vera, 2006). Other says, upland rice farmers use farming systems ranging from shifting to permanent cultivation. According to Guoqin, *et al,* (2008), multiple cropping on upland ecosystems could bring the best social, economic and ecological benefits, increase product yield and farmers' income and promote sustainable development of agricultural production. However, rice yields are generally low from 0.5 to 1.5 t/ha in Asia, about 0.5 t/ha in Africa and 1 to 4 t/ha in Latin America (De Datta, 1975) but average yield is about 1 t/ha in low input systems that may reach about 2 t/ha in the favourable uplands. In Bangladesh, mustered, til, soybean and line seed are the main oils crops being grown at about 1.6 lakh ha of land that can supply only about1/3 of edible oil of the total requirement for the country. Pulses are 20-30% protein by weight, which is double the protein content of wheat and three times that of rice, For this reason, pulses are called vegetable meat (Schneider, 2002) Pulses have significant nutritional and health advantages for consumers. They are the most dietary predictor of survival in older people of different ethnicities (Darmadi-Blackberry, 2004) and in a study it has observed that legume consumption was highly correlated with a reduced mortality from coronary heart disease (*Menotti, et al,* 1999). Pulses are especially high in amylose starch making them a good source of prebiotic resistant starch (FAO, 1994). Moreover, compared with the stable foods of corn and rice, most of the vegetable varieties obtain a higher market value (Westermann, 1995). Farmers however, need to be encouraged to move to new and more profitable crops. Therefore, an experiment was designed with several alternative direct seeded Aus rice based cropping patterns to evaluate their productivity as well as to diversify cropping intensity of upland ecosystem.

## MATERIALS AND METHODS

We did the experiment at the BRRI farm Gazipur during Kharif-1 season 2005-06. The experimental plots were laid out in RCB design with three replications. BR21 was grown as direct seeded Aus rice followed by nine Rabi crops viz mustard (Tori-7 & SS-75), pea (Faridpuri), edible podded pea, bush bean, chickpea (Nabin), linseed (Nila 1), soybean (Sohag) and sunflower (Kironi). DSR BR21 was seeded on 5 May and all the tested Rabi crops were seeded on 13 November.

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Fertilizers (kg/ha of N-$P_2O_5$-$K_2O$-S-Zn): Tori-7: 100-80-50-30-4; SS-75: 120-80-60-40-4; Pea, Edible podded pea and Bushbean: 30-85-35-20-4; Soybean:30-80-100-20-4; Chickpea:30-90-60-20-4; Linseed: 35-60-30-0-0; Sunflower: 100-100-100-30-4 as per fertilizer recommendation guide (BARC, 1996). All other cultural practices for rice and non-rice crops were followed as per recommendation of BRRI and BARI. For optimum germination of the Rabi crops, irrigation was applied one day after seeding and at 30 days after seeding. All the Rabi crops except bush bean and edible podded pea were harvested at seed maturity whereas edible podded pea and bush bean were harvested at 80 and 71 days after seeding respectively, as green pods. Crop residues yield of all Rabi crops and nitrogen accumulated in the crop residue were recorded. The productivity of the tested cropping patterns have been expressed in terms of rice equivalent yield (REY).

## RESULTS AND DISCUSSION

Yield of direct seeded Aus rice in different cropping patterns ranged from 2.10 to 2.50 t/ha. The rice equivalent yields varied from 2.45 to13.05 t/ha (Table 1). Single rice pattern produced the lowest grain yield (2.45 t/ha) than the rest of the tested patterns. The direct seeded Aus rice-edible podded pea pattern produced the highest rice equivalent yield (13.05 t/ha). This was followed by DS Aus rice-bushbean cropping pattern (10.15 t/ha) and DS Aus rice-Chickpea pattern (9.5 t/ha). The yield of Rabi crops contributed for achieving of higher total rice equivalent yields in these patterns. Crop residue yield of Rabi crop at harvest indicated that sunflower produced the highest dry crop residue (3.67 t/ha), which was followed by chickpea (3.33 t/ha) and edible podded pea (2.25 t/ha). Linseed cake accumulated the highest nitrogen (60.76 kg/ha) followed by edible podded pea residues (35.10 kg/ha). Results of the present study suggested that the upland ecosystem could be diversified and its productivity could be enhanced by growing edible podded pea, chickpea and linseed after DS Aus rice (BR21).

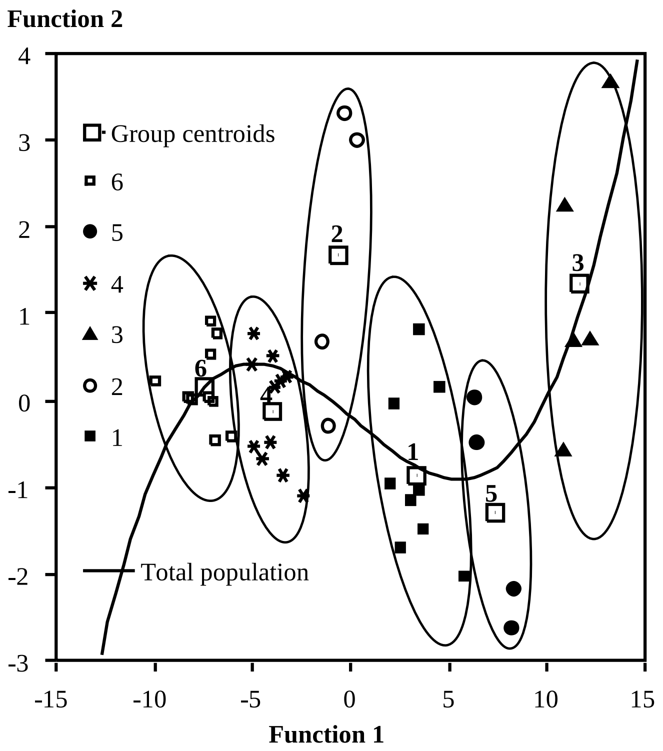


Fig. 1. Showing groups/clusters of 44 rice varieties based on different parameters.

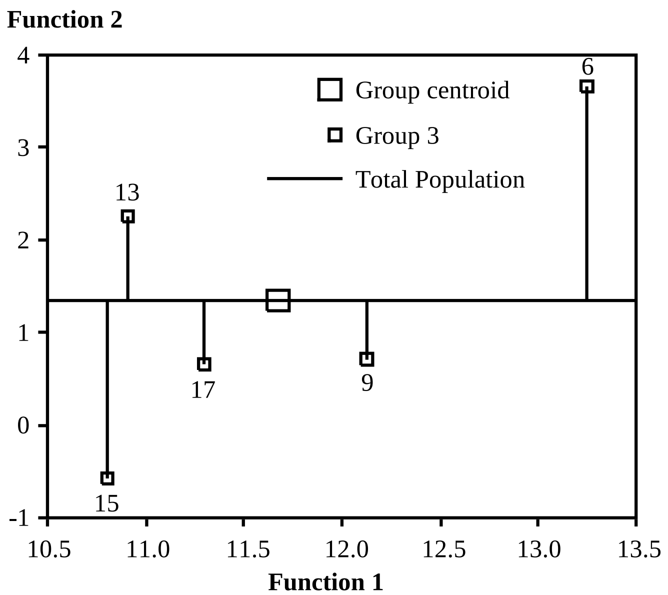


Fig. 2. Graphical illustrations of discriminatory analysis six group's 44 genotypes.

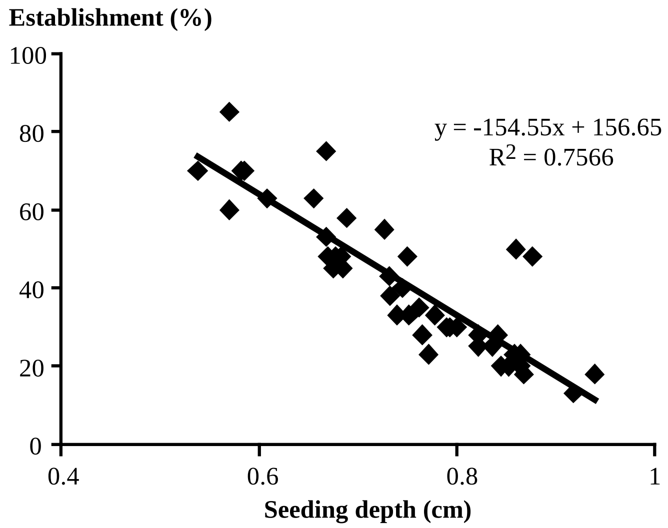

**Table 1. Productivity of the tested direct-seeded Aus based cropping patterns in the upland ecosystems, BRRI, Gazipur, 2005-06.**

| Cropping pattern[1] | | | Yield (t/ha) | | Total REY* (t/ha) |
|---|---|---|---|---|---|
| Kharif 1 | Kharif II | ***Rabi*** | Kharif I | *Rabi* | |
| DSR BR21 | F | Mustard (Tori-7) | 2.50 | 0.43 | 4.22 |
| DSR BR21 | F | Mustard (SS-75) | 2.30 | 0.50 | 4.80 |
| DSR BR21 | F | Pea | 2.10 | 1.26 | 5.88 |
| DSR BR21 | F | Edible podded Pea | 2.15 | 9.10 (Veg) | 13.05 |
| DSR BR21 | F | Bushbean | 2.30 | 7.90 (Veg) | 10.15 |
| DSR BR21 | F | Soybean | 2.20 | 0.40 | 2.92 |
| DSR BR21 | F | Chickpea | 2.15 | 2.50 | 9.50 |
| DSR BR21 | F | Linseed | 2.20 | 1.30 | 5.32 |
| DSR BR21 | F | Sunflower | 2.24 | 0.80 | 4.00 |
| DSR BR21 | F | F | 2.45 | - | 2.45 |

Prices of output (Tk/kg): Rough rice=5; Mustard (Tori-7):20; SS-75:22; Pea=15; Edible podded pea as vegetable: 6; Bush bean pod as vegetable:5; Soybean=10; Linseed=12.50; Sunflower=10 and Chichpea=15. *REY= Rice equivalent yield; F=Fallow

**Table 2. Yield of crop residues and N at different tested direct-seeded Aus based cropping patterns in the upland ecosystems, BRRI, Gazipur, 2005-06.**

| Cropping pattern[1] | | | Crop residue /byproduct yield (t/ha) | N in crop residue/ byproduct (%) | Total N accumulated (t/ha) |
|---|---|---|---|---|---|
| Kharif 1 | Kharif II | *Rabi* | | | |
| DSR BR21 | F | Mustard (Tori-7) | 0.32 (Oil cake) | 5.10 | 16.32 |
| DSR BR21 | F | Mustard (SS-75) | 0.38 (Oil cake) | 5.10 | 19.38 |
| DSR BR21 | F | Pea | 2.15 | 0.60 | 12.90 |
| DSR BR21 | F | Edible podded Pea | 2.25 | 1.56 | 35.10 |
| DSR BR21 | F | Bushbean | 0.91 | 2.00 | 18.00 |
| DSR BR21 | F | Soybean | 1.24 | 0.58 | 7.18 |
| DSR BR21 | F | Chickpea | 3.33 | 0.60 | 19.98 |
| DSR BR21 | F | Linseed | 0.98 (Oil cake) | 6.20 | 60.76 |
| DSR BR21 | F | Sunflower | 3.67 | 0.50 | 19.86 |
| DSR BR21 | F | F | - | - | - |

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# Evaluation of Selection Criteria in Premium Quality Rice Genotypes Through Genetic Variability, Character Association and Path Analysis

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ABSTRACT

This study evaluates yield contributing characters as selection criteria after studying genetic parameters, correlation coefficients and partitioning direct and indirect effects on yield of 21 premium quality rice genotypes in transplanted Aman season 2009. All the test characters were demonstrated significant variation. Considering genetic parameters, high genotypic coefficients of variation and high heritability coupled with high genetic advance over mean were observed for effective tiller number/$m^2$, panicle length (cm) and thousand grain weight (g). The characters also showed highly significant positive correlations with yield while plant height (cm) showed highly significant negative correlation with yield (t/ha) suggesting better opportunity for selecting genotypes based on these characters. Path coefficient analysis revealed that effective tiller number/$m^2$ exhibited higher direct effect on yield (t/ha) followed by panicle length (cm). All together with the genetic variability, correlation and path analysis revealed that effective tiller number/$m^2$, panicle length (cm), thousand grain weight (g) and plant height (cm) are the most four important selection criteria contributing higher rice yield. From the present investigation, it could be suggested that emphasis should be given on these characters for the selection of genotypes for higher yield in premium quality rice.

## INTRODUCTION

Rice yield depends on many yield contributing parameters as well as on the environmental factors. As yield is polygenically controlled and also influenced by its component characters, direct selection for yield is often misleading. Genetic variability, character association pattern and the direct and indirect effect of the yield contributing characters on yield are very useful tools for successful selection of desirable genotypes having high yield potential. Therefore, we did this study to explore the characters highly responsible for high yield potential through yield component analysis.

## MATERIALS AND METHOD

Twenty-one premium quality rice lines (Table 1) were evaluated at the BRRI regional station Comilla, in T. Aman 2009 using RCB design with three replications. Thirty-day-old seedlings were transplanted in 16.2 $m^2$ plots using 2-3 seedlings per hill. Fertilizers were applied at the rate of 80:60:40 kg N-P-K and 70 kg gypsum per hectare. All other fertilizers, except N, were used as basal dose and N was top dressed in two equal splits at 20 and 50 days after transplanting. Standard crop management practices were done as and when necessary. Data on plant height (cm), flag leaf area ($cm^2$), effective tiller number/$m^2$, panicle length (cm), spikelet fertility (%), days to 50% flowering, growth duration (day) and thousand grain weight (g) were taken from randomly selected ten plants from each plot. Yields were taken from whole plot crop cutting and converted it to ton per hectare. Genotypic variance ($\sigma^2_g$), phenotypic variance ($\sigma^2_p$), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense ($h^2_b$), genetic advance (GA) were estimated by the formula suggested by Singh and Chaudhury (1985). Genotypic and phenotypic correlation coefficients and path coefficient analysis were done using Basica stat software. The estimate of GCV and PCV was classified as low (0-10), medium (>10-20) and high (>20) (Sivasubramanian and Madhavamenon, 1973). The heritability was categorized as low (0-30), medium (>30-60) and high (>60) suggested by Robinson *et al*, (1949). Again, genetic advance was classified by adopting the method of Johnson *et al*, (1995).

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RESULTS AND DISCUSSION

**Genetic parameters**

The analysis of variance of the present study indicated highly significant variations among the genotypes for all the characters studied (Table 2). For clear understanding of the pattern of variations, the phenotypic variance has been partitioned into genotypic and environmental variance. The highest genotypic, environmental and phenotypic variance was found in flag leaf area ($cm^2$). The lowest magnitude of genotypic, environmental and phenotypic variance was recorded in grain yield (t/ha). The PCV and GCV were not very much different from each other for all of the characters except flag leaf area ($cm^2$) which indicated less environmental influence on the expression of those characters. This result suggests that selection for yield and yield contributing characters in present investigation would bring good response. The GCV and PCV were high in grain yield (t/ha), effective tiller number/$m^2$ and thousand grain weight (g) indicated higher degree of genetic variability in these traits but GCV and PCV were moderate for panicle length (cm) and spikelet fertility (%). This finding was mostly supported by Habib *et al*, (2005). Growth duration (days) and days to 50% flowering exhibited low genotypic as well as phenotypic coefficient of variations in the present study, suggesting that selection for these characters would not be effective. Heritability estimates in broad sense ($h^2b$) were relatively higher for all the traits studied. Although high heritability estimates have been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance but Johnson *et al*, (1955) suggested that heritability estimates coupled with high genetic advance were more useful in predicting the response to selection. High heritability along with high genetic advance was obtained in effective tiller number/$m^2$ followed by spikelets fertility (%) indicating most effectiveness in the selection of superior genotypes.

**Character associations**

Table 3 presents genotypic and phenotypic correlation coefficients among grain yield and eight yield contributing characters for 21 rice genotypes. Genotypic correlation coefficients were higher than the phenotypic correlation coefficients in most of the cases, which suggested that character association had not been largely influenced by environment in these characters. Grain yield was found positively and significantly associated with both genotypic and phenotypic level for effective tiller number/$m^2$, panicle length (cm) and thousand grain weight (g). Similar result was also reported by Yolanda and Das (1995) for panicle length (cm), Bai *et al*, (1992) for effective tiller number/$m^2$ and Biswas *et al*, (2000) for thousand grain weight (g). The results emphasized the importance of these component characters as potential contributors to high yield and ultimately to enrich the selection criteria in the selection of superior genotypes. However, plant height (cm) produced significantly negative correlation with grain yield. Similar result was reported by Biswas *et al*, (2000). Inter relationships among the yield contributing traits showed that plant height had highly significant but negative correlation with effective tiller number/$m^2$, panicle length (cm), spikelet fertility (%) and thousand grain weight (g). Flag leaf area ($cm^2$) showed significant negative correlation with spikelet fertility (%), days to 50% flowering and growth duration (day), which finally gave non-significant correlation with grain yield.

Positively significant correlation was observed with panicle length (cm), growth duration (day) and thousand grain weight (g) by the character effective tiller number/$m^2$. Positively significant relation was also observed between panicle length (cm) and thousand grain weight (g). Days to 50% flowering showed significant positive correlation with growth duration (day).

**Path co-efficient analysis**

In correlation studies, with the increasing number of variables, the indirect associations become complex and important. In such situations, path coefficient analysis is useful to find out direct and indirect causes of associations. Path coefficient analysis permits a critical examination to specific factors acting to produce a given correlation and measures the relative importance of each factor. From the results of path analysis (Table 4), it was evident that the highest positive direct effect on grain yield was obtained by effective tiller/$m^2$ followed by panicle length. The correlation coefficient for effective tiller/$m^2$ is almost equal to its direct effect indicating that it had true relationship with grain yield and direct selection through this trait would be effective. Chaudhary and Motiramani (2003) reported greater contribution of effective tiller/$m^2$ and spikelets density in rice. Again, similar results were also obtained by Rashid *et al,* (2007). Plant height exhibited highly significant negative direct effect with grain yield indicating high yield potential of short stature plant varieties. Spikelet fertility and days to 50% flowering showed negative and negligible direct effect among themselves but showed insignificant positive correlation with yield indicating that indirect causal factors are to be considered for selection of superior genotypes. Higher positive indirect effect of thousand grain weight and panicle length through effective tiller/$m^2$ might be due to highly significant positive correlation of thousand grain weight and panicle length with effective tiller/$m^2$. The result prescribed that while using panicle length and thousand grain weight as selection criteria, effective tiller/$m^2$ should be given proper importance.

The residual effect of the present study was 0.20, indicating that 80 percent of the variability in grain yield was contributed by the eight component characters studied in this path analysis. This gives an impression that a few other characters than those involved in the present study might also contributed to yield.

The genetic variability, character associations and path analysis of the present study finally proved that panicle length (cm), effective tiller number/$m^2$ and thousand grain weight (g) are the most important yield contributing characters on which emphasis should be given for the selection of superior premium quality rice genotypes.

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**Table 1. List of genotypes used in the study.**

| **Designation** | **Designation** |
|---|---|
| BR7873-*5(NIL)-37-HR4 | BR7150-11-5-5-9-14 |
| BR7873-*5(NIL)-37-HR5 | BR7878-*5(NIL)-72-HR6 |
| BR7873-*5(NIL)-52-HR6 | BR7878-*5(NIL)-37-HR2 |
| BR7873-*5(NIL)-52-HR10 | BR7878-*5(NIL)-66-HR15 |
| BR7875-*5(NIL)-52-HR1 | BR6817-25-2-2-3 |
| BR7877-*5(NIL)-63 | BR6817-75-2-2-3-HR3 |
| BR7877-*5(NIL)-64 | BR6818-17-4-3-3 |
| BR7150-11-5-4-2-11 | BR6818-25-3-2-3-HR12 |
| BR7150-11-7-4-2-12 | BRRI dhan34 |
| BR7150-11-7-4-2-16 | Dadkhani |
| BR7150-11-3-4-2-19 | |

**Table 2. Estimation of statistical and genetic parameters of yield and its contributing traits of 21 premium quality rice genotypes.**

| Parameter | Mean sum of square | Grand mean | Range | $\sigma^2_g$ | $\sigma^2_e$ | $\sigma^2_p$ | $h^2_b$ | GA | GCV | PCV |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant ht (cm) | 149.61** | 108.1 | 95.7-127 | 49.32 | 1.64 | 50.96 | 96.78 | 14.23 | 16.5 | 16.6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Flag leaf area ($cm^2$) | 402.34** | 57.07 | 32.7-96.1 | 113.66 | 61.36 | 175.02 | 64.94 | 17.7 | 18.68 | 23.18 |
| Effective tiller no./$m^2$ | 17.04** | 10 | 5.0-15.0 | 5.28 | 1.20 | 6.48 | 81.47 | 24.27 | 22.98 | 25.46 |
| Panicle length (cm) | 32.37** | 26.91 | 21.5-34 | 10.50 | 0.86 | 11.37 | 92.41 | 16.42 | 12.04 | 12.53 |
| Spikelet fertility (%) | 273.94** | 80.19 | 57-96 | 88.45 | 8.60 | 97.05 | 91.14 | 18.5 | 11.73 | 12.28 |
| Days to 50 % flowering | 73.50** | 96.21 | 88-105 | 24.41 | 0.27 | 24.68 | 98.92 | 10.12 | 5.14 | 5.16 |
| Growth duration (day) | 75.58** | 121.57 | 113-131 | 25.12 | 0.21 | 25.33 | 99.19 | 10.28 | 4.12 | 4.14 |
| 1000-grain wt (g) | 139.27** | 22.43 | 10.99-2.62 | 46.41 | 0.02 | 46.44 | 99.95 | 14.03 | 30.37 | 30.38 |
| Yield (t/ha) | 2.82** | 3.46 | 1.65-5.83 | 0.92 | 0.06 | 0.98 | 94.15 | 1.92 | 27.72 | 28.57 |

**=Significant at the 1% level. $\sigma^2_g$=Genotypic variance, $\sigma^2_e$=Environmental variance, $\sigma^2_p$=Phenotypic variance, $h^2_b$=Heritability in broad sense, GA=Genetic advance, GCV=Genotypic coefficients of variations and PCV=Phenotypic coefficients of variations.

**Table 3. Genotypic ($r_g$) and phenotypic ($r_p$) correlation coefficients among yield and its contributing traits of 21 premium quality rice genotypes.**

| Parameter | | Flag leaf area ($cm^2$) | Effective tiller no./$m^2$ | Panicle length (cm) | Spikelets fertility (%) | Days to 50% flowering | Growth duration (days) | 1000- grain wt (g) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Plant ht (cm) | $r_g$ | 0.0591 | -0.3387** | -0.2492* | -0.3757** | -0.0077 | 0.0972 | -0.3727** | -0.4126** |
| | $r_p$ | 0.0336 | -0.3185** | -0.2353* | -0.3634** | -0.0112 | 0.0944 | -0.3662** | -0.3953** |
| Flag leaf area ($cm^2$) | $r_g$ | | -0.1827 | -0.0400 | -0.4544** | -0.6494** | -0.7640** | 0.0297 | -0.0153 |
| | $r_p$ | | -0.1611 | -0.0395 | -0.3743** | -0.5201** | -0.5931** | 0.0194 | -0.0303 |
| Effective tiller no./$m^2$ | $r_g$ | | | 0.6664** | 0.1152 | 0.2061 | 0.2730** | 0.7968** | 0.9994** |
| | $r_p$ | | | 0.5915** | 0.1246 | 0.1995 | 0.2466** | 0.7198** | 0.8734** |
| Panicle length (cm) | $r_g$ | | | | 0.2366* | 0.2257 | 0.1943 | 0.8675** | 0.7382** |
| | $r_p$ | | | | 0.2103 | 0.2075 | 0.1837 | 0.8333** | 0.6944** |
| Spikelets fertility (%) | $r_g$ | | | | | 0.1616 | 0.2090 | 0.1494 | 0.0835 |
| | $r_p$ | | | | | 0.1501 | 0.2070 | 0.1441 | 0.0645 |
| Day to 50% flowering | $r_g$ | | | | | | 0.9458** | 0.0348 | 0.1085 |
| | $r_p$ | | | | | | 0.9362** | 0.0352 | 0.1053 |
| Growth duration (day) | $r_g$ | | | | | | | 0.0467 | 0.1382 |
| | $r_p$ | | | | | | | 0.0465 | 0.1349 |
| 1000-grain wt (g) | $r_g$ | | | | | | | | 0.8434** |
| | $r_p$ | | | | | | | | 0.8184** |

* and**indicates significant at the 5% and 1% level of significance, $r_g$ and $r_p$ indicates genotypic and phenotypic correlation coefficient, respectively.

**Table 4. Partitioning of genotypic correlation with grain yield into direct (bold) and indirect effect of yield contributing traits in 21 premium quality rice genotypes.**

| Parameter | Plant ht (cm) | Flag leaf area ($cm^2$) | Effective tiller no./$m^2$ | Panicle length (cm) | Spikelets fertility (%) | Days to 50% flowering | Growth duration (day) | 1000-grain wt (g) | Genotypic correlation with yield |
|---|---|---|---|---|---|---|---|---|---|
| Plant ht (cm) | **-0.1496** | 0.0049 | -0.2625 | -0.0527 | 0.0300 | 0.0015 | 0.0143 | 0.0015 | -0.4126** |
| Flag leaf area ($cm^2$) | -0.0070 | **0.1051** | -0.1380 | -0.0080 | 0.0341 | 0.1024 | -0.1038 | -0.0001 | -0.0153 |
| Effective tiller no./$m^2$ | 0.0477 | -0.0174 | **0.8397** | 0.1380 | -0.0096 | -0.0350 | 0.0392 | -0.0032 | 0.9994** |
| Panicle length (cm) | 0.0351 | -0.0040 | 0.5069 | **0.2312** | -0.0184 | -0.0375 | 0.0285 | -0.0036 | 0.7382** |
| Spikelet fertility (%) | 0.0534 | -0.0421 | 0.0944 | 0.0490 | **-0.0745** | -0.0271 | 0.0310 | -0.0006 | 0.0835 |
| Days to 50% flowering | 0.0012 | -0.0597 | 0.1618 | 0.0473 | -0.0128 | **-0.1700** | 0.1408 | -0.0001 | 0.1085 |
| Growth duration (days) | -0.0138 | -0.0695 | 0.2086 | 0.0412 | -0.0168 | -0.1618 | **0.1505** | -0.0002 | 0.1382 |
| 1000-grain wt (g) | 0.0534 | 0.0026 | 0.6092 | 0.1849 | -0.0120 | -0.0060 | 0.0070 | **0.0043** | 0.8434** |

**Indicates significant at the 1% level of significance, Residual effect, **R= 0.20.**

# Residual Effect of Fresh Poultry Litter on Rice Yield and Some Plant Parameters

J C Biswas and B C Roy[11]

ABSTRACT

This paper investigates the influence of fresh poultry litter (PL) and its residual effects at the Bangladesh Rice Research Institute farm in Gazipur. Absolute control, 3 t/ha and 5 t/ha fresh PL was applied as basal before three days of transplanting during first rice crop. We sub-divided the PL treated plots into two during the next cropping season for imposing N treatments at 80 kg/ha for T. Aman and 120 kg/ha for Boro rice crops. The fresh PL significantly improved rice grain yield because of increased panicle production. In succeeding rice crops, N addition significantly influenced panicle/$m^2$, grain and straw yields indicating that there was carry-over effect of PL application on succeeding crop, especially at a higher rate. Rice could be cultivated successfully by using residual effect of fresh PL, provided adequate N and K is used for mitigation of deficiency.

INTRODUCTION

In general, for each kilogram (kg) of feed consumed, a chicken approximately produce one kg of fresh manure with variable water content, while a commercial layer produce about 20 kg/year (Vest *et al*, 1994). So, one can easily predict how much poultry waste are produced from about 80 million poultry in Bangladesh. It is an excellent nutrient source of N, P and K. The PL application also increases the organic-matter content of the soil and improves soil quality. It can also be utilized for power generation (Dagnall, 1993).

Broiler litter contains 36-64% total digestible nutrients, 0.56-3.92% P, 0.81-6.13% Ca and 125-667 ppm Mg (Jacob *et al,* 1997). Cage layer manure contains the major plant nutrients of N, P, and K, which depend on age and diet of flock as well as moisture content and age of manure (Jacobs *et al*, 1996). Nutrient uptake by forages increased when PL was used as fertilizer along with nutrient accumulation in soils over time (Pederson *et al,* 2002).

Availability of fertilizer at the right time is one of the major constraints now a day for rice production in Bangladesh. The cost of fertilizer is also high. So, PL could be used under such conditions to supplement plant nutrients for rice production because it contains good amount of available nutrients (Jacobs *et al*, 1996; Dobermann and Fairhast, 2000). Fresh and one month decomposed PL was successfully utilized for rice cultivation (Biswas *et al,* 2008; BRRI, 2005) and thus saving of costly earned foreign exchange for fertilizer

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import. The positive impact of fresh PL application on our previous studies prompted us to investigate residual effect of added PL in succeeding rice crops.

## MATERIALS AND METHODS

The experiment was initiated during T. Aman 2008 at Bangladesh Rice Research Institute, Gazipur. Initial treatments were absolute control, 3 t/ha and 5 t/ha FPL as basal. The treatments assigned in a randomized complete block design with three replications. Water content of fresh PL was about 65%. The unit plot size was 6- × 3-m. After first crop, the plots were sub-divided into two parts during the next cropping season for imposing additional N treatments, but lay out remained same for the next cropping seasons. Nitrogen rate was 80 kg/ha for T. Aman and 120 kg/ha for Boro season. Nitrogen was applied in three equal splits at 10-15 DAT, 30-35 DAT and before panicle initiation (PI). Thirty-day-old seedlings of BRRI dhan49 were transplanted on 13/8/08 and 16/8/2009 at 20- × 20-cm spacing. BRRI dhan45 was used in Boro season and 45-day-old seedlings were transplanted with above-mentioned spacing on 03-01-2009. Standard cultural practices were followed for growing rice crops.

Data on plant height, panicles/$m^2$, grains/panicle, spikelet sterility, grain and straw yields were recorded. Phosphorus and K uptake was estimated considering nutrient removal for each ton of grain and straw production (Dobermann and Fairhurst, 2000) by the rice crop and then P and K balance after first crop was determined. The data were subjected to statistical analyses following Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

Plant height and spikelet sterility did not vary because of being imposed treatments; but addition of fresh PL caused significantly higher grain and straw yields during initial year (T. Aman, 2008) because of being increased panicle production as well as number of grains in a panicle (Table 1). The increase in grain yield was 30% and 44% for addition of 3 and 5 t/ha fresh PL respectively compared to control. Biswas *et al*, (2008) and BRRI (2011) also reported higher grain yield when PL was used alone or in combination with fertilizers.

There were significant variations in panicle/$m^2$, grain and straw yields due to addition of N fertilizer in succeeding rice crops (Tables 2 and 3). Plant height, grains in panicle and spikelet sterility did not vary significantly among the treatments in the succeeding Boro and T. Aman crops. These findings indicate that N was only the limiting nutrient for successful rice cultivation and other nutrients were available because of initial PL addition. Pederson *et al*, (2002) reported that nutrient accumulation occurs in soils over time because of PL application, which could be used by the succeeding crops. Shah *et al*, (2004) also showed residual effect of P fertilization in rice. In our study we added fresh PL one time only. In this case estimated P and K removal by the first crop shows that 9 kg P/ha was accumulated in soil when fresh PL was used at 5 t/ha basis (Table 4). However, there was negative K balances irrespective of treatments. Although negative K balance and minimum positive P balance after first crop implied that shortage of P was also initiated from second crop. Added fresh PL might have influenced availability of soil bound P and K for the use of the rice crop.

## CONCLUSION

Thus we conclude that rice could be cultivated successfully by using residual effect of fresh PL, especially when higher doses of PL is used along with adequate N supply and K fertilization for minimizing K mining. The severity of mining would be increased with increased cropping intensity after fresh PL application.

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**Table 1. Effect of fresh PL on wet season T. Aman rice, 2008, BRRI, Gazipur.**

| Treatment | Plant ht (cm) | Panicles /$m^2$ | Grains /panicle | Sterility (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Absolute control | 95b | 180b | 77b | 16.11a | 3.51b | 4.50b |
| 3 t/ha FPL | 99a | 203ab | 88ab | 17.32a | 4.55ab | 5.80a |
| 5 t/ha FPL | 100a | 218a | 92a | 16.98a | 5.07a | 6.31a |
| CV(%) | 3.1 | 4.5 | 5.1 | 10.1 | 6.1 | 7.71 |

Small letter(s) in a column compare means at the 0.05 level by DMRT.

**Table 2. Residual effect (first year) of fresh PL application on succeeding dry season irrigated rice, Boro (2008-09, BRRI, Gazipur.**

| Treatment | Plant ht (cm) | Panicles /m$^2$ | Grains /panicle | Sterility (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| Absolute control | 75a | 160b | 89a | 11.87a | 3.31b | 3.50b |
| 3 t/ha FPL | 72a | 165b | 82a | 15.39ab | 3.35b | 3.43b |
| 3 t/ha FPL + 120 kg/ha N | 81a | 304a | 90a | 14.05ab | 5.48a | 6.13a |
| 5 t/ha FPL | 76a | 153b | 87a | 10.13a | 3.47b | 4.01b |
| 5 t/ha FPL + 120 kg/ha N | 82a | 300a | 91a | 18.45b | 5.50a | 6.26a |
| CV(%) | 3.3 | 4.6 | 3.7 | 8.7 | 6.3 | 8.1 |

Small letter(s) in a column compare means at the 0.05 level by DMRT.

**Table 3. Residual effect (2$^{nd}$ year) of fresh PL application on succeeding wet season T. Aman rice, 2009, BRRI, Gazipur.**

| Treatment | Plant ht (cm) | Panicles /m$^2$ | Grains /panicle | Sterility (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| Absolute control | 98a | 180b | 75a | 15.38a | 2.95c | 3.68c |
| 3 t/ha FPL | 99a | 185b | 78a | 18.96ab | 3.33b | 4.26b |
| 3 t/ha FPL + 80 kg/ha N | 102a | 215a | 85a | 21.28b | 4.13a | 5.47a |
| 5 t/ha FPL | 100a | 198ab | 82a | 23.57b | 3.50b | 4.50b |
| 5 t/ha FPL + 80 kg/ha N | 101a | 220a | 90a | 20.45b | 4.25a | 5.67a |
| CV(%) | 2.5 | 3.6 | 4.2 | 9.8 | 7.5 | 8.9 |

Small letter(s) in a column compare means at the 0.05 level by DMRT.

**Table 4. Estimated P and K balance after harvesting of first crop, BRRI, Gazipur**.

| Treatment | Nutrient added (kg/ha) | | Nutrient removed (kg/ha) | | Balance (kg/ha) | |
|---|---|---|---|---|---|---|
| | P | K | P | K | P | K |
| Absolute control | 0 | 0 | 20.0 | 112.1 | -20.0 | -112.1 |
| 3 t/ha fresh PL | 26.30 | 34.0 | 25.9 | 144.9 | 0.4 | -110.9 |
| 5 t/ha fresh PL | 43.8 | 56.7 | 28.5 | 159.3 | 15.3 | -102.6 |

# Assessment of the Effect of Climate Change on Boro Rice Yield and Yield Gap using DSSAT Model

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ABSTRACT

The actual yield of different Boro varieties is often much lower than the potential yield (ie, yield without any water and fertilizer stress), commonly referred to as yield gap. We investigates the possible impact of climate change on Boro rice yield and yield gap by estimating the potential yield and yield under commonly employed crop management practices (ie, irrigation and fertilizer application) for the years 2030, 2050 and 2070 using the DSSAT modeling system. The model has been used for predicting yields of the BR3 and BR14 Boro rice varieties for 12 major rice growing locations in Bangladesh. Available data on soil and hydrologic characteristics of these locations, and typical crop management practice for Boro rice have been used in the simulations. The weather data required for the model (daily maximum and minimum temperatures, daily solar radiation and daily precipitation) were generated for the selected years and for the selected locations using the regional climate model PRECIS. The crop model predicted significantly lower yield of the Boro rice varieties and increasing trend of rice yield gap in the future under the present crop management practice, suggesting that among other measures, the currently used agricultural practices would have to be changed for offsetting the adverse effect of climate change on Boro yield. The model predicted that under currently employed practice, the average yield gap (average of 12 selected locations) for BR3 rice variety would be 30, 43 and 52% for the years 2030, 2050 and 2070 respectively. The corresponding yield gaps for BR14 rice variety were predicted to be 37, 49 and 58%. Increasing atmospheric carbon-dioxide concentrations have been predicted to increase rice yield gap in the future. Rice yield and yield gap have also been found to be sensitive to transplanting date. Such yield reductions under changed climatic conditions could significantly affect food production and food security in

Bangladesh. Among other initiatives, adaptation of proper crop management practices could reduce the severity of such adverse impacts. It is also necessary to develop high temperature-resistant rice varieties and modify management practices to offset the adverse effects of climate change.
**Keywords:** Bangladesh, climate change, Boro rice, rice yield, yield gap, DSSAT model

## INTRODUCTION

Most existing rice varieties, particularly modern varieties and hybrids, have a potential yield that is higher than the actual yield commonly achieved by farmers, and there is considerable variation in the actual yield levels achieved, even under similar production systems. Potential yield is commonly referred to as yield under no nitrogen (fertilizer) and water stress. Actual yields of irrigated rice in Bangladesh are only about 4 to 6 tones per ha, while the potential yield of modern rice varieties could be as high as 10 to 11 tones per ha. Yield differences among farmers in the same area are frequent because of the different levels of crop management and the diversity of environments in the area (FAO, 2004). The expert consultation on yield gap and productivity decline in rice production, convened by FAO in Rome in 2000, recognized that there is a sizeable yield gap between attainable and farm-level yields across the ecologies, the regions, within ecologies and the crop seasons in many rice growing countries. The yield gap between attainable and farm-level yields ranges from 10 to 60 percent. This yield gap could potentially increase in the future under adverse climatic conditions due to climate change, especially if current agricultural practices are continued.

A number of simulation studies have been carried out to assess impacts of climate change and variability on rice productivity in Bangladesh (eg, Basak *et al,* 2009; Mahmood *et al,* 2003; Mahmood, 1998; Karim *et al,* 1996) and some of these studies have predicted lower rice yield under different climate change scenarios. Basak (2009) and Basak *et al* (2010) reported predicted significant reduction in yield of some varieties of Boro rice due to climate change; yield reductions of over 20 and 50% have been predicted for the years 2050 and 2070 respectively. This study presents an assessment of the Boro rice yield gap (ie, difference between potential yield and yield under presently employed agricultural practice) under future climate scenarios.

In this study, future climate scenarios have been depicted using the climate model named Providing Regional Climates for Impact Studies (PRECIS). The weather data requirement for DSSAT (Decision Support System for Agrotechnology Transfer, version 4) model include daily maximum and minimum air temperatures, daily precipitation and daily solar radiation, all of which could affect rice yield significantly. Therefore, future climate scenarios, including daily maximum and minimum temperatures, precipitation and solar radiation, for selected locations of Bangladesh have been generated and used for predicting yield gaps of Boro rice. The yield of two Boro varieties (BR3 and BR14) have been simulated in the present study for the years 2008, 2030, 2050 and 2070, using the DSSAT modeling system.

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## MATERIALS AND METHODS

### Selection of simulation locations

The yield (both potential yield and rice yield under an assumed crop management practice) of two Boro rice varieties BR3 and BR14 for the years 2008, 2030, 2050 and 2070 have been simulated for 12 districts of Bangladesh, which were selected from among the major rice growing areas in different regions of Bangladesh. Among them, Rajshahi, Bogra and Dinajpur were selected from northwestern region; Mymensingh and Tangail were selected from central region; Jessore and Satkhira from southwestern region; Barisal and Madaripur from southern region; Chandpur and Comilla from southeastern region; and Sylhet district from eastern region. In addition, the yields (potential and actual yield) of the rice varieties under varying transplanting date were also assessed.

### Crop model

The DSSAT modeling system is an advanced physiologically based rice crop growth simulation model and has been widely applied to understand the relationship between rice and its environment. The model estimates yield of irrigated and non-irrigated rice, determine duration of growth stages, dry matter production and portioning, root system dynamics, effect of soil water and soil nitrogen contents on photosynthesis, carbon balance and water balance. Ritchie *et al* (1987) and Hoogenboom *et al* (2003) have provided a detailed description of the model. In the present study, the Introductory Crop Simulation (ICSim) of DSSAT modeling system has been used for all simulations.

### Selection of rice variety

The DSSAT model is variety-specific (eg, BR3 Boro) and is able to predict rice yield and rice plant response to various environmental conditions. In predicting crop growth and yield, the model takes into consideration of weather, crop management, genetics, and soil water, C and N. The model uses a detailed set of crop specific genetic coefficients, which allows the model to respond to diverse weather and management conditions.

Therefore, in order to get reliable results from model simulations, it is necessary to have the appropriate genetic coefficients for the selected cultivars. The two Boro rice varieties BR3 and BR14 have been selected in the present study because genetic coefficients for these varieties are available in the DSSAT modeling system. Although these varieties are not widely used at present, the effects of climate change and variability on these varieties provide insights into possible impact of climate change on Boro rice yield gap.

**Soil and crop management input**

The DSSAT model requires a detailed set of input data on soil and hydrologic characteristics (ie, pedological and hydrological data), and crop management. Input data related to soil characteristics include soil texture, number of layers in soil profile, soil layer depth, pH of soil for each depth, clay, silt and sand contents, organic matter and cation exchange capacity etc. Required data on soil and hydrologic characteristics for the 12 selected locations (districts) were collected from Bangladesh Rice Research Institute (BRRI, Gazipur; BARC, 2005; Karim *et al*, 1998) and Soil Resources Development Institute (SRDI, Dhaka). As an example, table 1 presents the soil profile data used in the model for the the Old Meghna Estuarine Floodplain (ie, Agro-ecological zone, AEZ-19) covering Kishoregani, Habiganj, Brahmanbaria, Comilla, Chandpur, Feni, Noakhali, Laksmipur, Narsingdi, Narayanganj, Dhaka, Shariatpur, Modaripur, Gopalganj and Barisal districts.

The crop management data (ie, agronomic data) required by the model include planting date, planting density, row spacing, planting depth, irrigation amount and frequency, fertilizer application dates and amounts. Table 2 shows the major crop management input data used in all model simulations in the present study. It represents typical practices (BRRI, 2006 and Rashid, 2008) in Bangladesh. Using these inputs, the average (of 12 locations) yields of BR3 and BR14 for 2008, estimated by the model, were about 5500 kg ha$^{-1}$ and 4050 kg ha$^{-1}$ respectively. These values are close to the reported yields of these varieties (BRRI, 2007). These crop management inputs were subsequently used in all model simulations under the predicted weather scenarios for 2008, 2030, 2050 and 2070. It should be noted that the DSSAT model does not count the water required for preparation of land before transplanting (which usually varies from 200 to 300 mm, depending on soil and weather condition).

**Weather data**

In this study, a regional climate model named Providing Regional Climate for Impacts Studies (PRECIS) was used to generate daily weather data needed for running the DSSAT model. The special report on emission scenarios (SRES) A2 of ECHAM4 has been used as PRECIS input. In this study PRECIS was run with 50-km horizontal resolution for the present climate (2008) using baseline lateral boundary conditions (LBCs). The model domain was selected 65-103°E and 6-35°N to cover Bangladesh and its surroundings. In the next step PRECIS run was completed for 2030, 2050 and 2070 using ECHAM 4 SRES A2 as the model input. The PRECIS outputs that were used in the DSSAT model include daily maximum temperature ($T_{max}$), daily minimum temperature ($T_{min}$), daily incoming solar radiation (Srad), and daily precipitation. These parameters were extracted at 12 locations mentioned in subsection named Selection of Simulation Locations.

## RESULTS AND DISCUSSIONS

**Impact of climate change on rice yield and yield gap**

Tables 3 and 4 show predicted rice yield (potential and actual yield) and yield gaps of BR3 and BR14 Boro rice varieties respectively at 12 locations of Bangladesh in 2030, 2050 and 2070. These predictions have been made using a fixed concentration of atmospheric $CO_2$ of 379 ppm (the value reported for 2005 in the fourth assessment report of IPCC) and for planting date of 15 January. In general, Tables 3 and 4 show significant reductions in predicted rice yield in the future due to predicted changes in climatic condition. These tables also show significant change in rice yield gaps in the future due to predicted changes in climatic condition and the predicted yield gaps increased significantly with time from 2030 to 2070 (Fig. 5). Predicted average rice yield gaps of BR3 variety for the 12 selected locations are about 30% for 2030, 43% for 2050 and 52% for 2070. The corresponding changes for BR14 variety are about 37, 49 and 58% for 2030, 2050 and 2070 respectively. Some regional variation could also be observed in the predictions, with somewhat higher rice yield gaps predicted for northwestern, central, southern and southwestern regions. Figures 1 and 2 show predicted average yield gaps of BR3 and BR14 rice varieties for 2030, 2050 and 2070.

Increasing atmospheric $CO_2$ concentration is likely to have some positive effect on rice yield. If rate of change of atmospheric $CO_2$ concentration from 1994 (358 ppm) to 2005 (379 ppm) (ie, about 1.9 ppm per year) is used to set the $CO_2$ concentrations in 2030 (at 427 ppm), 2050 (at 465 ppm), and 2070 (at 503 ppm), then the model predicts slightly higher yield gaps (compared to predicted yield gaps at 379 ppm $CO_2$). When the $CO_2$ levels were increased to 427, 465 and 503 ppm in 2030, 2050 and 2070, respectively, predicted rice yield gaps increased by 0.06 to 7.3% for BR3 rice and 0.01 to 4.6% for BR14 rice at different locations (Tables 5 and 6). Thus, while increasing $CO_2$ concentrations are predicted to increase yield to some extent, thus slightly offsetting the adverse effects of other climatic parameters on rice yield (Basak, 2009; Basak *et al*, 2010), it has been predicted to increase the yield gap of Boro rice even more. Figures 3 and 4 show effect of increasing $CO_2$ on yields of BR3 and BR14 rice varieties for 2030, 2050 and 2070. It should be noted that the predicted increase of potential yield for 2050 is higher than 2030 for some selected locations in Bangladesh, which could also be explained by the variation in predicted temperatures, rainfall and solar radiation at these locations (Basak, 2009).

**Sensitivity of rice yield and yield gap to climatic parameters**

The climatic parameters used in the model are daily maximum temperature ($T_{max}$), daily minimum temperature ($T_{min}$), daily solar radiation (Srad) and daily precipitation (Rain). In order to assess relative importance of these parameters on predicted rice yield gap, Basak (2009) carried out sensitivity analysis by predicting yield of BR3 and BR14 rice varieties for a number of locations using predicted climatic parameters for 2008 and 2070, changing one parameter at a time; atmospheric $CO_2$ concentration was kept fixed at 379 ppm. Table 7 shows the results of the sensitivity analysis for BR3 rice variety in Barisal.

Table 7 shows that $T_{max}$ has the most significant negative impact on rice yield, followed by rainfall, and $T_{min}$; predicted solar radiation, on the other hand, has some positive effect on yield. Analysis of predicted temperatures showed that average $T_{max}$ during January-May (ie, rice growing season) for 2008 and 2070 were 30.73 °C and 35.11 °C respectively; this significant increase in $T_{max}$ resulted in reduction of rice yield of BR3 by about 31% and for potential yield, it was 21%. Average $T_{min}$ during this period for 2008 and 2070 were 21.52 °C and 25.22 °C, and the increase in $T_{min}$ caused a reduction of 17% in the predicted rice yield and 10% for the potential yield. Average solar radiation in 2008 and 2070 are 15.37 and 16.71 $MJ/m^2$/day respectively and this increase in solar radiation actually increased the predicted rice yield by about 11% and 18% for potential yield. Like BR3, similar yield reductions were also predicted for BR14 rice, both actual and potential yields.

Table 7 shows significant negative effect of rainfall on BR3 rice yield. Since a fixed irrigation schedule (855 mm in 14 applications) was used in all model simulations, change in rainfall affected predicted yield by changing availability of water. Analysis of predicted rainfall data showed total rainfall (in January to May) of 144.6 mm and 356.1 mm for 2008 and 2070 respectively. So, total water available from rainfall was higher in 2070. However, a closer look shows that in 2008 significant rainfall (96.3 mm) is predicted in January to March, which represent the vegetative phase and a part of reproductive phase of rice plant and in which water requirement is the highest. In 2070 only 21.6 mm rainfall is predicted for this critical growth phase. On the other hand, relatively high rainfall of 334.5 mm is predicted for April-May, when water requirement is not significant. This variation in rainfall pattern was responsible for the predicted reduction in rice yield in 2070 consequently increase the rice yield gap during this period. Sensitivity analysis was also carried out for Dinajpur, Mymensingh, Jessore and Comilla (Basak, 2009). These analyses yielded similar results, demonstrating significant negative impact of increasing $T_{max}$ and $T_{min}$ on rice yield. Depending on rainfall pattern, the effects of rainfall on rice yield at these locations were different (Basak, 2009).

As noted earlier and shown in Fig. 5, the predicted rice yield gaps increased with time. This was found to be primarily due to significant increases in $T_{max}$ and $T_{min}$. For example, in Barisal, average $T_{max}$ in January-May (ie, rice growing season) for 2030 and 2070 are 29.79 °C and 35.11 °C respectively, average $T_{min}$ during this period for 2030 and 2070 are 20.28 °C and 25.22 °C. Predicted rice yield gaps for BR3 in Barisal for 2030 and 2070 are 43.3% and 68.6%, respectively (Fig. 5).

**Effect of planting date on rice yield and yield gap**

Basak (2009) and Basak *et al* (2010) reported significant reduction of Boro rice yield as transplanting date is delayed beyond 15 January. BRRI (2011) has recommended 15 December to 1 January for transplanting date of BR3 varieties and 23 December to 7 January for BR14. In this study, the effect of planting date on rice yield gap has been assessed by setting the planting date on 1, 5, 15 and 25 January and simulating yield for each case under fixed $CO_2$ concentration. In general, the predictions indicate significant increase in rice yield gaps for delayed planting, especially beyond 15 January. For planting dates of 15 and 25 January, the average rice yield gaps in BR3 variety (compared to yield for planting date of 1 January) for the six regions in Bangladesh are 28 and 38% respectively for 2030; the corresponding change of rice yield gaps for BR14 are 35 and 42% respectively for 2030. The effect appears to be more pronounced for 2050 and 2070. For transplanting dates beyond 15 January, average yield gaps for the six regions increased more than 40% in 2050 and 50% in 2070. Also the predicted yield gaps for both rice varieties appear to be more pronounced for locations in northwestern and southern regions. For example, for planting dates of 15 and 25 January, the average rice yield gaps in BR3 yield (compared to yield for planting date of 1 January) for the three locations in northwestern region are 48 and 50% respectively for 2050; and 51 and 52% respectively for 2070; the corresponding yield reductions for BR14 are 54 and 55% respectively for the year 2050; and 57 and 62% respectively for 2070 (Figs. 6 and 7). It may be noted that Mahmood *et al* (2003) reported significant reduction in yield of Aman (wet season rice) as planting is delayed beyond 1 June Thus, the climate change could not only cause significant increase in yield gap of Boro rice, but could also make yield and yield gap more sensitive to planting time.

CONCLUSIONS

Although currently the BR3 and BR14 Boro rice varieties are not widely cultivated in Bangladesh, the model simulations carried out in this study provide useful insight into the possible effects of climate change on rice yield and yield gap. The growth and yield of crops are directly related to the rate of photosynthesis and phenology and their response to temperature, solar radiation and rainfall. Optimum temperatures for maximum photosynthesis range from 25 to 30 °C for rice under the climatic conditions of Bangladesh. Increased temperatures during the growing season cause grain sterility. Very high temperatures, sometimes exceeding 35 °C, have been predicted, especially in 2050 and 2070, due to climate change. Although there are significant uncertainties in the predicted climate parameters, the crop model simulation results suggest that if climate change causes significant increase in temperatures, this may in turn could cause significant reduction in rice yield; if the current crop management practices (irrigation and fertilizer application) are continued, this could significantly increase rice yield gap. Sensitivity analysis indicates that rice yield is also sensitive to $CO_2$ levels and solar radiation. The model simulations also suggest that changes in rainfall pattern may also adversely affect rice yield and yield gap. Simulation results also suggest that planting dates could significantly affect rice yield and yield gap, and this effect could become more pronounced in the future. Rice yield gap could be significantly higher if the transplanting date is delayed beyond 15 January. In order to assess the effect of climate change on the rice varieties currently being grown in Bangladesh, it is necessary to determine their genetic coefficients through carefully controlled experiments. It is also necessary to develop high temperature-resistant rice varieties and modify crop management practices to offset the adverse effects of climate change. Modeling tools, such as the DSSAT modeling system, could be very useful in assessing possible impacts of climate change and management practices on rice yield. The predicted values of temperature and rainfall used in the present study have not been calibrated on daily scale. Uncertainty in assessing possible impacts of climate change may also be reduced using high resolution climate model outputs with ensembles and calibrated outputs.

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**Table 1. Soil profile data for Old Meghna Estuarine Floodplain (AEZ-19).**

| Depth bottom (cm) | Clay (%) | Silt (%) | Stones (%) | Organic carbon (%) | pH in water | Cation exchange capacity meq/100 gm | Total nitrogen (%) |
|---|---|---|---|---|---|---|---|
| 5 | 13 | 38 | 0 | 1.51 | 5.6 | 11.3 | 0.14 |
| 15 | 13 | 38 | 0 | 1.51 | 5.6 | 11.3 | 0.14 |
| 30 | 13 | 38 | 0 | 1.43 | 5.6 | 11.3 | 0.13 |
| 45 | 13 | 38 | 0 | 1.22 | 5.6 | 11.3 | 0.11 |

Soil texture: Silt loam.

**Table 2. Crop management data used in the model simulations.**

| Parameter | Input data |
|---|---|
| Planting method | Transplant |
| Transplanting date | 1, 5, 15 and 25 January |
| Planting distribution | Hill |
| Plant population at seedling | 35 plants per $m^2$ |
| Plant population at emergence | 33 plants per $m^2$ |
| Row spacing | 20 cm |
| Planting depth | 3 cm |
| Transplanting age | 35 days |
| Plant per hill | 2 |
| Fertilizer (N) application | |
| 18-day-after transplanting | 30 kg $ha^{-1}$ |
| 38-day-after transplanting | 70 kg $ha^{-1}$ |
| 56-day-after transplanting | 30 kg $ha^{-1}$ |
| Application of irrigation | 855 mm in 14 applications |

**Table 3. Predicted yield and potential yield (kg $ha^{-1}$) for BR3 rice at 12 selected locations in Bangladesh.** (fixed Carbon dioxide concentration 379 ppm)

| Station name | Potential yield | | | Rice yield | | | % change in rice yield gap | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 |
| Rajshahi | 7118 | 7073 | 3440 | 4083 | 3265 | 1785 | 42.6 | 53.8 | 48.1 |
| Bogra | 6650 | 7320 | 4144 | 5119 | 4070 | 2036 | 23.0 | 44.4 | 50.9 |
| Dinajpur | 7535 | 8058 | 5643 | 4824 | 4364 | 2692 | 36.0 | 45.8 | 52.3 |
| Mymensingh | 6418 | 7633 | 5529 | 5275 | 4455 | 2739 | 17.8 | 41.6 | 50.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tangail | 6749 | 7201 | 3799 | 5160 | 3874 | 1938 | 23.5 | 46.2 | 49.0 |
| Jessore | 7276 | 6946 | 4103 | 4432 | 4583 | 1997 | 39.1 | 34.0 | 51.3 |
| Satkhira | 7305 | 7106 | 4403 | 4364 | 3603 | 2066 | 40.3 | 49.3 | 53.1 |
| Barisal | 7067 | 7217 | 6649 | 4006 | 3972 | 2091 | 43.3 | 44.9 | 68.6 |
| Madaripur | 7126 | 7298 | 5154 | 4017 | 3647 | 2186 | 43.6 | 50.0 | 57.6 |
| Chandpur | 7092 | 7253 | 5684 | 5455 | 4039 | 2772 | 23.1 | 44.3 | 51.2 |
| Comilla | 7418 | 7578 | 5804 | 5987 | 4456 | 3075 | 19.3 | 41.2 | 47.0 |
| Sylhet | 5787 | 6897 | 6853 | 5117 | 5750 | 3595 | 11.6 | 16.6 | 47.5 |

**Table 4. Predicted yield and potential yield (kg ha$^{-1}$) for BR14 rice at 12 selected locations in Bangladesh.** (fixed Carbon dioxide concentration 379 ppm)

| Station name | Potential yield | | | Rice yield | | | % change in rice yield gap | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 |
| Rajshahi | 5640 | 5542 | 2607 | 2771 | 2392 | 1148 | 50.9 | 56.8 | 56.0 |
| Bogra | 5399 | 5703 | 3062 | 3668 | 2637 | 1398 | 32.1 | 53.8 | 54.3 |
| Dinajpur | 6021 | 6281 | 4014 | 3374 | 3023 | 1656 | 44.0 | 51.9 | 58.7 |
| Mymensingh | 5074 | 5936 | 4023 | 3790 | 3186 | 1873 | 25.3 | 46.3 | 53.4 |
| Tangail | 5382 | 5641 | 2937 | 3883 | 2565 | 1297 | 27.9 | 54.5 | 55.8 |
| Jessore | 5563 | 5465 | 3148 | 3160 | 3153 | 1305 | 43.2 | 42.3 | 58.5 |
| Satkhira | 5578 | 5513 | 3332 | 3171 | 2434 | 1377 | 43.2 | 55.9 | 58.7 |
| Barisal | 5475 | 5713 | 4952 | 2889 | 2705 | 1457 | 47.2 | 52.7 | 70.6 |
| Madaripur | 5471 | 5786 | 3873 | 2606 | 2578 | 1491 | 52.4 | 55.4 | 61.5 |
| Chandpur | 5500 | 5734 | 4402 | 3981 | 2801 | 1842 | 27.6 | 51.2 | 58.2 |
| Comilla | 5752 | 5791 | 4494 | 4368 | 3063 | 1978 | 24.1 | 47.1 | 56.0 |
| Sylhet | 4843 | 5582 | 5282 | 3764 | 4240 | 2378 | 22.3 | 24.0 | 55.0 |

**Table 5. Predicted yield and potential yield (kg ha$^{-1}$) for BR3 rice at 12 selected locations in Bangladesh.** (various carbon dioxide concentration 427 ppm, 465 ppm, 503 ppm).

| Station name | Potential yield | | | Rice yield | | | % change in rice yield gap | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 |
| Rajshahi | 7370 | 7544 | 3814 | 4141 | 3366 | 1700 | 43.8 | 55.4 | 55.4 |
| Bogra | 6891 | 7809 | 4574 | 5115 | 4151 | 2258 | 25.8 | 46.8 | 50.6 |
| Dinajpur | 7804 | 8586 | 6207 | 4868 | 4593 | 3011 | 37.6 | 46.5 | 51.5 |
| Mymensingh | 6647 | 8135 | 6080 | 5459 | 4590 | 2973 | 17.9 | 43.6 | 51.1 |
| Tangail | 6993 | 7680 | 4196 | 5301 | 4087 | 2066 | 24.2 | 46.8 | 50.8 |
| Jessore | 7543 | 7406 | 4538 | 4546 | 4717 | 2157 | 39.7 | 36.3 | 52.5 |
| Satkhira | 7571 | 7582 | 4875 | 4463 | 3815 | 2283 | 41.1 | 49.7 | 53.2 |
| Barisal | 7317 | 7659 | 7332 | 4097 | 4140 | 3453 | 44.0 | 46.0 | 52.9 |
| Madaripur | 7380 | 7783 | 5690 | 4099 | 3787 | 2410 | 44.5 | 51.3 | 57.6 |
| Chandpur | 7346 | 7735 | 6261 | 5660 | 4225 | 3118 | 23.0 | 45.4 | 50.2 |
| Comilla | 7679 | 8079 | 6384 | 6207 | 4468 | 3309 | 19.2 | 44.7 | 48.2 |
| Sylhet | 5994 | 7350 | 7521 | 5301 | 6063 | 3920 | 11.6 | 17.5 | 47.9 |

**Table 6. Predicted yield and potential yield (kg ha$^{-1}$) for BR14 rice at 12 selected locations in Bangladesh.** (various carbon dioxide concentration, 427 ppm, 465 ppm, 503 ppm)

| Station name | Potential yield | | | Rice yield | | | % change in rice yield gap | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 | 2030 | 2050 | 2070 |
| Rajshahi | 5852 | 5930 | 2902 | 2912 | 2478 | 1216 | 50.2 | 58.2 | 58.1 |
| Bogra | 5604 | 6104 | 3472 | 3772 | 2813 | 1467 | 32.7 | 53.9 | 57.7 |
| Dinajpur | 6246 | 6713 | 4432 | 3459 | 3255 | 1864 | 44.6 | 51.5 | 57.9 |
| Mymensingh | 5263 | 6345 | 4442 | 3940 | 3189 | 2074 | 25.1 | 49.7 | 53.3 |
| Tangail | 5585 | 6036 | 3259 | 3847 | 2744 | 1341 | 31.1 | 54.5 | 58.9 |
| Jessore | 5772 | 5845 | 3495 | 3179 | 3287 | 1448 | 41.9 | 43.8 | 58.6 |
| Satkhira | 5786 | 5898 | 3702 | 3250 | 2633 | 1527 | 43.8 | 55.4 | 58.8 |
| Barisal | 5675 | 6108 | 5481 | 2952 | 2808 | 2257 | 48.0 | 54.0 | 58.8 |
| Madaripur | 5673 | 6186 | 4292 | 2662 | 2666 | 1626 | 53.1 | 56.9 | 62.1 |
| Chandpur | 5705 | 6129 | 4868 | 4151 | 2975 | 2027 | 27.2 | 51.5 | 58.4 |
| Comilla | 5962 | 6190 | 4963 | 4256 | 3053 | 2249 | 28.6 | 50.7 | 54.7 |
| Sylhet | 5025 | 5967 | 5820 | 3915 | 4518 | 2603 | 22.1 | 24.3 | 55.3 |

**Table 7. Sensitivity of BR3 yield at Barisal on climatic parameters.**

| | $T_{max}$=2008 | $T_{max}$=2070 | $T_{max}$=2008 | $T_{max}$=2008 | $T_{max}$=2008 | $T_{max}$=2070 |
|---|---|---|---|---|---|---|

| | $T_{min}$=2008 Srad=2008 Rain=2008 | $T_{min}$=2008 Srad=2008 Rain=2008 | $T_{min}$=2070 Srad=2008 Rain=2008 | $T_{min}$=2008 Srad=2070 Rain=2008 | $T_{min}$=2008 Srad=2008 Rain=2070 | $T_{min}$=2070 Srad=2070 Rain=2070 |
|---|---|---|---|---|---|---|
| Rice yield (kg $ha^{-1}$) | 6043 | 4160 | 5039 | 6714 | 4354 | 2091 |
| Potential yield (kg $ha^{-1}$) | 7431 | 5848 | 6670 | 8746 | 7341 | 6649 |

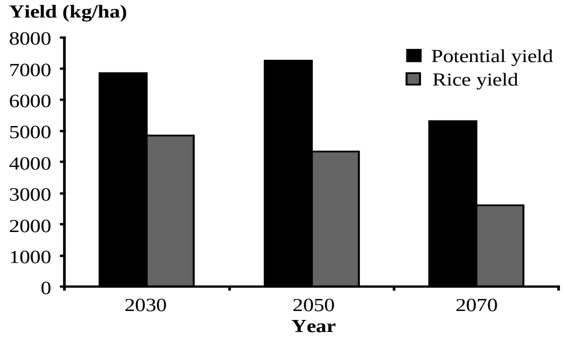


Fig. 1. Predicted average yield (average of 12 locations) and potential yield of BR3 Boro rice under fixed atmospheric CO2 concentration.

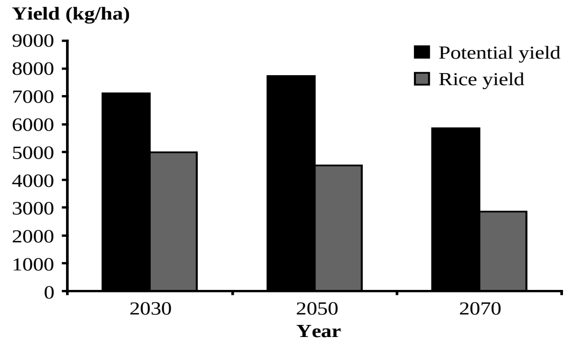


Fig. 2. Predicted average yield (average of 12 locations) and potential yield of BR3 Boro rice under different atmospheric CO2 concentration.

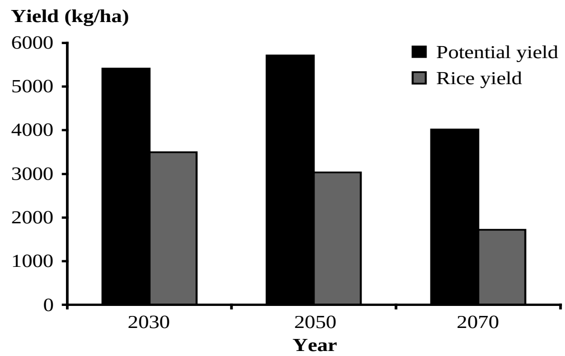


Fig. 3. Predicted average yield gap (average of 12 locations) of BR14 Boro rice under fixed atmospheric CO2 concentration.

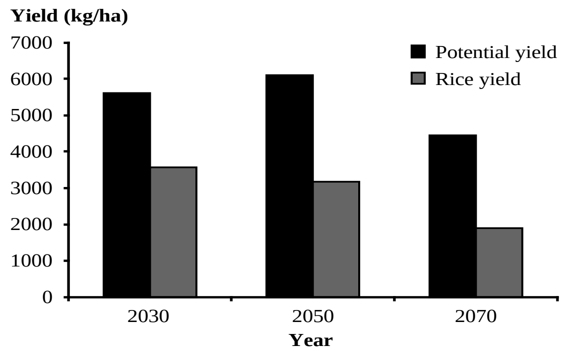


Fig. 4. Predicted average yield gap (average of 12 locations) of BR14 Boro rice under different atmospheric CO2 concentration.

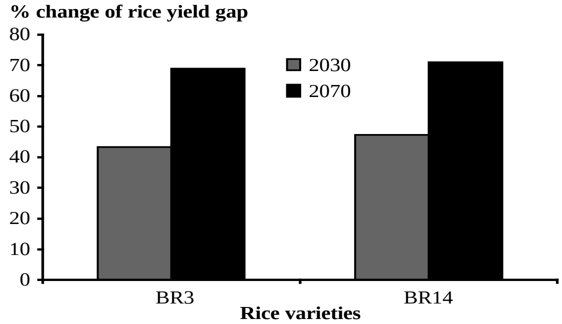


Fig. 5. Predicted rice yield gap of BR3 and BR14 Boro rice for Barisal in 2030 and 2070.

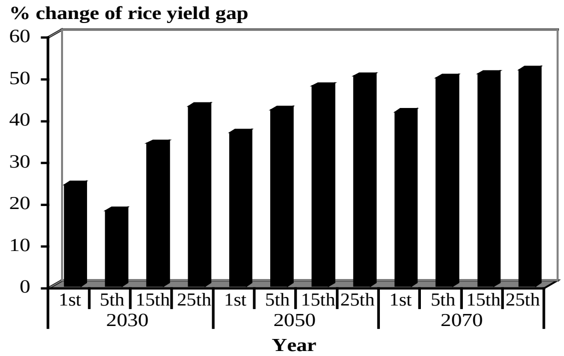


Fig. 6. Predicted average rice yield gap at Northwestern region (average of three locations) of BR3 under different planting dates of January.

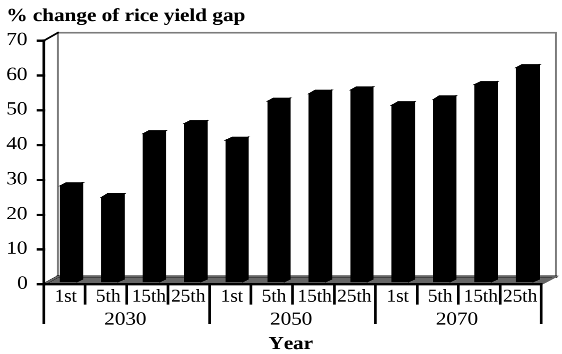


Fig. 7. Predicted average rice yield gap at Northwestern region (average of three locations) of BR14 under different planting dates of January.

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# Impacts of Land Fragmentation on Productivity and Efficiency of Rice Production

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ABSTRACT

Land fragmentation is one of the key issues for agriculture in Bangladesh where major part of the yield productivity depends on the land pattern, shape, size, soil fertility etc. Various land use patterns and dynamic land ownerships, various harmful changes are being taken place over agricultural land. This study has been conducted, based on the field data collected from the northern region in Bangladesh. It has focused on changing pattern of land ownership during 1984 to 2005. Land fragmentation into small plots makes mechanization inefficient, particularly, the use of power tillers and tractors, because of the form and dimensions of the plots. Analysis on land value and rice yield in local market price has revealed that 70 $m^2$ land was lost per hectare, which is counted 0.7% for each hectare and on average about 2 Kg rice yield was lost per meter square of border (*ail*) for a single growing season. The study also showed that fuel cost for power tiller operation increased up to Tk 0.36 per decimal, while the plot size was 8.35 decimal compared to 66.8 decimal and labour cost increased more than 70% for the two sizes of plots. From this study, it has also been found that more than 33% labour cost increased due to plow land by country plough and 67% for levelling, which has a significant negative impact on total production cost. Ninety-six percent of the respondents of this study believe that population is the main cause of land fragmentation. Therefore, proper management and planned use of agricultural land are very essential for increasing population and providing sufficient food to meet their demand.

**Keywords**: Bangladesh, land fragmentation, rice, rice yield

## INTRODUCTION

Land is an essential natural resource, both for the survival and prosperity of humanity, consequently to maintain the natural ecosystem and crop production. Land fragmentation is the practice of the farming of a number of spatially separated plots of owned or rented by the same farmers. According to Cheng and Wan (2001) and Binns (1950), land fragmentation is a spatial dispersion of fields into separate and distant parcels, ie fragmentation exists when a household operates more than one separated plots of land. Land fragmentation may arise involuntarily and it is the result of land scarcity and inheritance. A single cultivable land is being divided into two, three or sometimes more pieces. Thus, thousand hectares of land is losing productivity every year. Besides, urbanization, industrialization and acquisition of land by the government for different purposes have been causing negative impact on agriculture productivity, as well as socio-economic scenarios and food security situation of this country. Therefore, proper management and planned use of land is very essential for sustainable agricultural production and improvement of food security situation in future.

When ex-cooperative fields are subdivided into parcels of 6-8 meters, 5-6% of the surface area per hectare is lost. This is why a significant amount of yield is being lost every year. Due to land fragmentation in Bangladesh, the main problem which are generally seen:

(1) restricts agricultural modernization (mechanization, irrigation, agronomic practices);

(2) inhibits improvement of the land and heightens risk of abandonment of some parcels; and

(3) creates economic and production problems because of increased time, work, and organization required by the plots' distance.

Several studies (Binns, 1950; Swinnen, 1999; Cheng and Wan, 2001; Dijk, 2002; Kopeva and Noev, 2002) have been carried out to assess the impacts of land fragmentation on agricultural production. Rahman and Rahman (2008) reported that a 1% land fragmentation reduces rice output 0.05% and efficiency by 0.03%. The present study has been undertaken to investigate the main causes and effects of land fragmentation on rice yield, machine and labour productivity in Bangladesh.

## MATERIALS AND METHODS

**Selection of study area**

The study was carried out in Badalgachhi upazila of Naogaon district which was chosen purposively because of its suitability for the crop production according to the following environmental criteria: topography, ecology, land use, intensity of crop production, and amount of land per capita (Table 1).

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**Data collection**

Both primary and secondary data were used in this study. Primary data were cross-section data, which was generated by conducting sample survey as well as experimental test at the farmers' field. In turn, secondary data were compiled from Bangladesh Bureau of Statistics (BBS) and Directorate of Agricultural Extension (DAE). However, a field survey was conducted among 50 respondents having the plot size of 5.01 and 66.80 decimal in finding out the main causes of land fragmentation for the aforesaid area. Furthermore, secondary data on land ownership and cultivable land were also used to indentify the dynamic pattern of cultivable land. To assess the impacts of land fragmentation on plowing and reduction of rice production, field experiment was conducted on different sizes of plots from 5.01 to 66.80 decimal during Rabi season (15 November to 16 April 2010). The plots sizes were chosen based upon the maximum and minimum size of areas of plots available in the study areas.

**Measuring techniques**

Descriptive statistical techniques were applied in order to analyze the collected data. Measuring tape was used to measure the plot size as well as the area of border (*ail*) while oil measuring stick was used to quantify the oil requirement of power tiller in land preparation.

## RESULTS AND DISCUSION

**Trends of changing land ownership**

In Bangladesh, marginal farm (0.02-0.2 ha) was 2.63% in 1983-84, and rapidly increased to 11.20% in 2005 (Fig. 1). Therefore, proportion of marginal farm area increased to 8.57% in the last two decades. But in case of small farm (0.21-1.0 ha) it was 23.37% (Fig. 2). On the other hand, the proportion of medium (1.01-3.00 ha) and large farm (above 3 ha) was in a decreasing trend (Figs. 3 and 4). In the 22 years BBS data (1984 to 2005) showed that the medium farm decreased up to 13%, whereas for large farm, it was 19%. From the analysis, it is clear that number of marginal and small farms were increasing, while medium and large farms were decreasing from 1984 to 2005.

In 1983-84, the proportion of marginal farm in terms of cultivable land holding was 3%, for small farm was 25%, for medium farm was 43% and large farm was 29% (Fig. 5). But in 1996, corresponding figures were 4, 37, 42 and 17% respectively (Fig. 6) and in 2005, corresponding values were 11, 49, 30 and 10% respectively (Fig. 7). The analysis shows that in recent decades the rate of small holding farming increased at a significant rate.

From the above analysis, it is difficult to say that small holding farm increases land fragmentation but it is easy to say that it influences land fragmentation. Because if the number of small holding increases ie indicates that the size of 0.02 to 0.2 ha farm holder increase and it is one of the main barrier for agricultural modernization.

**Causes of land fragmentation**

While identifying the main causes of land fragmentation for the selected location, 96% of them (total 50 farmers) marked population growth as the main reason usually. A large agriculture plot subdivided into two or more because of population growth. To distribute the agricultural land among the generations to generations, the size of agriculture plot is being automatically decreased. Besides settlement of the huge population, urbanization, industrialization and acquisition of agricultural land by the government for different purposes to meet the demand for the growing population also influence land fragmentation. Farmers who have a small piece of land try to grow different types of crop in a single plot. For that reason different sizes and shapes of borders are constructed into plot which was one of the most occurring factors of land fragmentation and about 74% of the respondents had the same opinion. Of interviewed farmers, 64% said that Borders were constructed for distributing irrigation water at a same rate and level in all places due to uneven plot size. Twenty-four percent of them believed that changing land ownership was another cause, because they sold their land part by part to different persons and 38% for changing cropping pattern (Fig. 8). Due to growing various types of crops in different growing seasons in a single plot, land is to be prepared different shapes and patterns, which also influence land fragmentation significantly. A small number of respondents (4%) argued that land fragmentation was occurred because of soil erosion due to river bank erosion, heavy rainfall, nearer the surface water bodies like ponds, *bills, haors* etc. It should be noted that the respondents' view as percentage may be changed when we consider the overall Bangladesh but in this study, those were the main causes of land fragmentation.

**Effects of land fragmentation on cultivable land and rice production**

The consequence of fragmentation, such as loss of land and make a new land border (*ail*) depends on the shape and dimension and agricultural practices on plot. From the field data, it was found that when a 11.69 decimal (7 *kata*) plot was subdivided into five decimal (3 *kata*) and 6.69 decimal *(4 kata)* by a single border (length of border 14.2 m and [12]width 30 cm), then 4.26 $m^2$ land was directly lost, which was 0.91% to the total land area and nine kg rice yield was lost, which was 7% of the total production of the plot at national level and 4.6% at local level. But when a single *ail* whose width was 15 cm; divides the same plot the amount of land loss was 2.13 $m^2$ which was 0.45% to the total land area and 4.6 kg rice yield was lost, which was 3.5% compared to the total production at national level and 2.3% at local level.

On the other hand, when a 28.4 decimal (17 *kata*) plot was subdivided into four plots; one plot was 8.35 decimal (5 *kata*) and three plots were 6.69 decimal (4 *kata*) each by three border (width 30 cm), then 14.1 $m^2$ land was directly lost, which was 1.24% to the total land area and 30.01 kg rice yield was lost, which was 9.64% compared to the total production of the plot at national level and 6.3% at local level. If borders' (*ails*) width was 15 cm; the amount of land loss was 7.06 $m^2$, which was 0.62% to the total land area and 14.98 kg rice yield was lost, which was 4.82% compared to the total production of the plot at national level and 3.15% at local level. From Table 2 (taking weighted average), it was found that 70 $m^2$ land was lost per hectare or for each hectare 0.7% land was lost. It was also estimated that on average about 2 kg rice yield was lost per meter square of border (*ail*) which occurred due to land fragmentation. Table 2 shows the effects of land fragmentation on cultivable land and rice production.

**Effects on labour and machine productivity (power tiller)**

Fragmentation into small plots makes mechanization more inefficient, particularly, the use of power tillers and tractors, because of the form and dimensions. Numerous plots from a big plot were the most restrictive as well as most costly factor to increase agricultural production. From the field experiment, it was observed that the plots were so small that the power tiller and tractors faced difficulty to use and these were not easily maneuverable. It was found that the [13]power tiller required 0.41 liter diesel for 8.35 decimal (5 *kata*) plot, ie 0.05 liter per decimal. On the other hand, 2.75 liter diesel was required for 66.80 decimal (40 *kata*) plot, ie 0.04 liter per decimal (Fig. 9). It indicates that for large size plot, fuel consumption rate was significantly lower per unit area compared to small plot and from analysis; it was estimated that additional 10 ml diesel was required per decimal for the 8.35 decimal plots compared to 66.80 decimal ones (Table 3).

It was also found that for tilling purpose, power tiller required 16 minutes for 8.35 decimal (5 *kata*) land, ie 1.92 minutes per decimal. However, for 66.80 decimal (40 *kata*) plot, power tiller required 74 minutes, ie 1.10 minutes per decimal. It indicates that for large plot, time requirement rate was significantly lower per unit area compared to small ones and from analysis; it was also estimated that additional 0.82 minute or 48 seconds required per decimal for the 8.35 decimal plots compared to 66.80 decimal ones (Fig. 10). Moreover, it was observed that power tiller could not be used in corners of the plots, so farmers till the corners manually. Besides, time and fuel were lost when power tiller was moved from one plot to another. About two to three minutes were lost when power tiller moved one plot to another and clutch and gear the setting.

**Effects on labour and country plough productivity**

Country plough is a traditional agricultural equipment, which is being used in the rural agriculture in Bangladesh now-a-days. In this study, it was estimated that a medium age farmer (35-year-old) and a pair of bullock (10-year-old each) required one hour for cultivating 8.35 decimal (5 *kata* ) plot, ie 7.20 minutes per decimal; whereas for 33.40 decimal (20 *kata*) land required three hours, ie 5.40 minutes per decimal. It was indicated that for the large plot time requirement rate was comparatively lower than the small plot. From the field experiment data, it was estimated that additional 1.8 minutes were required per decimal, for the 8.35 decimal plots compared to the 33.40 decimal ones. It was also observed that country plough practice was efficient up to 50.10 decimal (30 *kata*). Above the plot size, time requirement per decimal was gradually increasing. Table 4 shows that time requirement per decimal was same for both 33.40 decimal (20 *kata*) and 50.10 decimal (30 *kata*) plot, because of the over pressure for both labour and bullock. Similar result was also found for leveling land before transplanting of paddy. Time required to level 8.35 decimal land was 25 minutes, ie three minutes per decimal, whereas for 33.40 decimal was one hour, ie was 1.80 minutes per decimal. Therefore, additional 1.2 minutes were required per decimal, for the plots size 8.35 decimal compared to 33.40 decimal.

**Economic loss from land fragmentation**

Land fragmentation has a significant negative impact on cost of production. The study shows that fuel cost for power tiller increased up to Tk 0.36 per decimal (33.33 percent), when the plot size was 8.35 decimal compared to 66.80 decimal. Fuel cost rapidly decreased from 8.35 decimal (5 *kata*) to 33.40 decimal (20 *kata*) plot size and after 33.40 decimal, it decreased gradually (Fig. 11). It indicates that plot size of cultivable land had a

[12]During the field experiment it is found that the maximum width of ail is 30 cm and minimum 15 cm in the selected location. In this study, we consider 30 cm and 15 cm width to assess the impact of land fragmentation.

[13]Power tiller name: Siphon; Horse Power: 12 and rpm: 2200. Calculation of power tiller is done for two cultivations at a time for both fuel and time. In Bangladesh, two cultivations are done at a time during the first field preparation. After the first field preparation, second time one to two cultivations is needed for final field preparation.

considerable role to total production cost. From this analysis, it is clear that fuel cost of power tiller increased with decreasing plot size and it was maximum Tk 2.21 per decimal for 8.35 decimal lands size. Like as fuel cost, labour cost also followed a similar trend for power tiller operation. Maximum labour cost was 8.35 decimal plot size (Tk 0.80 per decimal) and minimum for 66.80 decimal (Tk 0.46 per decimal). Therefore, labour cost increased more than 70% for 8.35 decimal plot size (Fig. 12). This study suggests that big cultivable land are more suitable for power tiller operation. As a result it appears as more economically efficient than the small ones.

Labour cost for cultivating soil and levelling before transplanting by country plough, both were also affected by land size. Labour cost was Tk 3.02 for each decimal for 8.35 decimal plot, whereas it was only Tk. 2.26 each one for 50.10 decimal plot and it increased by Tk 0.76 for every decimal plot. For levelling, it increased by Tk 0.50 per decimal for the sizes of plot. From the field experiment data, it was also found that more than 33% labour cost increased due to plow land and 67 percent for levelling, which had a significant negative impact on total production cost.

Any additional expenditure would increase the total production cost and reduce farm efficiency as well. It is clear from the present study that land fragmentation never increases the farm efficiency and its effect is significant when the cultivable plot size is small. Therefore, to increase farm efficiency and reduce production cost, it is necessary to maintain a proper land practices and it must be maximized.

## CONCLUSION

The proper management and planned use of agricultural land are very essential for increasing population and providing sufficient food to meet their demand. Agricultural land will not be increased with increasing population. Land use consequence is very important in the present context of Bangladesh. In every year, huge amount of agricultural lands are being lost due to land fragmentation for huge population growth, growing different types of crop in a same plot to meet their minimum food nutrient on their small land, changed cropping pattern and land ownership and also the impacts of natural disasters like floods, sea level rise, etc. We found that population growth is the main cause of land fragmentation in Bangladesh and the second is to grow different types of crops in a same plot. Therefore, the first and foremost work is to reduce the land fragmentation and for this reason, it is necessary to reduce the huge population pressure on cultivable land. Moreover, in rural Bangladesh farmers are subdividing their plots into two or more plots for proper irrigation practice in their fields and maintain a equal irrigation water level. It is even found that a small agriculture plots below 11.69 decimal are subdivided into two or more plots. As a result it increased the production cost on the total production system significantly. Additional productive time, fuel and labour are required for small plot, which is counted and it is considerably higher compared to a large plot. Therefore, government of Bangladesh must be determined to carry out its policy of modernization of land management to make it rational, effective and efficient. Government must be ensured to rationalize land management to increase productivity and to ensure optimum utilization of agriculture land. It also helps optimal use of land for higher productivity where sustainable agriculture production and food security become intertwined. Above all, public awareness of the impact of land fragmentation on agricultural production deserves priority.

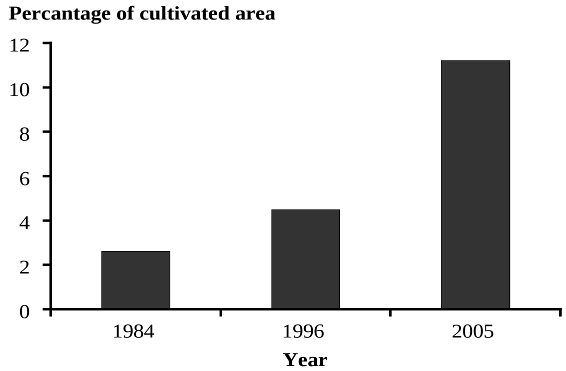


Fig. 1. Marginal farmer land distribution (Source: BBS, 2007).

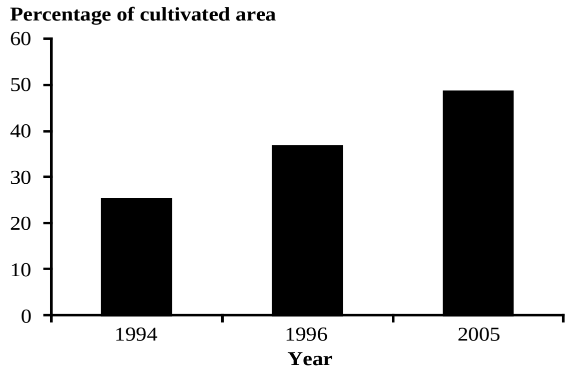


Fig. 2. Small farmer land distribution (Source: BBS, 2007).

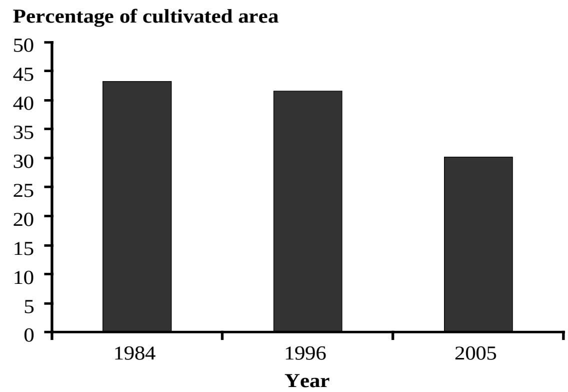


Fig. 3. Medium farmer land distribution (Source: BBS, 2007).

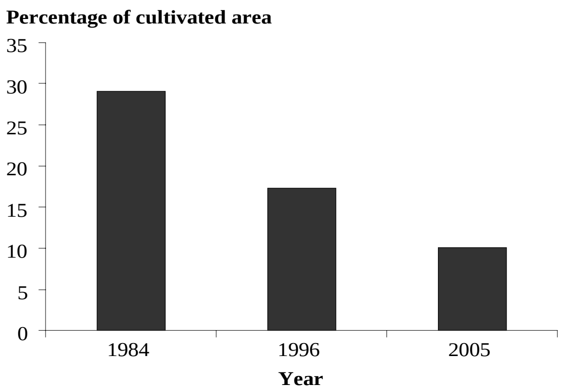


Fig. 4. Large farmer land distribution (Source: BBS, 2007).

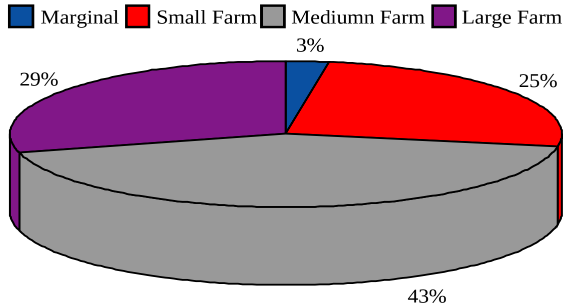


Fig. 5. Cultivable land distribution pattern in 1984 (Source: BBS, 2007).

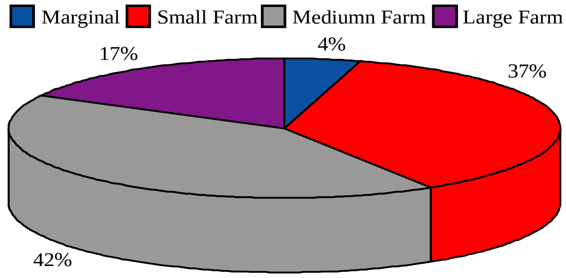


Fig. 6. Cultivable land distribution pattern in 1995 (Source: BBS, 2007).

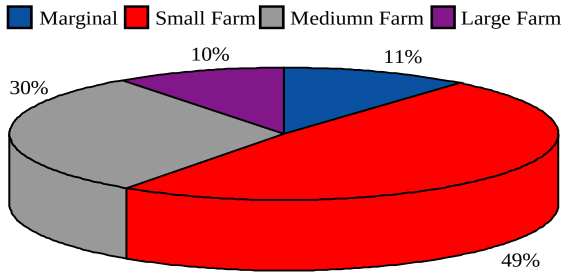


Fig. 7. Cultivable land distribution pattern in 2005 (Source: BBS, 2007).

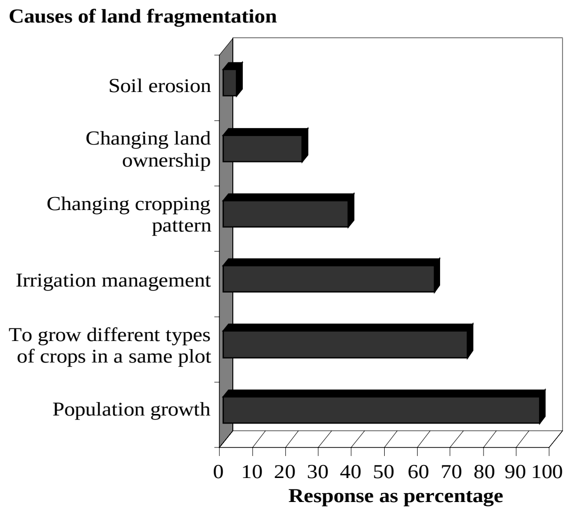


Fig. 8. Main causes of land fragmentation for the selected location (Source: Authors' calculation based on field survey data, 2010) (Multiple response from the respondents).

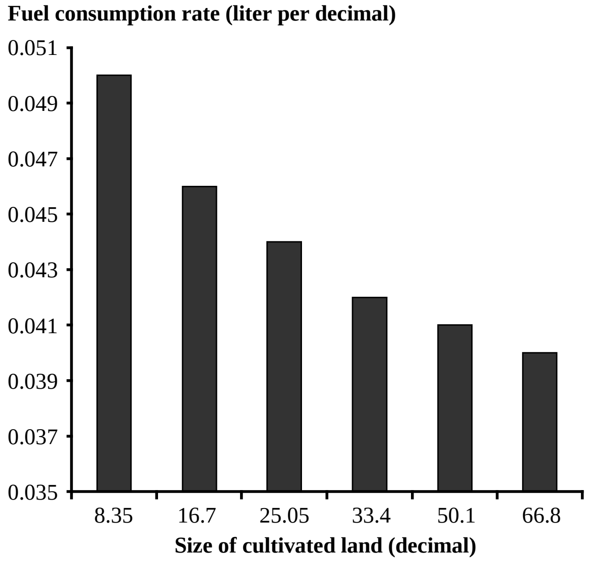


Fig. 9. Fuel consumption rate for cultivating different sizes of land by power tiller (Source: Authors' calculation based on field level data, 2010

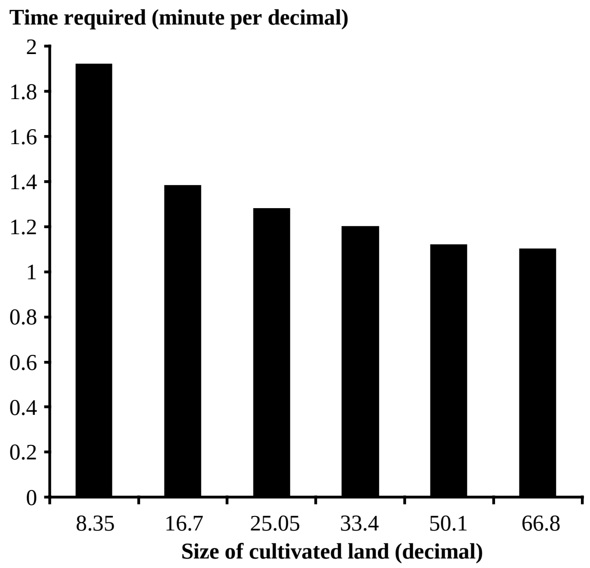


Fig. 10. Time required for cultivating different sizes of land by power tiller (Source: Authors' calculation based on field level data, 2010).

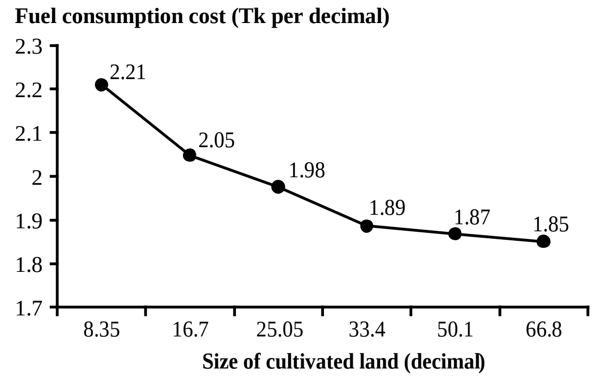


Fig. 11. Fuel consumption cost for cultivating different sizes of land by power tiller (Source: Authors' calculation based on field survey data 2010).

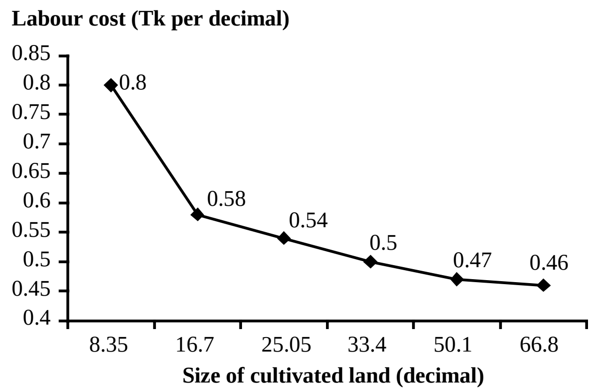


Fig. 12. Labour cost for cultivating different sizes of land by power tiller (Source: Authors' calculation based on field survey data 2010).

**Table 1. Area under different rice based cropping patterns and its share to total cultivable land of Badalgachhi upazila.**

| Kharif 1 | Kharif 2 | Rabi | Cultivable land | Compared to the total cultivable land land as |
|---|---|---|---|---|
| Aus | Aman | Boro | 30485 | 185.27 |
| Fallow land | Aman | Boro | 26485 | 160.96 |
| Aus | Aman | Wheat | 18050 | 109.69 |
| Fallow land | Aman | Potato+Boro | 11000 | 105.74 |
| Fallow land | Aman | Mustard oil+Boro | 5000 | 30.38 |

Source: BBS, 2001; Manual of land and soil resource use, Badalgachhi, Naogaon and DAE Boro farmer survey (2008-2009) report, 2009.

**Table 2. Effects of land fragmentation on cultivable land and rice production.**

| Area | | | Land border *(ail)* | | Land loss | | Yield loss | | |
|---|---|---|---|---|---|---|---|---|---|
| Meter square | Decimal | Kata | Area (l*B) | Area (m²) | Land loss (m²) | Percentage of land loss | Yield loss (kg) | Percentage of yield loss | |
| | | | | | | | | *National level | Local level |
| 468.30 | 11.69 | 7 (4+3) | 14.2 m ×30 cm | 4.26 | 4.26 | 0.91 | 9.00 | 7.00 | 4.60 |
| | | | 14.2 m ×15 cm | 2.13 | 2.13 | 0.45 | 4.50 | 3.50 | 2.30 |
| 535.20 | 13.36 | 8 (6+3) | 22.5 m ×30 cm | 6.75 | 6.75 | 1.26 | 14.63 | 10.00 | 6.53 |
| | | | 22.5 m ×15 cm | 3.38 | 3.38 | 0.63 | 7.31 | 5.00 | 3.26 |
| 602.10 | 15.03 | 9 (5+4) | 15.5 m ×30 cm | 4.65 | 4.65 | 0.80 | 9.38 | 5.70 | 3.72 |
| | | | 15.5 m ×15 cm | 2.33 | 2.33 | 0.40 | 4.70 | 2.85 | 1.86 |
| 802.80 | 20 | 12 (6+6) | 16.3 m ×30 cm | 4.89 | 4.89 | 0.61 | 11.25 | 5.12 | 3.34 |
| | | | 16.3 m ×15 cm | 2.45 | 2.45 | 0.31 | 5.63 | 2.56 | 1.67 |
| 1338.00 | 33.40 | 20 (10+10) | 24.5 m ×30 cm | 7.35 | 7.35 | 0.55 | 18.75 | 5.12 | 3.33 |
| | | | 24.5 m ×15 cm | 3.68 | 3.68 | 0.27 | 9.40 | 2.56 | 1.67 |
| 1137.30 | 28.40 | 17 (5+4+4+4) | 15.5 m ×30 cm | 4.65 | | | | | |
| | | | 15.5 m ×30 cm | 4.65 | 14.10 | 1.24 | 30.01 | 9.64 | 6.30 |
| | | | 16.0 m ×30 cm | 4.80 | | | | | |
| | | | 15.5 m ×15 cm | 2.33 | | | | | |
| | | | 15.5 m ×15 cm | 2.33 | 7.06 | 0.62 | 14.98 | 4.82 | 3.15 |
| | | | 16.0 m ×15 cm | 2.40 | | | | | |
| 2676.00 | 66.80 | 40 (11+10+10+9) | 24.5 m ×30 cm | 7.35 | | | | | |
| | | | 24.5 m ×30 cm | 7.35 | 27.60 | 1.03 | 70.51 | 9.63 | 6.30 |
| | | | 21.0 m ×30 cm | 6.30 | | | | | |
| | | | 22.0 m ×30 cm | 6.60 | | | | | |
| | | | 24.5 m ×15 cm | 3.68 | | | | | |
| | | | 24.5 m ×15 cm | 3.68 | 13.81 | 0.52 | 35.26 | 4.82 | 3.15 |
| | | | 21.0 m ×15 cm | 3.15 | | | | | |
| | | | 22.0 m ×15 cm | 3.30 | | | | | |

Source: Author's calculation based on field level data at Naogaon district; *Calculation based on BBS, 2009.

**Table 3. Effects on machine productivity (power tiller).**

| Area | | | *Fuel (liter) | Average (liter) | Fuel consumption rate (liter per decimal) | Time (min) | Average (min) | Time required (min per decimal) |
|---|---|---|---|---|---|---|---|---|
| Meter square | Decimal | Kata | | | | | | |
| 334.50 | 8.35 | 5 | 0.39-0.43 | 0.41 | 0.050 | 14-18 | 16 | 1.92 |
| 669.00 | 16.70 | 10 | 0.73-0.78 | 0.76 | 0.046 | 20-26 | 23 | 1.38 |
| 1003.50 | 25.05 | 15 | 1.0-1.20 | 1.10 | 0.044 | 29-35 | 32 | 1.28 |
| 1338.00 | 33.40 | 20 | 1.35-1.45 | 1.40 | 0.042 | 38-42 | 40 | 1.20 |
| 2007.00 | 50.10 | 30 | 2.0-2.15 | 2.08 | 0.041 | 54-58 | 56 | 1.12 |
| 2676.00 | 66.80 | 40 | 2.70-2.80 | 2.75 | 0.040 | 70-78 | 74 | 1.10 |

(Source: Author's calculation based on field level data at Naogaon district) (* Fuel: diesel operated power tiller, diesel)

**Table 4. Effects on country plough productivity.**

| Area | | | Time required to cultivate land | | | Time required to level the cultivable land | | |
|---|---|---|---|---|---|---|---|---|
| Meter square | Decimal | Kata | Time (min) | Average (min) | Time required (min per decimal) | Time (min) | Average (min) | Time required (min per decimal) |
| 334.50 | 8.35 | 5 | 55-65 | 60 (1 hr 0 min) | 7.20 | 20-30 | 25 | 3.00 |
| 669.00 | 16.70 | 10 | 90-110 | 100 (1 hr 40 min) | 6.00 | 32-42 | 37 (0.5 hr 7 min) | 2.22 |
| 1003.50 | 25.05 | 15 | 135-155 | 145 (2 hr 25 min) | 5.80 | 45-55 | 50 (0.5 hr 20 min) | 2.00 |
| 1338.00 | 33.40 | 20 | 170-190 | 180 (3 hr 0 min) | 5.39 | 55-65 | 60 (1 hr) | 1.80 |
| 2007.00 | 50.10 | 30 | 260-280 | 270 (4 hr 30 min) | 5.40 | 85-95 | 90 (1 hr 30 min) | 1.80 |

(Source: Author's calculation based on field level data at Naogaon district)

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# Comparative Economic Analysis of BRRI dhan29 and Hybrid Rice Hira in Some Selected Areas of Gazipur District

M A Quayum[1] and M A Salam[2]

**ABSTRACT**

We conducted a study in 2008 at some selected areas of Gazipur district of Bangladesh to estimate the comparative profitability of Hybrid rice (Hira) and BRRI dhan29. The findings indicated that the germination percentage of Hybrid rice was 3% lower than that of BRRI dhan29. However, the total human labour used and yield were higher for hybrid rice cultivation. The seed cost was found to be eight times higher than that of BRRI dhan29. The total cost both on full cost and cash cost basis as well as the gross return of Hybrid rice was found higher compared to BRRI dhan29. In contrast, the net return and the BCR (benefit cost ratio) of hybrid rice both on full cost and cash cost basis were lower than the BRRI dhan29. Partial budgeting analysis made sure that BRRI dhan29 was more profitable by Tk 5,163/ha compared to the hybrid rice in the study area, although the yield of hybrid rice was 13% higher than that of BRRI dhan29. Regression analysis revealed that the total human labour, fertilizer and irrigation had significant contribution on the total return of both the varieties. High price of hybrid seeds and low output price were the main constraints to grow hybrid rice in the study areas. Thus, farmers might be more benefited growing hybrid rice if cost of hybrid rice production is reduced and output price remains same as the inbred one.
**Key words:** Profitability, hybrid rice, gross return, benefits, partial budgeting.

## INTRODUCTION

Bangladesh has a land area of 14.85 million hectares out of which total cultivable area is 9.10 million hectares (BBS, 2009). About 80 percent of the total arable land is devoted to rice production, the staple food crop in Bangladesh. Total cropped area is about 13.88 million hectares whereas rice covered about 77 percent of total cropped area (Jufiquar et al, 2009). The share of rice to the total food grain is more than 90% (BBS, 2009). About 87% of the Boro rice area is planted with MVs (Ahmed and Meisner, 1996). Improved seed or high yielding varieties of seeds are the other vital factor to meet the demand for growing population. Increased rice production with MV seeds in a land scarce country like Bangladesh will not be able to keep pace with the increase in population. Hybrid rice gives 20% higher yield than the highest yielder of MV rice (TCTTI, 1995). The average yield of hybrid rice and MV rice is 6.6 t/ha and 4.10 t/ha respectively in the Boro season (BBS, 2008). The highest recorded yield of hybrid rice in Vietnam was 14.0 metric ton/ha (TCTTI, 1995).

FAO reported that, in 1990, hybrid rice was grown in about 10% of the rice cultivated area. If MV rice can be replaced by hybrid rice then the rice production would be double and additional 100 crore people in the world can be fed with this rice (TCTTI, 1995). Thus, the food problem or hunger problem can be solved for the human kind in the world if the production of hybrid rice can be expedited. The target of area coverage for hybrid rice is 50 percent of Boro area, 23 percent of Aus area and 25 percent of Aman area by foreseeable future of 2020-21. Use of these hybrid seeds can produce additional quantity of 2.49 million ton rice to ensure food security (Anwar Faruque, 2009). Bangladesh Rice Research Institute (BRRI) has developed BRRI hybrid dhan1, 2 and 3 for Boro season and BRRI hybrid dhan4 for Aman season (Adhunik Dhaner Chash, 2010).

Farmer's education, irrigation, seed subsidy and farm size influenced hybrid rice adoption. Farmers had to bear 5-10 percent higher inputs cost than that of conventional MVs but it generated higher profit of 37, 28 and 40% than MVs in the North, Central and South Vietnam respectively as it gave higher productivity (Ut and Hossain, 2002). Hybrid rice is less preferred than MVs due to its less taste and flavour. Its price is also less compared to MVs. High seed cost of hybrid rice discourages the farmers to expand its area under cultivation.

Therefore, one important innovation could be the development of Hybrid rice varieties, which is expected to shift the yield potential by 15-20% or more with the application of almost same amount of agricultural inputs (Husain *et al*, 2000). Hybrid rice out yielded the existing conventional high yielding rice varieties (HYVs) by 15-20% in India, Bangladesh and Vietnam where hybrid rice were first cultivated in the 1990s (Janaiah *e tal*, 2002). Husain *et al* (2000) found that grain yield of hybrids was 14% higher than that of HYVs. But in

Vietnam, hybrid rice produced 21-22% higher yield (Hossain *et al*, 2003). So Hybrid rice cultivation could be a possible alternative to increase food production, resulting to self-sufficiency in food.

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Hybrid rice cultivation in the Boro season in Bangladesh started in 2001. It has been gaining quick ground since then. During the Boro season in 2007-08, MVs and Hybrids occupied 75% and 21% area respectively (Masum, 2009). BRRI hybrid rice1 was harvested 7-10 days earlier than BRRI dhan29 (Bari, 2004).

Expansion of hybrid rice cultivation would have positive impact in Bangladesh. Thus hybrid rice technology is at present a reality to break the existing rice yield ceiling to meet the demand for the future human kind in Bangladesh as well as in the world. Therefore, the present study was undertaken to determine the profitability level of hybrid rice and BRRI dhan29 in the Boro season in some selected areas of Gazipur district.

## OBJECTIVES

Specific objectives of the study were to:

- Know the socio-economic conditions of the hybrid and MV rice growing farmers in the study area;
- Know the existing inputs used and yield performance of hybrid rice Hira and BRRI dhan29;
- Estimate the comparative profitability of hybrid rice and BRRI dhan29 in the study area; and
- Identify the constraints to grow hybrid rice in the study area.

## METHODOLOGY

Gazipur sadar, Sreepur and Kapasia upazilas in Gazipur district were purposively selected for the study. Two villages were randomly selected from each upazila and ten sample farmers from each village for each variety were selected randomly from a list of growing hybrid and MV rice farmers. In total, 120 sample farmers out which 60 farmers for hybrid rice and other 60 farmers for BRRI dhan29 were randomly selected. Farmers were listed with the help of agriculture extension personnel and data were collected through pre-tested and pre-designed questionnaire just after the harvest of Boro rice cultivation in 2008. Primary and secondary data were used in the study. Collected data were analyzed using cost-return analysis and partial budgeting technique. In addition regression analysis was employed:

In order to assess the relative contribution of different biophysical and socio-economic factors influencing the gross return to hybrid rice production at farm level, a multiple regression model of the following form was employed (Draper and Smith, 1976):

$$LnY_i = \beta_0 + \sum_{i=1}^{n} \beta_i LnX_{ij} + e_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, Y= gross return**,**

$Ln =$ Logarithm

$X_i$ = Independent/explanatory variables (1………..5), where,

$X_1 =$ Total human labour,

$X_2 =$ Seeds,

$X_3 =$ Fertilizer,

$X_4 =$ Insecticides, and

$X_5 =$ Irrigation

$I = 1\ldots\ldots\ldots\ldots\ldots k$, (ie number of independent variables),

$J = 1\ldots\ldots\ldots\ldots n$, (ie number of observations),

$\beta_i$ = the regression coefficients

$\beta_0$ = intercept

$e$ = error term

RESULTS AND DISCUSSION

The average farm size of Hybrid rice and MV Boro rice growers were found 1.05 ha and 0.92 ha respectively (Table 1). The owned land and cultivated rice area in the Boro season by the hybrid rice growers were found 0.85 and 1.00 ha respectively, while in case of land occupied by the MV rice growers these figures were 0.90 and 0.91. The germination percentage of MV Boro rice reported by the respondents was found 3% higher than that of hybrid rice in the study area.

**Table 1. Socio-economic conditions of the Hybrid rice (Hira) and MV Boro rice (BRRI dhan29) growers at Gazipur area in the Boro season 2008.**

| **Item/variety** | Hybrid rice (Hira) | MV Boro rice (BRRI dhan29) |
|---|---|---|
| Farm size (ha) | 1.05 | 0.92 |
| Owned land (ha) | 0.85 | 0.90 |
| Rented out (ha) | - | 0.02 |
| Rented in (ha) | 0.24 | 0.14 |
| Mortgage in (ha) | 0.08 | 0.10 |
| Mortgage out (ha) | 0.04 | - |
| Cultivated rice area (ha) | 1.00 | 0.90 |
| Plot size (ha) | 0.13 | 0.15 |
| Germination (%) | 83.00 | 86.00 |

The seedbed preparation was mainly done by family labour and these were 9.65 and 9.20 man-days/ha for hybrid and BRRI dhan29 respectively (Table 2). The higher human labour was needed for hybrid rice cultivation than the BRRI dhan29 in case of uprooting and transplanting due to use of more hired labour and intensive care for this operation.

The total human labour for uprooting and transplanting for hybrid rice and BRRI dhan29 were 40.53 and 30.98 days/ha respectively. Table 2 showed that the labour needed for every cultural operation for hybrid rice growing were higher compared to BRRI dhan29. The human labour needed for irrigation was also higher for hybrid rice compared to BRRI dhan29. As a result, the total human labour needed for hybrid rice growing was 159.90 man-days/ha, which was 21.58 man days/ha (16%) higher than that of the MV Boro rice growing (138.32 man-days). Similar findings were found in case of land preparation. The total bullock power and power tiller for hybrid rice cultivation were 82.98 and 7.72 hr/ha while in case of BRRI dhan29 cultivation these figures were 76.36 and 6.92 hr/ha respectively.

Table 2. Human labour (days/ha) and animal labour (hours/ha) used for growing hybrid rice and MV Boro rice at Gazipur area in 2008.

| Item | Hybrid rice (Hira) | | | MV Boro rice (BRRI dhan29) | | |
|---|---|---|---|---|---|---|
| | Owned labour | Hired labour | Total | Owned labour | Hired labour | Total |
| Seedbed preparation | 9.65 | 1.93 | 11.58 | 9.20 | 1.22 | 10.42 |
| Uprooting and transplanting | 13.51 | 27.02 | 40.53 | 20.48 | 10.50 | 30.98 |
| Fertilizing and top-dressing | 4.38 | - | 4.38 | 3.50 | - | 3.50 |
| **Manuring** | 3.86 | - | 3.86 | 3.11 | 2.08 | 5.19 |
| Weeding | 10.65 | 23.00 | 33.65 | 12.32 | 18.00 | 30.32 |
| Pest management. | 0.28 | - | 0.28 | 0.19 | - | 0.19 |
| Irrigation | 9.65 | 3.86 | 13.51 | 8.14 | 2.18 | 10.32 |
| Harvesting | 7.72 | 19.30 | 27.02 | 5.84 | 21.10 | 26.94 |
| Carrying and threshing | 5.79 | 5.79 | 11.58 | 7.20 | 2.84 | 10.04 |
| Winnowing and drying | 7.72 | 5.79 | 13.51 | 7.42 | 3.00 | 10.42 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total | 73.21 | 86.69 | 159.90 | 77.40 | 60.92 | 138.32 |
| Animal power/Power tiller (hrs/ha): Bullock power | 82.98 | - | 82.98 | 46.16 | 30.20 | 76.36 |
| Power tiller | - | 7.72 | 7.72 | - | 6.92 | 6.92 |

Farmers used about 14 kg/ha seeds for hybrid rice while MV Boro rice farmers used about 30 kg/ha (Table 3). But the price of hybrid rice seed was too high of Tk 200/kg while the price of MV rice seed was only Tk 25/kg. Farmers of both hybrid rice and BRRI dhan29 used more or less equal amount of fertilizers in their crop field. The fertilizer price was also found more or less same for both the varieties.

The total human labour cost for hybrid rice was found higher than that of BRRI dhan29 but in percentage of full cost basis it was almost equal (Table 4). The hired human labour cost was higher for hybrid rice cultivation (21.44%) while it was 17.30% of the total cost for BRRI dhan29 on full cost basis. Similar findings were found on cash cost basis. Animal labour cost was found a bit more for hybrid rice than that of BRRI dhan29. The cost for hybrid rice seeds was eight times higher than BRRI dhan29. Fertilizer cost was found more or less equal but on full cost and cash cost basis the percentage of fertilizer cost (inorganic) of the total cost for MV were higher compared to hybrid rice. On full cost basis the inorganic fertilizer cost of the total cost for hybrid and MV rice were 18.25 and 21.95% while on cash cost basis these were 27.76 and 35.34% respectively.

Table 3. Inputs used (kg/ha) for growing hybrid rice and MV rice at Gazipur area in the Boro season, 2008.

| Inputs | Hybrid rice (Hira) | | | MV rice (BRRI dhan29) | | |
|---|---|---|---|---|---|---|
| | Owned (Qty) | Purchased (Qty) | Price of inputs (Tk/kg) | Owned (Qty) | Purchased (Qty) | Price of inputs (Tk/kg) |
| Seeds (Kg/ha) | - | 14 | 200 | 11 | 18 | 25 |
| Urea | - | 111 | 12.5 | - | 119 | 12.5 |
| TSP | - | 99 | 55 | - | 98 | 55 |
| MP | - | 69 | 55 | - | 68 | 55 |
| Gypsum | - | 60 | 8 | - | 52 | 8 |
| Manure | 5100 | - | 0.30 | 4200 | - | 0.28 |
| Labour (Tk/day) | 73.21 | 86.69 | 150 | 77.40 | 60.92 | 145 |
| Bullock power (Tk/hr) | 82.98 | - | 25 | 46.16 | 24 | 24 |
| Power tiller (Tk/hr) | - | 7.72 | 180 | - | 6.92 | 172 |

The insecticides cost was 4.27 % and 6.50% of the total cost on full cost and cash cost basis in case of hybrid rice. On the other hand, the percentage of this cost for BRRI dhan29 was found lower both on full cost and cash cost basis. Irrigation cost was found a bit higher for hybrid rice than BRRI dhan29 in the study area.

**Table 4. Comparative cost structure (Tk/ha) for hybrid rice and MV Boro rice production, 2008.**

| Item | Hybrid rice (Hira) | | | MV Boro rice (BRRI dhan29) | | |
|---|---|---|---|---|---|---|
| | | % of the total cost | | | % of the total cost | |
| | Cost | Full cost basis | Cash cost basis | Cost | Full cost basis | Cash cost basis |
| Human labour | 24000 | 39.44 | | 19865 | 39.51 | |
| Family | 10950 | 17.99 | | 11165 | 22.21 | |
| Hired | 13050 | 21.44 | 32.61 | 8700 | 17.30 | 27.87 |
| Animal labour: | 2075 | 3.41 | | 1684 | 3.35 | |
| Family | 2075 | 3.41 | | 1108 | 2.20 | |
| Hired | 0 | | | 576 | 1.15 | 1.84 |
| Power tiller: | 1390 | 2.28 | 3.47 | 1190 | 2.37 | 3.81 |
| Hired | 1390 | 2.28 | 3.47 | 1190 | 2.37 | 3.81 |
| Seeds: | 2800 | 4.60 | 7.00 | 725 | 1.44 | |
| Owned | 0 | 0.00 | 0.00 | 275 | 0.55 | |
| Purchased | 2800 | 4.76 | 7.00 | 450 | 0.90 | 1.44 |
| Fertilizer: | 0 | 0.00 | | | 0.00 | |
| Inorganic | 11108 | 18.25 | 27.76 | 11034 | 21.95 | 35.34 |
| Organic | 1530 | 2.51 | | 1176 | 2.34 | |
| Insecticides | 2600 | 4.27 | 6.50 | 650 | 1.29 | 2.08 |
| Irrigation | 9070 | 14.90 | 22.66 | 8620 | 17.15 | 27.61 |
| Land rent | 4942 | 8.12 | | 4942 | 9.83 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Interest @ 10% for 4 months | 1340 | 2.20 | | 1040 | 2.07 | |
| Total cost: | | | | | | |
| Full cost basis | 60855 | 100 | | 50276 | 100 | |
| Cash cost basis | 40018 | - | 100.00 | 31220 | - | 100 |

Average yield of hybrid rice was found 13% higher than that of BRRI dhan29 (Table 5). The gross returns were estimated at Tk 94,279/ha and Tk 89,163/ha for hybrid rice and BRRI dhan29 respectively resulting to 6% higher for hybrid rice. But the net return of BRRI dhan29 was found higher than hybrid rice both on full cost and cash cost basis and those were 14 and 6% respectively. The benefit cost analysis indicated that the benefits were 12 and 17% higher for MV Boro rice cultivation than that of hybrid rice on full cost and cash cost basis respectively. The production cost for hybrid rice was higher than BRRI Dhan29 on both full cost and cash cost basis and these were Tk 10.55/kg and Tk 6.94/kg for hybrid rice while Tk 9.86/kg and Tk 6.13/kg for BRRI dhan29 respectively.

**Table 5. Comparative average cost and return (Tk/ha) for hybrid rice and MV Boro rice production, 2008.**

| Item | Hybrid rice (Hira) | MV Boro rice (BRRI dhan29) | Difference |
|---|---|---|---|
| Yield (kg/ha) | 5766 | 5096 | 670(13) |
| Price (Tk/ha) | 15.5 | 16.5 | 1.00(-6) |
| Straw yield (kg/ha) | 4,266 | 4096 | 170 (4) |
| Price of straw (Tk/kg) | 1.15 | 1.24 | -0.09 (-7) |
| Gross return (Tk/ha) | 94,279 | 89163 | 5116 (6) |
| Net return (TK./ha): | | | |
| Full cost basis | 33,424 | 38887 | -5463 (-14) |
| Cash cost basis | 54,261 | 57943 | -3682 (-6) |
| Benefit cost ratio: | | | |
| Full cost basis | 1.55 | 1.77 | -0.22(-12) |
| Cash cost basis | 2.36 | 2.86 | -0.50 (-17) |
| Production cost (Tk/kg): | | | |
| Full cost basis | 10.55 | 9.86 | 0.69 (7) |
| Cash cost basis | 6.94 | 6.132 | 0.81 (13) |

A simple linear production function was fitted to the contributions of different inputs on the total return of BRRI dhan29 and hybrid rice. Table 6 showed the estimated value of the coefficients and constant term and $R^2$ value. The total human labour, fertilizer and irrigation had significant contribution on the total return of both the varieties.

**Table 6. Estimated coefficients of log linear production function for total return of BRRI dhan29 and hybrid rice in the study area, 2007.**

| Variable(s)<br>Dependent variable: Total return per hectare | Hybrid rice<br>Hira | MV Boro rice<br>BRRI dhan29 |
|---|---|---|
| Constant (α) | 0.212 (4.13)*** | 0.472 (5.31)* |
| Human labour cost ($\log x_1$) | 0.56 (2.96)** | 0.1 (7.15)*** |
| Seed cost ($\log x_2$) | -0.0329 (1.51)ns | 0.05 (14.02)*** |
| Fertilizer cost ($\log x_3$) | 0.250 (6.7)* | 0.325 (3.5)* |
| Insecticides cost ($\log x_4$) | 0.42 (0.125)ns | 0.021 (0.142)ns |
| Irrigation cost ($\log x_5$) | 0.26 (2.53)** | 0.39 (4.7)* |
| $R^2$ | 78 | 89 |

Figures in parentheses indicate t values; ***, ** and * means significant at the 1%, 5% and 10% level respectively.

Table 6 presents the estimated parameters of the Cobb-Douglas production function for inbred and hybrid rice. The empirical analysis revealed that the coefficients of the variables in the production function are the elasticity of average output with respect to the different inputs used in the rice production as specified in the earlier equation (Equation no.1). The empirical results showed that, the sign and magnitudes of the estimated $\beta$ coefficient in majority cases were consistent with prior expectation. The elasticity of human labour cost for MV Boro rice was positive and significant at the 1% level, which indicated that if human labour increased by 1%, the yield of hybrid rice would be increased by 0.1%, whereas the sign of estimated co-efficient of labour cost for hybrid rice was positive and significant at the 5%, indicating that if human labour cost increased by 1%, the yield of MV Boro rice would be increased by 0.56%. The estimated coefficient of hybrid seed cost was negative and insignificant while the sign of estimated coefficient of seed cost of MV Boro was positive and significant at the 1% level.

The sign of coefficient for the fertilizer was positive and significant at the 10% level for both hybrid and MV Boro rice implying that if the chemical fertilizer cost increased by 1%, the yield of both the varieties would be increased by 0.25 and 0.33% respectively. The co-efficient of insecticides cost for both hybrid and MV Boro was positive and insignificant. The coefficient for irrigation cost was positive and significant at the 5 and 10% level for both hybrid and MV Boro rice respectively implying that if the cost of irrigation increased by 1%, the yield of both hybrid and MV Boro rice would be increased by 0.26 and 0.39% respectively. The $R^2$ values for both hybrid and MV Boro rice were 78 and 89, indicating that the yield of both hybrid and MV Boro rice would be explained by 78 and 89% by the adopted independent variables in the estimated model, respectively.

**Table 7. Partial budget, Hybrid rice versus BRRI dhan29.**

| Item | Debit (Tk/ha) | Item | Credit (Tk/ha) |
|---|---|---|---|
| Cost of growing Hybrid rice | 54573 | Return from growing Hybrid rice | 94279 |
| Return forgone for not growing BRRI dhan29 | 89163 | Cost saved for not growing BRRI dhan29 | 44294 |
| Profit/Loss | -5163 | | |
| | 138573 | | 138573 |

Table 7 showed partial budgeting analysis of hybrid rice versus BRRI dhan29 indicating that Tk 5,163/ha was found more profitable for growing BRRI dhan29 instead of hybrid rice. It might be the fact that the impressive profit was earned as the price of paddy in 2008 was higher. Another earlier study supported that Tk 3,857/ha and Tk 4,787/ha were found more profitable for growing BR14 and BRRI dhan29 respectively in stead of hybrid rice in Bangladesh (Quayum *et al*, 2001).

## CONSTRAINTS

Table 8 showed problems and constraints on hybrid rice cultivation. Almost all sample farmers mentioned that high price of hybrid seeds, low output price immediately after harvesting and production of hybrid seed at the farm level were major constraints to hybrid rice cultivation and 100, 98 and 96% farmers respectively passed their opinions about these constraints. More than eighty percent farmers reported that lack of adequate capital and higher input requirements, availability of adequate amount of quality seeds and lack of knowledge were also major problems to hybrid rice cultivation. Seventy percent respondents reported that taste of hybrid rice is not as good as inbred rice.

**Table 8. Problems and constraints faced by the respondents (%) for hybrid rice production in the study areas, 2008.**

| Constraint | % of farmers opined |
|---|---|
| Availability of adequate amount of quality seeds | 82 |
| Seeds are not available in time | 65 |
| High price of hybrid seeds | 100 |
| Low output price immediately after harvesting | 98 |
| Production of hybrid seed at the farm level not possible | 96 |
| lack of adequate capital and higher input requirements | 83 |

| | |
|---|---|
| Lack of knowledge | 86 |
| Taste of hybrid rice is not same as Inbred rice | 70 |

Source: Field survey, 2008.

## CONCLUSION

The yield and gross return as well as the total cost of production of hybrid rice were found higher than BRRI dhan29. The cost of human labour and insecticides were found higher for hybrid rice than that of BRRI dhan29. But the net return and benefit cost ratio were higher in case of BRRI dhan29. Partial budgeting analysis indicated that the BRRI Dhan29 was more profitable than hybrid rice in the study area. Production function analysis indicated that if the chemical fertilizer cost increased by 1%, the yield of both hybrid and MV Boro rice would be increased by 0.25 and 0.33% respectively. The sign of the estimated coefficient of hybrid seed cost was negative and insignificant while the estimated coefficient of seed cost of MV Boro rice was significantly positive at the 1% level. High price of hybrid rice seeds and low output price due to low quality of rice and taste are the main constraints to hybrid rice production. So government should provide subsidy on hybrid rice seed and facilitate the farmers' easy access to hybrid seeds. On the other hand, scientists should improve the quality of hybrid rice so that farmers devote their land more to enhance rice production for future food security for the increased population as well as productivity of the cropped land per unit. However, further study in a large scale is needed to confirm the findings. However, it can be concluded that if the cost of production of hybrid rice can be reduced then this variety may be more profitable than BRRI variety.

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# Anaerobic and Submergence Tolerance of Swarna *Sub 1* and Some other Rice Genotypes

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ABSTRACT

A genotype with traits of anoxia as well as submergence tolerance would provide a better opportunity to establish and withstand the submergence thrust under lowland conditions. Swarna *Sub 1*, a rice genotype developed through introgression of *Sub 1* QTL from FR13A (Donor parent) is able to tolerate submergence stress under flood-prone transplanted Aman environment. However, its potential as an anaerobically established genotype has not yet been studied. Therefore, two experiments were conducted to study the nature of anaerobic and submergence tolerance of Swarna *Sub 1,* with some other rice genotypes. Swarna *Sub 1* showed comparable seedling establishment under lowland conditions. Irrespective of genotypes anaerobically grown, 20-day-old seedlings could not recover after 10-day of submergence.

**Key words**: Submergence tolerance, seedling establishment.

## INTRODUCTION

In Bangladesh, rainfed lowland rice covers an area of 4.5 million hectares (Islam *et al*, 1997) and is grown as transplanting Aman (T. Aman) rice from June to September, the peak period of monsoon rainfall. Dey *et al*, (1996) reported the abiotic factors like submergence and drought are the two top constraints in rainfed T. Aman rice. The poor crop establishment due to submergence at the seedling stage appears to cause substantial yield loss. Therefore, submergence is an important constraint in T. Aman rice. The shifting of transplanting practice toward anaerobic seeding, using genotype tolerant to anaerobic conditions could be a breakthrough for saving crop establishment cost (Yamauchi *et al*, 1993). Anaerobic tolerance of a genotype is designated as the ability of a genotype to establish under lowland conditions (Yamauchi and Biswas, 1996).The successful development of high yielding rice cultivars with submergence and anaerobic tolerance may be an effective alternative for saving huge losses of food crops in the Aman crop.

BR11 could sustain submergence to some extent under clear water. In contrast, BRRI dhan32 have some tolerance to the similar stress both under clear and turbid water (Pervin *et al*, 2006). However, the performance of these varieties across the ecosystem might not be stable as they are not having submergence tolerant quantitative trait loci (QTL) or gene. Very recently, FR13A (tolerant to submergence) *Sub 1* locus has been introgressed into widely grown Asian cultivar (Swarna) using marker-assisted selection procedure (Xu *et al*, 2006). This variety is now designated as Swarna *Sub 1* and able to protect itself against the submergence thrust. However, the nature of seedling establishment under lowland conditions of this variety have not yet been understood. Literally, more emphasis has been given to Swarna *Sub 1* as the genotype is enriched with the presence of Sub *1* A, an ethylene-response-factor-like gene that confers submergence tolerance to rice. FR13A was also reported to establish seedling under lowland conditions (Yamauchi *et al*, 1993). Accordingly, Swarna *Sub 1*, progeny of FR13A is expected to establish under the same conditions. The exploitation of this genotype (Swarna *Sub 1*) as anoxia-tolerant one would yield double benefit to ensure crop security for farmers in a submergence prone rainfed Aman area. The objectives of the study were as follows to:

- Determine the anaerobic tolerance of Swarna *Sub 1*;
- Study the ability of submergence tolerance of this genotype following as anaerobic thrust in the process of germination.

## MATERIALS AND METHOD

We conducted two experiments at the Plant Physiology Division of Bangladesh Rice Research Institute (BRRI), Gazipur in 2007.

### Experiment 1

Twelve varieties (Table 1) were considered in the experiment 1, layed out in CRD with four replications. The treatments of the experiments were aerobic, hypoxic, and anoxic conditions. Prior to go for germination, the seeds were treated with 2% sodium hypoclorite for 15 minutes. Seedlings were grown under aerobic (in a petridish (100×90-mm) lined with soaked paper) hypoxic and anoxic conditions. The hypoxic condition was maintained in the test tube (100×25-mm) containing 20 mm of distilled water with 50 mm water depth above the seed. Under anoxic conditions the test tube, containing 18 ml of distilled water and 2 ml olive oil. Five sprouted seeds were allowed to grow in each test tube. The test tubes were kept under 30°C in a germinator. The coleoptile length of seedlings were considered for observation.

### Experiment 2

Out of 12 varieties (from Experiment 1), five genotypes were considered in this study. Except BR11 and Swarna *Sub 1*, the others were known as anoxia tolerant genotype (Islam., 2005; Yamauchi *et al*, 1993). Plastic trays (32×28×13-cm) were used for this study. The trays were filled with 16 kg clay loam soil (OM = 0.9-1.5%, pH = 4.5-6) fertilized with urea, TSP, MP, and gypsum @ 8 g, 5 g, 5 g and 3.2 g respectively per tray. The soil was soaked, puddled and kept flooded for seven days to reduce the accumulated volatile fatty acids. There were two kinds of seeding; aerobic (seeds were surface seeded) and anaerobic (seeds were placed 1 cm below the soil surface and the tray was irrigated up to 1 cm depth). Each tray contained six lines and 10 sprouted seeds were sown per line. Each variety was replicated thrice in three trays. Percent seedling establishment was recorded.

Twenty-day-old established seedlings were submerged in a cemented water tank (submergence tank) to a depth of 70 cm above the soil level. The water was made turbid twice daily by mixing mud (soil particle of the water was 1.53 g/L; Pervin *et al*, 2006). After a day of submergence, the trays were transferred to net-house. Recovery percentages after seven days were recorded.

The percent seedling establishment was analyzed as CRD with necessary transformation.

## RESULTS AND DISCUSSIONS

### *Experiment 1*

**Coleoptile.** Coleoptile growth was the lowest under aerobic condition. In contrast, significantly enhanced growth was observed under hypoxic conditions. According to Takahashi (1976) coleoptile elongation can be enhanced by high $CO_2$ and low $O_2$ tension. Ethylene plays an important role in coleoptile elongation also. The effect of low $O_2$, high $CO_2$ and ethylene are additive, and each gas can promote growth independently of the others (Raskin and Kende, 1983). So if there is no $O_2$ assisted ethylene activity, $CO_2$ alone can influence growth. That might be the reason why significant coleoptile growth was observed in hypoxic condition where additive effect of both $CO_2$ and ethylene is possible. Some enhancement in coleoptile growth was observed under anoxic condition, where ethylene concentration must be very insignificant as there was no $O_2$. Since, $CO_2$ was not absorbed by any absorbent (KOH), whatever growth enhancement had been occurred, must be in presence of $CO_2$ only. Biswas (1994) observed genotypic difference in response to coleoptile growth. The coleoptile length in aerobic conditions varied from 10.70 mm to 28.40 mm (Table 1). Under hypoxic condition Bitchi Bokri. BRRI dhan32, were able to produce coleoptile length >50.0 mm. The coleoptile length of Swarna *Sub 1*, Bashful (tolerant to anoxia) were 42.35 mm, 46.20 mm and 44.25 mm respectively. They were not significantly different from each other. Apparently anoxia tolerant other genotypes like Banajira, Jahmir, Chaita Boro had the coleoptile lengths of 27.85, 36.65 and 33.00 mm, respectively under the same conditions. Another tolerant variety Boro 109/2 showed 28.60 mm. Submergence tolerant FR13A performed the shortest coleoptile length (13.25 mm). BRRI dhan29 performed statistically similar to those of some anoxia tolerant genotype like Chaita Boro and Boro 109/2.

Under (extreme) anoxic condition, similar performances were observed in Swarna *Sub 1* (37.40 mm) and BR11 (38.90 mm), followed by Bashful (31.85 mm) and Banajira (30.50 mm). BRRI dhan32, Boro 109/2, Chaita Boro, Jahmir and FR13A showed also similar performance of around 27.0 mm what was not statistically different from Bashful and the others. Bitchi Borki executed the shortest coleoptile length, similar to those of BR5 and BRRI dhan29.

**Leaf growth and development.** The leaf growth and development is designated by first leaf length, leaf number and plant height. Growing condition and varietal interaction effect was marginally insignificant (P = 0.06) for first leaf growth. But the interaction was significant for plant height (ANOVA table not shown). Hypoxic conditions suppressed Plant height significantly (Table 2). Significant variation was observed among the varieties. Many of the varieties like Jahmir, Bashful and Boro 109/2 had significantly higher plant height. Even varieties like Swarna *Sub 1* and BR11 showed equivalent plant height to those of apparently anoxia tolerant Chaita Boro and Bitchi Borki. In contrast, Banajira and FR13A could not produce any leaf. That might be due to the variation of tolerance to the accumulated volatile fatty acids (Biswas *et al*, 2001) under hypoxia or anoxia. However, BRRI dhan29 showing poor coleoptile length executed some leaf development. Swarna *Sub 1* bearing the similar QTL for submergence of FR13A was able to produce first leaf length upto 5.95 mm that was similar to the anoxia-tolerant Bitchi Borki (8.10 mm) and Chaita Boro (8.20 mm).

Seedling establishment under lowland conditions was characterized by the ability of a variety to produce first leaf (Biswas and Yamauchi, 1997). Hypoxic condition is equivalent to that of simulated lowland condition. The result generated from this condition appears to translate in lowland conditions. Therefore, it could be said that variety Jahmir and Bashful have better potential to establish seedling under lowland conditions. Accordingly, Swarna *Sub 1* should have the ability to establish seedling to some extent under lowland conditions. Despite showing better establishment ability FR13A failed to establish in the present study.

**Root growth and development.** Root growth and development was characterized by nodal and seminal root. The interaction between growing condition verses nodal and seminal root was significant. Hypoxic conditions severely affected root growth and development (Table 2). The seminal root length ranges from 37.80 mm to 95 mm under aerobic conditions and 0 mm to 11.07 mm under hypoxic conditions. Variety Jahmir maintained the longest seminal root length both under aerobic (95 mm) and hypoxic conditions (11.07 mm) (Table 2). The leading anoxia-tolerant genotypes maintained more less the similar pattern both under aerobic and hypoxic conditions. Swarna *Sub 1*, BRRI dhan29 and BRRI dhan32 showed similar seminal root length under hypoxic conditions. Despite being tolerant to submergence FR13A failed to develop any root development under hypoxic conditions (Table 2).

Nodal root originated from the coleoptile node was considered in this study. The longest one was measured for our purpose. Under aerobic conditions the longest nodal root was observed in Jahmir (28.50 mm) and Boro 109/2 (29.55 mm) followed by BR11 and BRRI dhan32 (≈17.0 mm). Chaita Boro had the similar nodal length almost similar to that of BR5. Under hypoxic conditions the nodal root length varied from zero (Chaita Boro, BR5 and FR13A) to 3.27 (Bichi Borki). However, there were no significant differences among the varieties (Table 2).

Root emergence occurs after coleoptile emergence when it germinates under hypoxia (Cobb and Kennedy, 1987; Biswas and Yamauchi, 1997). The present study revealed the similar result with some varietal variations (Table 2). Kordan (1976a) reported that low $O_2$ concentration root growth more than that of shoot growth in germinating rice seedlings. However, the adventitious (nodal) root primordia can form but the growth is not visible (Kordan, 1976b). Although primary root emergence is completely suppressed under $O_2$ deficiency, this suppression is not indicative of physiological inactivity of the primary root development in rice seedling germinated under $O_2$ deficient condition (Kordan, 1977a). Thus root growth may be blocked in seeds that germinate under water until shoot develops, thereby providing a mechanism to conserve energy during the early phase of seed germination.

**Experiment 2**

The varieties, seeded (sprouted seeds sown) aerobically onto wet bed, were able to produce seedlings ranging from 79.21 (Swarna Sub 1), to Banajira and FR13A (92.16%). Hypoxic condition affected seedling growth severely (Table 3). Under anaerobic conditions/lowland conditions, BR11 was able to establish more than 75.69% seedling. In contrast, Swarna *Sub 1* established 51.98% what was not different from the tolerant Banajira. More so, Swarna *Sub 1* performed significantly better than the tolerant cultivar Bashful (45.96%). So, Swarna *Sub 1* could be considered as anoxia-tolerant genotype. But FR13A had its seedling establishment only 35.16%, which was significantly lower than the lowest performing Bashful (45.96%). The seedling establishment under aerobic condition was quite satisfactory (79.21% to 92.16%). When the seedlings were 20-day-old, they were submerged for 10 days. Seedling age used in our study (20-day) to survive submergence stress was quite low. Pervin (2005) observed that 15-day-old FR13A seedling submerged for 10 days could not survive under Bangladesh condition. But under similar stress, 20-day-old FR13A seedling survived and recovered, successfully.

In our study similar treatment was imposed having seedling grown both under aerobic and anaerobic conditions. Aerobically grown seedlings FR13A and Swarna *Sub 1* survived submergence tolerance 31.06% and 2.02%, respectively (Table 3) (percentage based on initial seeds sown). The anoxia-tolerant genotypes could not survive the stress. No anaerobically grown seedling (including Swarna *Sub 1*) survived the submergence stress. FR13A survived only 9.97% (Table 3). Undoubtedly the stress was too extreme to survive the genotypes. The water of the submergence tank was made turbid twice a day. Under this condition tissue anoxia might develop at night and turbid condition to prevent photosynthetic $O_2$ generation during the day. Under such circumstances, roots will be especially vulnerable to $O_2$ shortage since the soil will be anaerobic, rendering them entirely dependent upon shoot (Jackson and Ram, 2003). As the shoot is completely submerged, it has little opportunity to capture $O_2$.There is also report that anoxically damaged roots cause injury to the shoot (Boamfa *et al*, 2003). That might cause poor recovery of FR13A and no recovery of Swarna *Sub 1*.

The ability to produce elongated coleoptile and first leaf under hypoxic condition is directly correlated to the ability to establish seedlings under lowland conditions. Swarna *Sub 1* could produce first leaf and they were able to establish under lowland conditions. Despite failure in the production of the first leaf, BR11 was able to establish the highest percentage of seedling under lowland conditions. This performance deserves conformation. According to Yamauchi et al, (1993) FR13A have some tolerance to low land conditions. But in our study this genotype (FR13A) did not show any morphological attributes to be considered as anoxia-tolerant genotype.

Accordingly, the genotypes showed its poorest seedling establishment (35%) under lowland conditions. In contrast, Swarna *Sub1* showed quite better seedling establishment under lowland conditions failed to sustain the submergence thrust. Even the recovery from submergence for both FR13A and Swarna *Sub1* for aerobically grown seedlings were 31.06 and 2.02 respectively. The figure for FR13A was quite better compared to that of Swarna *Sub 1*, still not acceptable. Does it mean that the mechanism of anoxia or hypoxia tolerance during seedling establishment and submergence is different? The answer is probably yes and might not be mediated by similar biochemical pathway. However, the phenomenon deserves exploration. It also appears that the seedling age play an important role to activate the role of QTL *Sub 1*.

Based on the results and discussion the following conclusions were drawn:

- Swarna *Sub 1* showed some better seedling attributes under hypoxic conditions leading to superior seedling establishment under lowland conditions.
- Irrespective of genotype, anaerobically and aerobically grown 20-day-old seedlings could not recover after 10-day submergence.

**Table 1. Coleoptile length (mm) of 12 rice genotype as affected by different growing conditions.**

| Variety | Coleoptile | | |
|---|---|---|---|
| | Growing condition | | |
| | Aerobic condition | Hypoxic condition | Anoxic condition |
| Swarna *Sub 1* | 13.45 | 46.20 | 37.40 |
| Banajira | 10.70 | 27.85 | 30.50 |
| Bichi Borki | 21.40 | 52.55 | 18.10 |
| BR11 | 14.95 | 42.35 | 38.90 |
| Jahmir | 17.65 | 36.65 | 27.70 |
| Chaita Boro | 12.95 | 33.00 | 24.40 |
| BR5 | 10.45 | 19.90 | 17.25 |
| FR13A | 22.25 | 13.25 | 27.40 |
| Boro 109/2 | 28.40 | 28.60 | 24.95 |
| BRRI dhan29 | 14.10 | 23.85 | 5.60 |
| Bashful | 20.20 | 44.25 | 31.85 |
| BRRI dhan32 | 20.65 | 50.30 | 27.70 |
| LSD0.05 | 5.87% | | |
| CV% | 16.22 | | |

**Table 2. First leaf (mm), leaf number (mm), plant height (mm), nodal root length (mm) and seminal root length (mm) of 12 rice varieties as affected by different growing conditions.**

| Variety | First leaf length. | | Leaf number | | Plant height | | Nodal root length | | Seminal root length | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Growing condition | | Growing condition | | Growing condition | | Growing condition | | Growing condition | |
| | Aerobic condition | Hypoxic condition | Aerobic condition | Hypoxic condition | Aerobic condition | Hypoxic condition | Aerobic condition | Hypoxic condition | Aerobic condition | Hypoxic condition |
| Swarna *Sub 1* | 20.55 | 5.95 | 1.90 | 0.25 | 44.95 | 8.25 | 11.45 | 73.65 | 73.65 | 3.17 |
| Banajira | 28.05 | 0.00 | 2.00 | 0.00 | 60.00 | 0.00 | 12.65 | 50.10 | 50.10 | 0.35 |
| Bichi Borki | 33.40 | 8.10 | 2.00 | 0.20 | 70.45 | 9.40 | 10.60 | 76.40 | 76.40 | 8.42 |
| BR11 | 19.20 | 0.00 | 1.40 | 0.00 | 39.60 | 0.00 | 17.05 | 59.10 | 59.10 | 1.60 |
| Jahmir | 28.85 | 16.85 | 2.00 | 0.50 | 75.10 | 22.35 | 28.50 | 95.00 | 95.00 | 11.07 |
| Chaita Boro | 24.70 | 8.20 | 1.75 | 0.10 | 32.90 | 7.90 | 3.90 | 65.55 | 65.55 | 1.00 |
| BR5 | 7.80 | 0.00 | 1.10 | 0.00 | 17.05 | 0.00 | 3.50 | 37.80 | 37.80 | 0.00 |
| FR13A | 26.95 | 0.00 | 1.90 | 0.00 | 43.35 | 0.00 | 13.60 | 67.75 | 67.75 | 0.00 |
| Boro 109/2 | 36.40 | 12.55 | 2.00 | 0.25 | 75.70 | 17.05 | 29.55 | 83.00 | 83.00 | 9.20 |
| BRRI dhan29 | 26.45 | 7.20 | 2.00 | 0.25 | 47.40 | 8.85 | 14.00 | 71.20 | 71.20 | 4.70 |
| Bashful | 29.30 | 14.10 | 2.00 | 0.20 | 65.95 | 26.90 | 12.60 | 92.60 | 92.60 | 7.50 |
| BRRI dhan32 | 27.85 | 2.60 | 1.95 | 0.10 | 55.00 | 3.50 | 17.60 | 71.10 | 71.10 | 3.20 |
| LSD0.05 | 9.30 | | 0.46 | | 15.85 | | 5.42 | | 15.42 | |
| CV% | 41.80 | | 32.26 | | 36.40 | | 48.35 | | 30.38 | |

**Table 3. Seedling establishment (%) and recovery (%) after submergence.**

| Variety | Initial seedling establishment (%) | | Recovery after submergence (% of total seed sown) | |
|---|---|---|---|---|
| | Aerobic condition | Lowland condition | Aerobic condition | Lowland condition |
| Swarna *Sub 1* | 79.21 | 51.98 | 2.02 | 0.00 |
| Banajira | 92.16 | 54.76 | 0.00 | 0.00 |
| BR11 | 86.49 | 75.69 | 0.00 | 0.00 |
| FR13A | 92.16 | 35.16 | 31.06 | 9.97 |
| Bashful | 88.36 | 45.96 | 0.00 | 0.00 |
| LSD% | 5.76 | | - | |

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# Effect of Fresh and Decomposed Poultry Litter on Growth and Yield of Boro Rice

B C Roy and J C Biswas[14]

ABSTRACT

**We did the experiments at Bangladesh Rice Research Institute (BRRI), Gazipur during Boro seasons of 2010 and 2011. Fresh (0-3-day-old droppings) and one-month decomposed poultry litter (DPL) was used at variable rates and in combination with chemical fertilizers and compared with absolute control. Plant height, panicles/m$^2$ and grains per panicle were found statistically similar among the sole and integrated use of PL with chemical fertilizer treatments. Excessive vegetative growth was observed when fresh poultry litter (FPL) was applied @ 6 t/ha or more. The highest grain yields were recorded when 5 t/ha FPL along with 38 kg/ha N was used in both the years but the highest grain yield was observed when DPL @ 3 t/ha along with 65-11 kg/ha NP was used. The average requirement of FPL and DPL irrespective of its rate, N and P variations, grain yield was about 5.88 t/ha with FPl and 5.91 t/ha with DPL. This implies that both FPL and DPL can be utilized successfully for growing rice in Bangladesh.**

## INTRODUCTION

The poultry litter contains a considerable amount of plant nutrients that can be used successfully for rice production (Biswas *et al*, 2009, Jacob *et al*, 1997). There are 188.4 lakh fowl and ducks in Bangladesh (BBS, 2010) and produced a huge amount of litter, which can be used for crop production (Jacob *et al,* 1997, Kunkle *et al*, 1997) and as well as power generation (Dangnall, 1993). The organic source of nutrients not only contributes to crop production but also conserve the nature. Moreover, poultry litter (PL) could be used to supplement triple super phosphate and muriate of potash fertilizers. The fresh poultry litter (FPL) and decomposed poultry litter (DPL) could be used as sole source of plant nutrients or in combination with chemical fertilizers for crop production. The present study was, therefore, undertaken to find out the effect of FPL and DPL on growth and yield of Boro rice.

## MATERIALS AND METHODS

We did the experiments at Bangladesh Rice Research Institute (BRRI), Gazipur during two subsequent Boro seasons 2010 and 2011. Fresh (0-3-day-old droppings) and one-month decomposed PL was used at different rates and in combination with chemical fertilizers and compared with absolute control. The treatments imposed were, FPL 7 t/ha ($T_1$); FPL 6 t/ha ($T_2$); FPL 5 t/ha ($T_3$); FPL 5 t/ha along with N 38 kg/ha ($T_4$); FPL 3.5 t/ha along with NP 64-3 kg/ha ($T_5$); FPL 2.5 t/ha along with NP 82-11 kg/ha ($T_6$); DPL 3 t/ha along with NP 64-15 kg/ha ($T_7$); DPL 3.5 t/ha along with NP 64-3 kg/ha ($T_8$); DPL 2.5 t/ha along with NP 82-11 kg/ha ($T_9$) and no fertilizer application ($T_{10}$). In the treatments of integrated use of PL and chemical fertilizer, the amount of NPK in PL were calculated and then N, P and K were adjusted as of soil test based (STB) fertilizer application. The treatments were assigned in a randomized complete block design with three replications. Unit plot size was 4 x 3 m.

The FPL and DPL were used before final land preparation as per treatments and seedlings were transplanted after three days of PL application. Forty-day-old seedlings of BRRI dhan45 were transplanted on 04-01-2010 and 07.01.2011 at 20- × 20-cm spacing. Urea was top dressed thrice at 20 days after transplanting (DAT), 35 DAT and 5 days before panicle initiation. Triple super phosphate, muriate of potash, gypsum and zinc fertilizers were applied as basal. Initially continuous standing water was maintained for about two weeks and then normal water management practices were followed. Weeds were controlled by applying pre-emergence Butachlor (Vachete 5G) herbicide followed by one hand weeding at 40 DAT. Insecticide was applied as and when necessary. Data on plant height, panicles/m$^2$, grains per panicle, sterility percentage; grain and straw yields were

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recorded. The collected data were analysed following Gomez and Gomez (1984) and means were compared at the 5% level of probability.

## RESULTS AND DISCUSSION

**Plant height, panicles/m$^2$, grains per panicle and sterility percentage were found statistically identical among the sole PL treated plots and integrated use of PL and chemical fertilizer treated plots (Tables 1 and 2). Excessive vegetative growth was observed when FPL was applied @ 6 t/ha or more in both the years. The highest grain yields were recorded when FPL 5 t/ha along with N 38 kg/ha was used in both the years (Tables 1 and 2). However, the highest straw yields (more than 7.5 t/ha) were recorded when FPL 7 t/ha was used (Tables 1 and 2). On the other hand, the highest grain and straw yields were observed when DPL 3 t/ha along with NP 65-11 kg/ha was used. It was also observed from this study that when greater amount of P as TSP was applied in combination with DPL, grain yield improved compared to lower P rates. Biswas et al, (2008) also reported that Boro rice could be successively cultivated with PL alone.**

**Both fresh and decomposed PL contains a good amount of plant nutrients, especially NPK (Dobermann and Fairhurst, 2000) and consequently, the application of PL can reduce the amount of N and P fertilizers according to the rate of its application for rice cultivation. The sole application of PL, if available, also produced a considerably higher grain yield and it was statistically identical compared to integrated application of PL and chemical fertilizers. However, integrated application of PL and chemical fertilizers were better (BRRI, 2010 and 2011). A major portion of production cost goes for fertilizer purchase in our country. So, the use of PL may help in reducing cost of production and odor free environment as well. However, poultry litter could be used as sole source or in combination of inorganic fertilizers to supplement nutrients for rice cultivation, because it contains a good amount of plant nutrients (Shah *et al,* 2004).**

**The average grain yield of FPL and DPL irrespective of rate, N and P variations was 5.95 and 6.01 t/ha with FPL and DPL, in Boro, 2010 and 5.81 and 5.82 t/ha in Boro, 2011 respectively (Fig. 1). This implies that both FPL and DPL could be utilized successfully for growing Boro rice in Bangladesh.**

## CONCLUSION

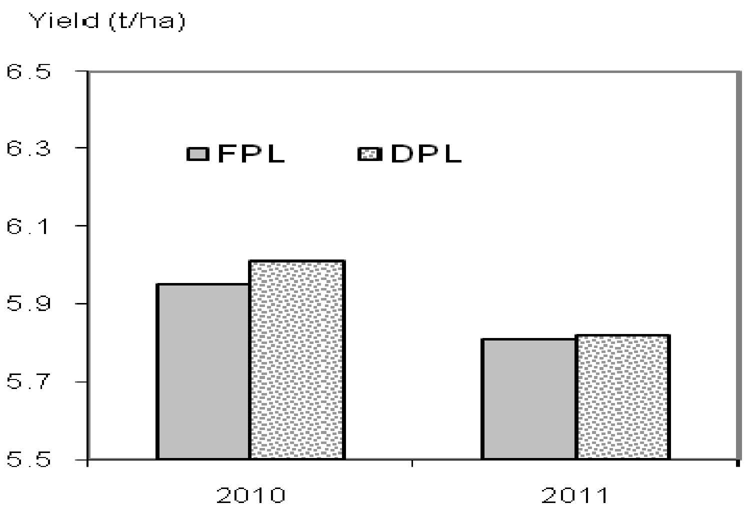
**Thus we conclude that both the fresh and one-month decomposed poultry litter can be used either in combination with fertilizers or alone for satisfactory grain yield of Boro rice.**

Table 1. Effect of fresh and decomposed poultry litter on growth parameters and yield of rice in dry season, 2010, BRRI, Gazipur.

| Treatment | Plant ht (cm) | Panicle (no./m$^2$) | Grains (no./pan) | Sterility (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| $T_1$-7 t/ha FPL | 103 | 270 | 92 | 11.45 | 5.94 | 7.70 |
| $T_2$-6 t/ha FPL | 96 | 245 | 96 | 11.58 | 5.72 | 7.52 |
| $T_3$-5 t/ha FPL | 100 | 232 | 100 | 15.25 | 5.81 | 7.23 |
| $T_4$-5 FPL + 38 kg/ha N | 104 | 267 | 98 | 14.04 | 6.39 | 7.26 |
| $T_5$-3.5 t/ha FPL + 66-3 kg/ha NP | 103 | 275 | 96 | 13.49 | 5.97 | 7.10 |
| $T_6$-2.5 t/ha FPL + 84-11 kg/ha NP | 97 | 233 | 98 | 16.74 | 5.85 | 6.99 |
| $T_7$-3.5 t/ha DPL + 66-3 kg/ha NP | 102 | 260 | 100 | 12.09 | 5.66 | 6.93 |
| $T_8$-3 t/ha DPL + 65-15 kg/ha NP | 96 | 268 | 104 | 18.09 | 6.55 | 7.52 |
| $T_9$-2.5 t/ha DPL + 84-11 kg/ha NP | 99 | 245 | 89 | 14.88 | 5.82 | 6.89 |
| $T_{10}$-without fertilizer | 94 | 200 | 81 | 13.69 | 5.01 | 6.00 |
| CV (%) | 3.9 | 6.39 | 8.6 | 12.41 | 8.6 | 9.92 |
| LSD (0.05) | 7 | 26 | 13 | 3.16 | 0.44 | 0.59 |

Table 2. Effect of fresh and decomposed poultry litter on growth parameters and yield of rice in dry season, 2011, BRRI, Gazipur.

| Treatment | Plant ht (cm) | Panicle (no./m$^2$) | Grains (no./pan) | Sterility (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| $T_1$-7 t/ha FPL | 99 | 250 | 92 | 15.44 | 5.74 | 7.57 |
| $T_2$-6 t/ha FPL | 96 | 243 | 96 | 13.50 | 5.62 | 7.42 |
| $T_3$-5 t/ha FPL | 95 | 242 | 100 | 13.05 | 5.65 | 7.03 |
| $T_4$-5 FPL + 38 kg/ha N | 94 | 265 | 98 | 14.13 | 6.09 | 7.23 |
| $T_5$-3.5 t/ha FPL + 66-3 kg/ha NP | 97 | 267 | 96 | 13.43 | 5.88 | 7.13 |
| $T_6$-2.5 t/ha FPL + 84-11 kg/ha NP | 97 | 243 | 98 | 15.71 | 5.87 | 7.00 |
| $T_7$-3.5 t/ha DPL + 66-3 kg/ha NP | 98 | 255 | 100 | 13.45 | 5.80 | 6.98 |
| $T_8$-3 t/ha DPL + 65-15 kg/ha NP | 96 | 258 | 104 | 17.11 | 5.85 | 7.25 |
| $T_9$-2.5 t/ha DPL + 84-11 kg/ha NP | 95 | 245 | 89 | 15.88 | 5.82 | 6.99 |
| $T_{10}$-without fertilizer | 90 | 200 | 81 | 12.13 | 4.01 | 5.40 |
| CV (%) | 4.7 | 8.44 | 10.7 | 11.91 | 7.9 | 10.12 |
| LSD (0.05) | 5 | 22 | 11 | 4.13 | 0.52 | 0.57 |




**Year**

Fig. 1. Grain yield of BRRI dha45 as influenced by fresh and decomposed poultry litter, BRRI, Gazipur.

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# Genetic Diversity of BRRI Varieties Using Microsatellite Markers

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ABSTRACT

Genetic diversity of 50 BRRI developed modern rice varieties was studied through DNA profiling to protect them from biopiracy. Simple sequence repeat (SSR/microsatellites) markers were chosen due to their comparative superiority over other markers for this purpose. A total of 110 microsatellite markers were used to characterize and discriminate the test materials. Fifty-one primers showed polymorphism giving 191 alleles. The number of alleles per locus ranged from two (RM17, RM119, RM174, RM346, RM348, RM431, RM482, RM495 and RM517) to eight (RM310, RM219), where average number of allele was 3.745. The polymorphism information contents (PIC) lied between 0.106 (RM348) to 0.80 (RM310). Most robust marker was RM310 since it provided the highest PIC value (0.8023). Pair-wise genetic dissimilarity co-efficient values detected BR5 and BR21 as the most genetically distant varieties, whereas BR22 and BR23 were the closest. UPGMA clustering system grouped BRRI varieties into seven major clusters at 0.49 similarity co-efficient. Cluster 1 was identified as the largest cluster comprising 18 varieties. Cluster 3 and cluster 6 were the smallest with only two varieties. All the aromatic varieties (BRRI dhan34, BRRI dhan37, BRRI dhan38 and BR5) grouped in the same cluster indicating their genetic closeness. The information obtained from DNA fingerprinting studies helps to distinctly identify and characterize 50 BRRI varieties using 51 different microsatellite markers. This information can be used in background selections during backcross breeding programmes. This study inferred that most of the BRRI varieties have narrow genetic base and hence inclusion of new landraces in future breeding programmes is recommended to broaden it.

## INTRODUCTION

The world's rice production has been doubled during the last 25 years, largely due to the use of improved technology such as high yielding varieties and better crop management practices (Byerlee, 1996). These days, the cultural practices have come to almost a stand still. So, for increasing rice production and ensuring present and future food security, we have to upgrade our high yield potential varieties. This upgradation would depend on the extensive use of genetic diversity in plant breeding programmes. As, new strategies have recently been developed to make better use of plant germplasm collections for crop improvement, such as using advanced backcross QTL population and introgression lines to identify and transfer beneficial alleles from exotic germplasm (Li *et al*, 2005; Tanksley and McCouch 1997). So, plant breeders are very interested assessing genetic variation level among the cultivated rice varieties (Islam *et al*, 2007).

The breeders are also very keen for rice cultivar identification, registration, patenting and establishing breeders rights (Islam *et al*, 2007), nowadays which are much more imperative due to the advent of trade related aspects of intellectual property rights agreement (TRIPs) under World Trade Organization (WTO). It has resulted worldwide shift from free exchange and unhindered exploitation to controlled access in plant genetic resources. Similarly UN Convention on Biological Diversity (CBD, 1993) recognizes the sovereignty of nations over their plant genetic resources and rights of farming community to receive compensation for direct and indirect commercial exploitation of traditional varieties.

So far this variety identification and diversity analysis have been done by conventional morphological descriptors in Bangladesh. These descriptors have many drawbacks like requiring the plants full maturity prior to identification, environmental influence on traits, epistasic interactions, pleiotrophic effects etc. Protein or isozyme markers are also environmentally influenced (Chakravarthi and Naravaneni, 2006). In this circumstance, the straightforward method to distinguish crop varieties and parental lines would be sequencing the genomes under comparison since all genetic differences between individuals are laid down in the DNA sequences of their genomes. But sequencing requires huge monitory investment and it is practically impossible to sequence the whole genomes of all varieties (Bhat, 2001). So, DNA fingerprinting would be the alternative option and genetic diversity study on the basis of DNA fingerprinting data is the best choice.

Several molecular markers are presently available doing this sort of DNA based analysis viz, RFLP (Becker *et al*, 1995; Paran and Michelmore, 1993;), RAPD (Tingey and Deltufo, 1993; Williams *et al*, 1990), SSRs (Levinson and Gutman, 1987), ISSRs (Albani and Wikinson, 1998; Blair *et al*, 1999), AFLP (Mackill *et al*, 1996; Thomas *et al*, 1995; Vos *et al*, 1995; Zhu *et al*, 1998) and SNPs (Vieux, *et al*, 2002). Among these, microsatellites (SSRs) are increasingly being popular for their abundance, high degree of polymorphism, reproducibility and cost-effectiveness (Islam *et al*, 2007). These microsatellites are tandem repeats of short DNA motifs (1-6 bp in length) that frequently exhibit variation in repeat numbers at a locus. They are very useful to distinguish rice varieties especially with narrow genetic base. Hence it can be used in distinctness, uniformity, and stability (DUS) testing in crop varieties (Bonow *et al*, 2009).

Bangladesh Rice Research Institute (BRRI) has released rice varieties possessing variable features in cropping seasons, photosensitivity, morphology, grain quality etc. But the available information on DNA fingerprinting and molecular markers based genetic diversity of these varieties are very much fragmentary. So, to protect the intellectual property rights (IPR) of our breeders by DNA fingerprinting and to assess the genetic variability among 50 BRRI developed rice varieties, the present investigation was carried out using microsatellite markers considering their best suitability.

## MATERIALS AND METHODS

Fifty BRRI released rice varieties were taken. The seeds were obtained from Biotechnology Division, BRRI, Gazipur. They were germinated in petri dishes and sown in earthen pots to raise seedlings.

Fresh leaf samples of 21-day-old rice seedlings were used as the source of genomic DNA. DNA was isolated following CTAB method with minor modifications described by Zheng *et al.* (1995). At first leaf tissue were cut into small pieces, homogenized and digested with extraction buffer (1M Tris, 0.5M EDTA, 5M NaCl and 20% SDS, pH 8.0). After incubation for 20 min at 65°C with intermittent swirling, the mixture was emulsified with chloroform: IAA mix (24: 1 mixture of chloroform and isoamyl alcohol). After centrifugation, the upper aqueous layer was removed into a different tube and cold ethanol was added. After centrifugation a small pellet was visible. The pellets were then washed with 70% ethanol, dried by a concentrator and resuspended in an appropriate volume of TE buffer (1M Tris, 0.5M EDTA, pH 8.0). DNA quality was checked by agarose gel electrophoresis with lambda DNA (50 ng/µl) and quantification was done using a spectrophotometer (Nano drop 1000 V3.6, USA).

PCR was carried out in 10 µl reactions volume containing 1 µl of $MgCl_2$ free 10 × PCR buffer with $(NH_4)_2SO_4$, 1.2 µl of 25 mM $MgCl_2$, 0.2 µl of 10 mM dNTPs, 0.2 µl of 5 U/µl Taq DNA polymerase, 0.5 µl of 10 µM forward and reverse primers (Promega corporation, USA) and 3 µl (10 ng) of DNA using a 96 well thermal cycler. Amplification were carried out in a thermal cycler (G-strom, GSI, England ) with the following program: 94°C for 5 min (initial denaturation) followed by 35 cycles of 94°C for 1 min (denaturation), 55°C for 1 min (annealing), 72°C for 2 min (extension) with a final extension for 7 min at 72° C. The annealing temperatures were adjusted based on the specific requirements of each primer combination. After amplification, PCR products were mixed with gel loading dye (bromophenol blue, xylene cyanol and sucrose), and electrophoresed using vertical polyacrylamide gels (8% denatured polyacrylamide gel containing 19: 1 acrylamide: bhisacrylamide) for manual genotyping. Four µl of the amplification products were resolved by running the gel in 1 × TBE buffer for 1.5 to 2.5 hrs (depending on the allele size) at around 90 volts and 500 mA electricity (CBS scientific, USA). The gels were stained in 1 µg/ml ethidium bromide and documented using UVPRO (Uvipro Platinum, EU) gel documentation unit. A total of 51 SSR markers (distributed across the 12 chromosomes) with clear amplifications were selected for genetic diversity analysis.

Size for each amplified allele was measured in base pair using Alpha-Ease FC 5.0 software (Alpha Innotech, USA). The summary statistics including the number of alleles per locus, major allele frequency, gene diversity, Polymorphism Information Content (PIC) values were determined using Power Marker version3.25 (Liu and Muse 2005). The allele frequency data from PowerMarker was used to export in binary format (allele presence=1 and allele absence=0) for analysis with NTSYS-pc version 2.1 (Rohlf 2002). The Excel file containing the binary data was imported into NT-Edit of NTSYS-pc. The similarity matrix was used to calculate similarity as DICE co-efficient using SIMQUAL sub routine in SIMILARITY routine. The resultant similarity matrix was employed to construct dendrograms using sequential agglomerative hierarchical nesting (SAHN) based unweighted pair group method with arithmetic means (UPGMA).

## RESULTS AND DISCUSSION

Fifty BRRI varieties were assessed for genetic variability using 51 polymorphic microsatellite markers (Table 1). A total of 191 alleles were detected at the loci of 51 microsatellite markers across the genotypes. The highest amplicon size was produced by RM 517 (289 bp) and the lowest by RM413 (73 bp). The highest range of band sizes was found in RM5551 (180- 230) followed by RM547 (202 -250) and RM206 (125 - 168) (Table 1) respectively. The number of alleles per locus ranged from 2 (RM17, RM346, RM495, RM431, RM174, RM482, RM119, RM348 and RM517) to 8 (RM219 andRM310) with an average of 3.745 alleles across the 51 loci. The frequency of the most common allele at each locus ranged from 26.53% (RM310) to 94% (RM348). On average, 60.20% of the 50 rice genotypes shared a common major allele at any given locus. Polymorphism information content (PIC) values ranged from 0.106 to 0.80 with an average of 0.464. The highest PIC value (0.8) was obtained for RM310 followed by RM11 (0.74), RM252 (0.73) and RM 206 (0.70) respectively (Table 1). Therefore, depending upon the PIC values it can be concluded that among the 51 marker tested, RM310 and RM566 markers were found to be suitable for distinguishing four BRRI hybrids and their parental lines. DNA profile of markers RM231 and RM310 for all 50 genotypes are shown in Figures 1 and 2 respectively.

Similar results were observed in previous fingerprinting and diversity studies, having 1-8 alleles with an average of 4.58 alleles for various classes of microsatellite (Siwach *et al,* 2004) and also 3 to 9 alleles, with an average of 4.53 alleles per locus for 30 microsatellite markers (Hossain *et al,* 2008). In another study, Rahman *et al.* (2009) found an average of 6.33 alleles per locus in rice using Bangladeshi high yielding varieties, local cultivars and wild races. We can compare our frequency for most common alleles found by Thomson *et al.* (2007) which ranged from 21 (RM154) to 73% (RM214). The PIC values of the present study are comparable to other two previous studies in rice viz 0.20-0.90 with an average of 0.56 (Jain *et al,* 2003) and 0.30-0.84 with an average of 0.58 (Hossain *et al,* 2008).

**Table 1. Data on the number of alleles, allele size, major allele, major allele frequency and polymorphism information content (PIC) found among 50 rice varieties for 51 microsatellite markers.**

| Marker | Chr. no | Position (Mbp) | Allele no. | Allele size (Mbp) | Maj.All. (Mbp) | Maj.All.Fr. | PIC |
|---|---|---|---|---|---|---|---|
| **RM495** | 1 | 0.21 | 2.0000 | 157-168 | 168.0000 | 0.6800 | 0.3405 |
| **RM84** | 1 | 6.66 | 4.0000 | 100-128 | 112.0000 | 0.7917 | 0.3360 |
| **RM493** | 1 | 12.26 | 4.0000 | 191-204 | 202.0000 | 0.6735 | 0.4454 |
| **RM5** | 1 | 24.13 | 3.0000 | 112-125 | 115.0000 | 0.5581 | 0.4306 |
| **RM226** | 1 | 34.36 | 4.0000 | 268-277 | 270.0000 | 0.8125 | 0.3045 |
| **RM431** | 1 | 39.22 | 2.0000 | 249-251 | 251.0000 | 0.9167 | 0.1411 |
| **RM211** | 2 | 3.66 | 3.0000 | 145-165 | 145.0000 | 0.3800 | 0.5874 |
| **RM174** | 2 | 7.00 | 2.0000 | 214-225 | 214.0000 | 0.7447 | 0.3080 |
| **RM327** | 2 | 17.16 | 3.0000 | 206-218 | 206.0000 | 0.5319 | 0.4036 |
| **RM341** | 2 | 21.04 | 4.0000 | 135-172 | 172.0000 | 0.6122 | 0.5324 |
| **RM526** | 2 | 26.66 | 3.0000 | 205-227 | 227.0000 | 0.8600 | 0.2316 |
| **RM482** | 2 | 35.27 | 2.0000 | 194-197 | 194.0000 | 0.8333 | 0.2392 |
| **RM231** | 3 | 64.00 | 3.0000 | 178-198 | 195.0000 | 0.5306 | 0.4509 |
| **RM168** | 3 | 28.04 | 4.0000 | 92-115 | 107.0000 | 0.4792 | 0.6072 |
| **RM570** | 3 | 35.53 | 4.0000 | 190-207 | 204.0000 | 0.5000 | 0.5191 |
| **RM7** | 3 | 64.00 | 3.0000 | 188-197 | 195.0000 | 0.7000 | 0.4164 |
| **RM251** | 3 | 79.10 | 3.0000 | 146-171 | 153.0000 | 0.4468 | 0.5183 |
| **RM551** | 4 | 0.17 | 5.0000 | 180-230 | 197.0000 | 0.7600 | 0.3705 |
| **RM119** | 4 | 21.22 | 2.0000 | 166-174 | 174.0000 | 0.7200 | 0.3219 |
| **RM348** | 4 | 32.62 | 2.0000 | 136-145 | 136.0000 | 0.9400 | 0.1064 |
| **RM280** | 4 | 34.95 | 4.0000 | 156-185 | 162.0000 | 0.6304 | 0.4984 |
| **RM252** | 4 | 25.19 | 5.0000 | 216-239 | 229.0000 | 0.3261 | 0.7264 |
| **RM153** | 5 | 0.17 | 5.0000 | 195-235 | 210.0000 | 0.5000 | 0.5366 |
| **RM413** | 5 | 2.19 | 7.0000 | 73-114 | 82.0000 | 0.5800 | 0.5360 |
| **RM163** | 5 | 19.16 | 4.0000 | 113-152 | 117.0000 | 0.4884 | 0.6238 |
| **RM586** | 6 | 1.47 | 4.0000 | 250-280 | 273.0000 | 0.7200 | 0.4127 |
| **RM541** | 6 | 19.21 | 3.0000 | 178-195 | 185.0000 | 0.8200 | 0.2666 |
| **RM584** | 6 | 3.41 | 3.0000 | 170-188 | 188.0000 | 0.7200 | 0.3946 |
| **RM517** | 6 | 6.14 | 2.0000 | 266-289 | 266.0000 | 0.6939 | 0.3346 |
| **RM314** | 6 | 8.50 | 3.0000 | 110-120 | 110.0000 | 0.5306 | 0.5253 |
| **RM461** | 6 | 30.11 | 3.0000 | 173-188 | 173.0000 | 0.4286 | 0.5788 |
| **RM501** | 7 | 7.66 | 3.0000 | 173-185 | 173.0000 | 0.4783 | 0.5524 |
| **RM11** | 7 | 19.25 | 6.0000 | 132-153 | 132.0000 | 0.3400 | 0.7383 |
| **RM346** | 7 | 19.17 | 2.0000 | 145-161 | 161.0000 | 0.8600 | 0.2118 |
| **RM408** | 8 | 0.12 | 3.0000 | 125-132 | 125.0000 | 0.8200 | 0.2778 |
| **RM25** | 8 | 13.28 | 7.0000 | 126-149 | 146.0000 | 0.5400 | 0.6380 |
| **RM310** | 8 | 5.11 | 8.0000 | 80-121 | 106.0000 | 0.2653 | 0.8023 |
| **RM547** | 8 | 5.58 | 5.0000 | 202-250 | 202.0000 | 0.5000 | 0.5984 |
| **RM264** | 8 | 32.72 | 3.0000 | 187-193 | 190.0000 | 0.3800 | 0.5874 |
| **RM219** | 9 | 2.98 | 8.0000 | 161-200 | 171.0000 | 0.4200 | 0.6771 |
| **RM444** | 9 | 5.9 | 4.0000 | 162-199 | 199.0000 | 0.5870 | 0.5551 |
| **RM105** | 9 | 8.17 | 4.0000 | 130-141 | 135.0000 | 0.3400 | 0.6703 |
| **RM222** | 10 | 2.88 | 4.0000 | 213-236 | 225.0000 | 0.5800 | 0.5143 |
| **RM244** | 10 | 3.82 | 3.0000 | 153-163 | 156.0000 | 0.6200 | 0.4577 |
| **RM258** | 10 | 18.06 | 4.0000 | 136-153 | 140.0000 | 0.3400 | 0.6876 |
| **RM216** | 10 | 5.1 | 3.0000 | 138-151 | 138.0000 | 0.6800 | 0.3635 |
| **RM206** | 11 | 21.97 | 6.0000 | 125-168 | 168.0000 | 0.4583 | 0.6957 |
| **RM224** | 11 | 30.53 | 3.0000 | 181-195 | 195.0000 | 0.4200 | 0.5798 |
| **RM277** | 12 | 14.55 | 3.0000 | 113-123 | 119.0000 | 0.8163 | 0.2704 |
| **RM519** | 12 | 19.9 | 5.0000 | 100-118 | 114.0000 | 0.7660 | 0.3807 |
| **RM17** | 12 | 26.95 | 2.0000 | 170-193 | 193.0000 | 0.5800 | 0.3685 |
| **Mean** | | | 3.7451 | | | 0.6020 | 0.4642 |

Fig. 1. DNA profile of the 50 varieties with the SSR markers RM231.


Fig. 2. DNA profile of the 50 varieties with the SSR markers RM310.

**Legend.** 1=BR4, 2= BR5, 3= BR6, 4= BR8, 5= BR11, 6= BR12, 7= BR14, 8= BR15, 9= BR16, 10= BR21, 11= BR22, 12= BR23, 13= BR24, 14= BR25,15= BR26, 16= BRRI dhan27, 17= BRRI dhan30, 18= BRRI dhan33, 19= BRRI dhan35, 20= BRRI dhan36,21= BRRI dhan37, 22= BRRI dhan38, 23= BRRI dhan39,24= BRRI dhan42, 25= BRRI dhan43, 26= BRRI dhan44, 27= BRRI dhan45, 28= BRRI dhan46, 29= BRRI dhan47, 30= BR1, 31= BR2, 32= BR3, 33= BR7, 34= BR9, 35= BR10, 36= BR17, 37= BR18, 38= BR19, 39= BR20, 40= BRRI dhan28, 41= BRRI dhan29, 42= BRRI dhan31, 43= BRRI dhan32, 44= BRRI dhan34, 45= BRRI dhan40, 46= BRRI dhan41, 47= BRRI hybrid rice1,48=BRRI dhan48, 49= BRRI dhan49, 50= BRRI dhan50.

Pair-wise genetic dissimilarity co-efficient was measured among the test entries. The highest and lowest dissimilarity values were 0.8222 and 0.021 respectively (Table 2). BR21 and BR5 were found as the most diverged genotypes, which are followed by several other pairs like BRRI dhan37 vs BRRI dhan38, BRRI dhan34 vs BR7 and BRRI dhan34 vs BRRI dhan42 (Table 2). To get maximum heterosis, diverged genotypes should be exploited in breeding programmes. Cluster analysis was used to group the BRRI varieties to construct a dendogram. The unweighted pair group method with arithmetic means (UPGMA) based dendogram obtained from the binary data deduced from the DNA profiles of the analyzed samples. A total of seven distinct groups resulted out of pooled SSR marker data analysis at a cut-off similarity co-efficient 0.49 (Fig. 3), UPGMA clustering system of varieties revealed that, they have very strong parental linkage (Haque *et al*, 2002 and Kabir *et al*, 1994). This fingerprinting data will identify the genotypes very easily and the information generated from the study could be used in further molecular characterization with other genotypes.

We can conclude that the genetic information gathered here provides unique DNA profiles for BRRI released rice varieties, which will serve as a strong weapon to provide our breeders IPR and further it will be of greater help in background selections during back cross breeding programmes. Moreover, these data will help the breeders to select parents for future breeding programmes as the identification and use of diverse genetic resources is a prerequisite for plant improvement. This study concludes that most BRRI varieties have narrow genetic base. So it is recommended to use genetically diverse varieties for future breeding programme or include new and untouched landraces to incorporate new genes and broaden genetic base.

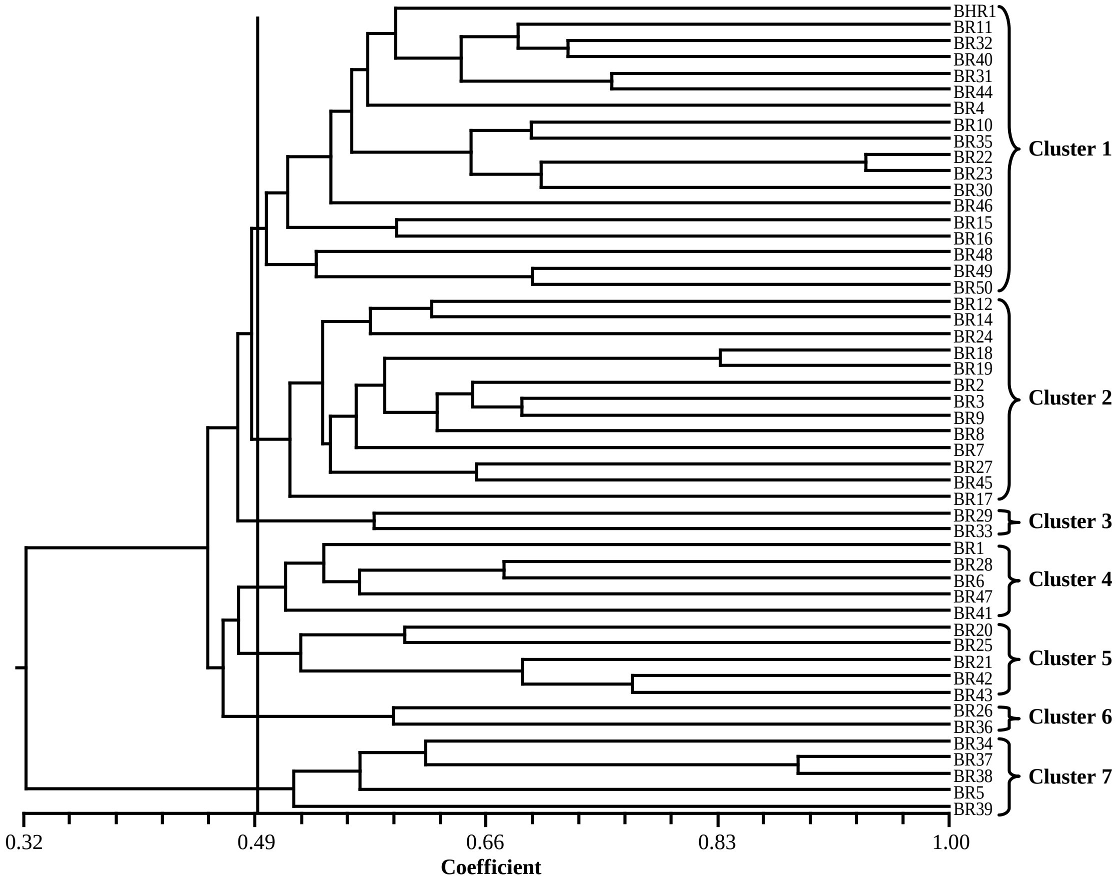


Fig. 3. A UPGMA cluster dendogram showing the genetic relationship among 50 BRRI rice varieties based on allele detected by 51 microsatellite markers.

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