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Influence of Nitrogen on Growth Performance of Hybrid and Inbred Rice (*Oryza sativa* L.) Varieties in Boro Season

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Abstract

Field experiments were conducted during boro season of 2002 and 2003 at the Bangladesh Rice Research Institute (BRRI) farm having silty clay loam soil. Hybrid variety Sonarbangla-1 and BRRI hybrid dhan1 and modern inbred variety BRRI dhan29 were used in the experiments. Zero to 160 kg N ha^{-1} with 40 kg interval and different application schedules, chlorophyll meter based (SPAD35) N application and urea supper granules (USG) @ 80 kg N ha^{-1} were used as N treatments. During boro 2002, BRRI hybrid dhan1 had 10-15% higher tiller number, leaf area index (LAI) and crop growth rate (CGR) than Sonarbangla-1 and BRRI dhan29. Among the N managements, N_9 (USG), N_5 (160 kg N ha^{-1} with basal), N_6 (160 kg N ha^{-1} without basal), and N_7 (SPAD based N application with basal) showed 10-15% higher plant height, tiller $hill^{-1}$, LAI and CGR. During boro 2003, Sonarbangla-1 and BRRI hybrid dhan1 had 10-15% higher plant height, tiller $hill^{-1}$, LAI and CGR compared to the BRRI dhan29. Among the N management, N_9 (USG), N_5, N_6, N_7, N_3 (120 kg N ha^{-1} with basal) and N_4 (120 kg N ha^{-1} without basal) treated plots performed better in terms of growth. The LAI and CGR were reduced by 20-25 % at 60 DAT during 2003 compared to 2002 due to cold and the growth of BRRI dhan29 was restricted much.

Keywords: Growth, hybrid, inbred, nitrogen

1. Introduction

The heterosis for higher yield in hybrid rice comes from vegetative growth. The life cycles of hybrid and inbred rice are almost similar, but hybrid rice is more vigorous in the vegetative phase especially at seedling stage. Hybrid rice has higher seedling dry matter content, thicker leaves, larger leaf area and longer root system (BRRI, 2000). Hybrid rice gives 10-15% yield advantage over modern inbred varieties through vigorous growth, extensive root system, efficient and greater sink size, larger leaf area index and higher carbohydrate translocation from vegetative parts to spikelets during the grain filling stage (Peng *et al*. 1998). During the vegetative growth, hybrid rice accumulates more dry matter, which results in more spikelets $panicle^{-1}$, whereas inbred rice depends basically on the accumulation of assimilates after heading (Yan, 1988). Dry matter production at different growth stages shows different patterns for hybrid and inbred rice. While hybrid rice has more dry matter accumulation in the early and mid growth stages, inbred rice has the same in the later growth stages (Yan, 1988). High grain yield of hybrid rice is attributed to high vegetative biomass production, high leaf area and large number of panicle (Peng *et al*.1998).

Nitrogen is the most essential element in determining the growth and yield of rice. Both excess and insufficient supply of nitrogen is harmful to crop growth. The efficient use of N fertilizer is recognized as an important factor for rice production but it has always been a problem to raise the N utilization rate by rice plants. Low N use efficiency remains a problem in rice production in Asia (Hussain *et al*., 2000). Often large amount of N fertilizer application by the farmers to increase yield of HYV was not justified agronomically and ecologically (Hossain *et al*., 2005). According to Mikkelsen *et al*. (1995), the major N requirement occurs during early vegetative growth and then at panicle initiation stage. The tropical hybrid responded more to N application at the basal and mid-tillering stages than the inbred cultivars (Peng *et al*., 1998). So, selecting varieties with higher N use efficiency, application of N fertilizer with proper dose and time, crop demand based N application, USG placement below the soil surface would be important options to improve crop growth as well as increase yield.

The present study was taken to compare the growth of selected hybrid and inbred rice varieties under different nitrogen management practices in field condition.

2. Materials and Methods

2.1. Site and soil

The field experiments were conducted at the experimental farm of the Bangladesh Rice Research Institute (BRRI), Gazipur during June 2002 to June 2003. The soil was a silty clay loam and slightly acidic (p^H = 6.0 to 6.4). The percentage of total N and organic matter (OM) were 0.11 and 2.05, respectively.

2.2. Design and treatments

The experiment was conducted in a factorial randomized complete block design (RCBD) with two factors viz: nitrogen management and variety using three replications.

The following N- management treatments were imposed in the experiment:

N_0 = Control (N_0)

N_1 = 40 kg N ha^{-1} in 2 equal splits at early tillering (ET) and panicle initiation (PI) stage

N_2 = 80 kg N ha^{-1} in 2 equal splits at ET and PI stage

N_3 = 120 kg N ha^{-1} in 3 equal splits at basal, mid-tillering (MT) and PI stage

N_4 = 120 kg N ha^{-1} in 3 equal splits at ET, MT and PI stage

N_5 = 160 kg N ha^{-1} in 4 equal splits at basal, MT, PI and heading stage

N_6 = 160 kg N ha^{-1} in 4 equal splits at ET, MT, PI and heading stage

N_7 = 30 kg N ha^{-1} at ≤ 35 Soil Plant Analysis Development (SPAD) value with basal 30 kg N ha^{-1}

N_8 = 30 kg N ha^{-1} at ≤ 35 SPAD value (from 20 DAT to heading) without basal N

N_9 = 80 kg N ha^{-1} as USG deep placement [3 granule (0.9 g size) in-between alternate 4 hills]

Hybrid Sonarbangla-1, BRRI hybrid dhan1 and inbred modern variety BRRI dhan31 were used in the experiment.

2.3. Crop establishment, fertilizer management and cultural practices

The unit plot size was 4 × 4 m, a buffer of 75 cm and 30 cm were maintained in between the replications and unit plots, respectively. Transplanting was done manually in well-puddled field in 40-day old seedlings. One healthy seedling (for both hybrid and inbred varieties) was transplanted with a spacing of 20 × 20 cm. Gap filling for dead seedlings were done within 10 days after transplanting (DAT). Fertilizers were applied @ 26-41-10-5 kg ha^{-1} of P, K, S and Zn as triple super phosphate, muriate of potash, gypsum and zinc sulphate during final land preparation and were thoroughly incorporated into the soil. Cultural practices like mulching, weeding etc. were done as and when necessary.

2.4. Data collection

Data on plant height, tiller plant^{-1}, leaf area index (LAI) and crop growth rate (CGR) were taken at 30, 60 and 90 DAT through destructive sampling. Four plants were uprooted from each plot out side the final harvested area to estimate the growth parameters. The roots of the uprooted hills were cut off and removed. Plant height was measured from the base to the tip of plant and tiller number was counted. Plants are separated into leaf blade and the stem including leaf sheath. After measuring the leaf area with an area meter (Delta T devices MKZ, Cambridge, UK) leaf and stem samples were dried in a hot air circulating oven at 70 ^{0}C for 72 hours and dry weight of leaf and stem was taken.

Leaf area index (LAI) was estimated following Yoshida (1981):

$$\text{LAI} = \frac{\text{Sum of the leaf area of all leaves}}{\text{Ground area from where the leaves were collected}}$$

Crop growth rate (CGR) was calculated as the increase of plant material per unit time per unit of land area and was measured by taking the total dry matter (TDM) (leaf + stem) at different growth stages following the formula:

$$\text{CGR} = \frac{dw}{dt} \times \frac{1}{p} = \frac{w_2 - w_1}{t_1 - t_2} \times \frac{1}{p}$$

Where, w_1 = total dry matter at time t_1 w_2 = total dry matter at time t_2 and p = Ground area

2.5. Statistical analysis

Data on different parameters were arranged in MS Excel program and statistical analysis was done using M Stat program. Analysis of variance and DMRT were used to compare the treatment means.

3. Results and Discussion

3.1. Plant height

In 2002, plant height of Sonarbangla-1, BRRI hybrid dhan1 and BRRI dhan29 significantly differed among treatments at all growth stages, except at 90 DAT (Table 1a). Sonarbangla-1 had significantly higher plant height of 33.6 cm at 30 DAT, but lowest at maturity. BRRI hybrid dhan1 had higher plant height at 60 DAT and at maturity. BRRI dhan29 had the lowest plant height at 30, 60 and 90 DAT but had the tallest plants (89.8 cm) at maturity like BRRI hybrid dhan1. In 2003, Sonarbangla-1 had significantly higher plant height than BRRI dhan29 at 30 and 60 DAT. BRRI hybrid dhan1 recorded higher plant height at all stages except at 60 DAT (Table 1a), whereas BRRI dhan29 had the lowest plant height at all growth stages.

The differences in increasing plant height might have been caused by variation in sensitivity to low temperature, growth duration, response to nitrogen and panicle length of those varieties. Plant height of both the hybrids was less affected by low temperature at early growth stages compared to the inbred BRRI dhan29. This result is in good agreement with those of Kaw and Khush (1985), who reported that hybrid rice has the tolerance to low temperature (10-15^{0}C) with faster growth capacity at early growth stage compared to inbred varieties. Sonarbangla-1 was the tallest variety only at early growth stages.

Irrespective of variety, plant height was influenced significantly by N management at all growth stages in both the years. In 2002, significantly taller plants were observed in N_9 (USG) and N_5 which were statistically similar to N_6 (160 kg N ha^{-1} without basal), at 30, 60 and 90 DAT. The plants treated with USG were statistically similar to those in N_5 at maturity (Table 1a). The highest plant height in N_9 (USG) and N_5 might be due to adequate and uniform N-supply to the crops. In 2003, significantly higher plant height was observed in N_5, N_9 (USG) and T_7 followed by N_3, N_4 and N_7 (Table 1a). It might be due to higher N rates (160 kg N ha^{-1}) for N_5 and N_6; crop demand based N application in N_7 and uniform N-supply to plants in N_9.

The interaction of variety × nitrogen management was significant only at maturity in 2003 (Table 1b). The tallest plant was observed with 160 kg N ha^{-1} for both hybrid and inbred varieties. BRRI hybrid dhan1 was the tallest variety at maturity followed by BRRI dhan29.

Table 1a. Effect of variety and N management on plant height (cm) at different DAT stage in Boro season.

Variety	30 DAT		60 DAT		90 DAT		Harvest
	2002	2003	2002	2003	2002	2003	2002
Sonarbangla-1	33.6 a	24.6 a	55.0 a	50.9 a	85.2	73.4 b	82.2 b
BRRI hybrid dhan1	29.9 b	24.1 a	55.3 a	43.2 b	85.1	76.2 a	89.8 a
BRRI dhan29	28.4 c	19.9 b	52.3 b	40.1 c	84.2	69.8 c	89.8 a
N management							
Control (N_0)	27.8 d	21.1 e	47.7 c	41.0 e	74.8 e	65.5 e	79.0 g
40 kg N ha^{-1} (N_1)	30.0 c	21.7 ce	49.7bc	42.2 de	78.3 d	69.9 d	83.4 f
80 kg N ha^{-1} (N_2)	30.3 bc	22.1 be	51.7 b	44.0 bd	83.1 c	73.6 bc	87.0 de
120 kg N ha^{-1} + basal (N_3)	31.8 ab	23.9 ab	55.6 a	45.5 ac	87.9 ab	74.1 ac	88.4 cd
120 kg N ha^{-1}- basal (N_4)	31.1 ac	23.1 ad	55.9 a	46.1 ac	86.1 bc	74.3 ac	88.2 cd
160 kg N ha^{-1} + basal (N_5)	32.7 a	24.8 a	57.2 a	48.0 a	89.0 ab	76.7 a	90.8 ab
160 kg N ha^{-1} – basal (N_6)	31.2 ac	23.4 ad	57.7 a	46.5 ab	88.2 ab	75.7 ab	89.6 bc
SPAD + basal (N_7)	31.5 ac	23.6 ac	56.8 a	43.6 ce	87.7 ab	73.6 bc	88.9 bd
SPAD – basal (N_8)	28.1 d	21.5 de	51.6 b	42.4 de	83.3 c	71.8 cd	84.9 ef
USG 80 kg N ha^{-1} (N_9)	32.0 a	23.4 ad	57.8 a	48.0 a	89.7 a	76.0 ab	92.3 a
CV (%)	5.35	8.03	4.65	6.67	3.64	5.83	2.65

In a column, means followed by same letter (s) are not significantly different at 5 % level of probability as per DMRT.

Table 1b. Interaction effect of variety and N management on plant height at harvest in Boro season, 2003

N management	Sonarbangla-1	BRRI hybrid dhan1	BRRI dhan29
Control (N_0)	78.7 dB	83.0 fA	82.0 eA
40 kg N ha^{-1} (N_1)	79.3 dB	86.7 eA	85.3 dA
80 kg N ha^{-1} (N_2)	82.3 cdB	90.3 deA	88.3 cA
120 kg N ha^{-1} + basal (N_3)	85.0 bcB	93.0 cdA	90.0 cA
120 kg N ha^{-1}- basal (N_4)	88.0 aB	96.0 bcA	90.0 cA
160 kg N ha^{-1} + basal (N_5)	88.0 aB	101.0 aA	97.7 aA
160 kg N ha^{-1} – basal (N_6)	87.0 abB	100 abA	98.7 aA
SPAD + basal (N_7)	83.0 bcC	98. 7 abA	92.0 bcB
SPAD – basal (N_8)	80.0 cdB	92.0 cdA	89.3 cA
USG 80 kg N ha^{-1} (N_9)	89.0 aC	102.0 aA	93.0 bB

In a column and row, means followed by same small and capital letter (s) are not significantly different at 5 % level of probability as per DMRT.

3.2. Number of tillers hill^{-1}

Variety × nitrogen interaction effect on tiller number hill^{-1} was not significant. Tiller number hill^{-1} of Sonarbangla-1, BRRI hybrid dhan1 and BRRI dhan29 significantly differed at 30, 60 DAT and at maturity in both the years (Table 2). In 2002, larger number of tillers was observed in BRRI hybrid dhan1 at all growth stages, followed by BRRI dhan29. In 2003, up to 30 DAT, no tiller was produced in any variety which was due to low temperature (10-12º C). Virmani (1999) also reported that low temperature (10-15ºC) for 30 days during seedling and early vegetative phase, delayed tiller production. BRRI hybrid dhan1 produced significantly more tillers at 60 and 90 DAT but at maturity stage, it gave the least number of tillers (10.3), which might be due to difference in tiller production pattern of the varieties.

Tiller number hill^{-1} was significantly influenced by N management at all growth stages in both the years. Significantly large number of tillers was recorded in N_3 (120 kg N ha^{-1} with basal) at 30 DAT and in N_9 (USG) plots at other stages of growth followed by N_5 (160 kg N ha^{-1} with basal), N_6 (160 kg N ha^{-1} without basal) and N_7 (SPAD based N management with basal) in 2002 (Table 2). In 2003, tiller number $hill^{-1}$ was significantly influenced by N management at all growth stages except at 30 DAT. Large number of tillers was observed in N_9 (USG), N_5 and N_6, which were followed by N_7, N_4 and N_3 (Table 2). Large number of tillers $hill^{-1}$ in N_9 (USG) might be due to adequate and uniform N-supply to the crops and in N_5 and N_6, it might be due to higher N doses (160 kg N ha^{-1}), which enhanced tiller production.

3.3. Leaf area index (LAI)

Leaf area index did not vary at 30 DAT among the treatments. However, BRRI hybrid dhan1 and BRRI dhan29 had higher (2.2) LAI than Sonarbangla-1, which had LAI of only 1.8 in 2002 (Fig. 1a). After that, BRRI hybrid dhan1 and BRRI dhan29 showed increasing trend up to 90 DAT but Sonarbangla-1 showed plateau trend (Fig. 1a). It was due to early leaf senescence of Sonarbangla-1 at 90 DAT that resulted from shorter growth duration. In 2003, at 30 DAT, LAI of all varieties were very low and after that the 3 varieties showed increasing trend (Fig. 1b). At 60 DAT, the 3 varieties showed sharply increasing LAI up to 90 DAT (Fig. 2a). Very low LAI at early stage of all varieties was perhaps due to the prevailing cold at early growth stages during January 2003. All varieties showed lower LAI of 1.5-2.5 at 60-90 DAT (booting –flower initiation stage) in 2002, whereas the modern varieties generally showed LAI of about 3.0-4.0 at maximum tillering to flower initiation stage (Mamin, 2002). In 2003, all varieties showed lower LAI than 2002 in all growth stages due to cold weather.

Table 2. Varietal influence and N management on tiller production at different DAT grown in boro seasons of 2002 and 2003

Variety	30 DAT		60 DAT		90 DAT		Harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Sonarbangla-1	2.7 b	1.0	10.4 b	8.4 b	10.9	13.0 c	11.4 b	11.0 a
BRRI hybrid dhan1	3.2 a	1.0	13.6 a	9.1 a	11.5	16.8 a	12.0 a	10.3 b
BRRI dhan29	3.0 ab	1.0	12.9 a	8.1 b	11.5	15.0 b	11.7 ab	11.2 a
N management								
Control (N_0)	2.3 c	1.0	7.4 f	6.0 e	7.1 f	8.3 e	8.0 g	7.7 f
40 kg N ha^{-1} (N_1)	2.6 bc	1.0	9.2 e	6.3 de	8.7 e	10.8 d	9.7 f	8.7 e
80 kg N ha^{-1} (N_2)	2.8 a-c	1.0	11.0 d	7.3 d	10.6 d	13.3 c	10.7 e	10.3 cd
120 kg N ha^{-1} + basal (N_3)	3.4 a	1.0	12.8 c	8.0 cd	11.9 c	15.0 bc	12.7 cd	11.3 c
120 kg N ha^{-1}- basal (N_4)	3.2 ab	1.0	13.0 c	8.9 bc	11.8 c	16.7 b	11.9 d	11.1 c
160 kg N ha^{-1} + basal (N_5)	3.1 a-c	1.0	14.8 b	10.9 a	13.3 ab	19.6 a	13.6 b	12.7 a
160 kg N ha^{-1} – basal (N_6)	3.1 a-c	1.0	13.8 bc	10.2 a	12.4 bc	18.4 a	12.4 cd	12.3 ab
SPAD + basal (N_7)	2.9 a-c	1.0	13.7 bc	9.1 b	12.4 bc	15.2 b	13 bc	11.3 bc
SPAD – basal (N_8)	2.9 a-c	1.0	10.7 d	7.9 cd	10.4 d	13.4 c	10.3 ef	9.7 d
USG 80 kg N ha^{-1} (N_9)	3.2 ab	1.0	16.4 a	10.7 a	14.3 a	18.6 a	14.8 a	13.1 a
CV (%)	14.7	-	12.4	12.4	10.0	11.4	7.2	9.6

In a column, means followed by same letter (s) are not significantly different at 5 % level of probability as per DMRT.

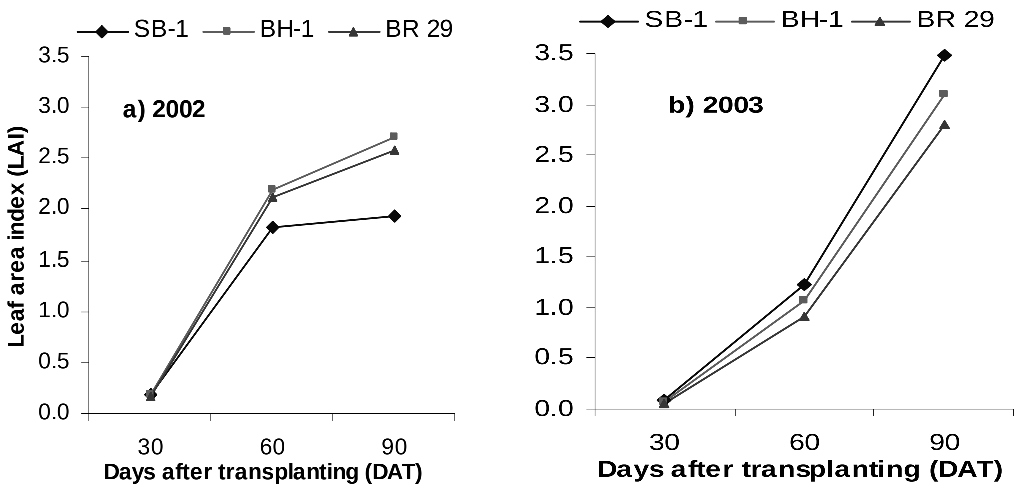


Fig. 1. Leaf area index of different rice varieties in Boro season during 2002 and 2003 (SB-1= Sonarbangla-1, BH-1= BRRI hybrid dhan1 and BR29= BRRI dhan29)

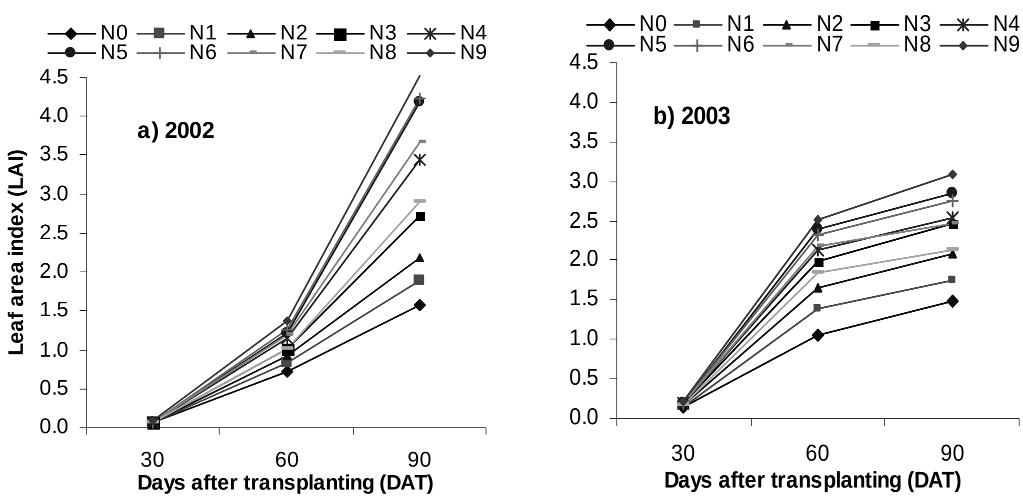


Fig. 2. Leaf area index under different N managements in Boro season during 2002 and 2003

[Ligend: N0 = Control, N1 = 40 kg N ha^{-1} at ET & PI, N2 = 80 kg N ha^{-1} at ET & PI, N3 = 120 kg N ha^{-1} at basal, MT & PI, N4 = 120 kg N ha^{-1} at ET, MT & PI, N5 = 160 kg N ha^{-1} at basal, MT, PI & FI, N6 = 160 kg N ha^{-1} at ET, MT, PI & FI, N7 = 30 kg N ha^{-1} at $\leq$ 35 SPAD with basal N8 = 30 kg N ha^{-1} at $\leq$ 35 SPAD without basal and N9 = USG @ 80 kg N ha^{-1}]

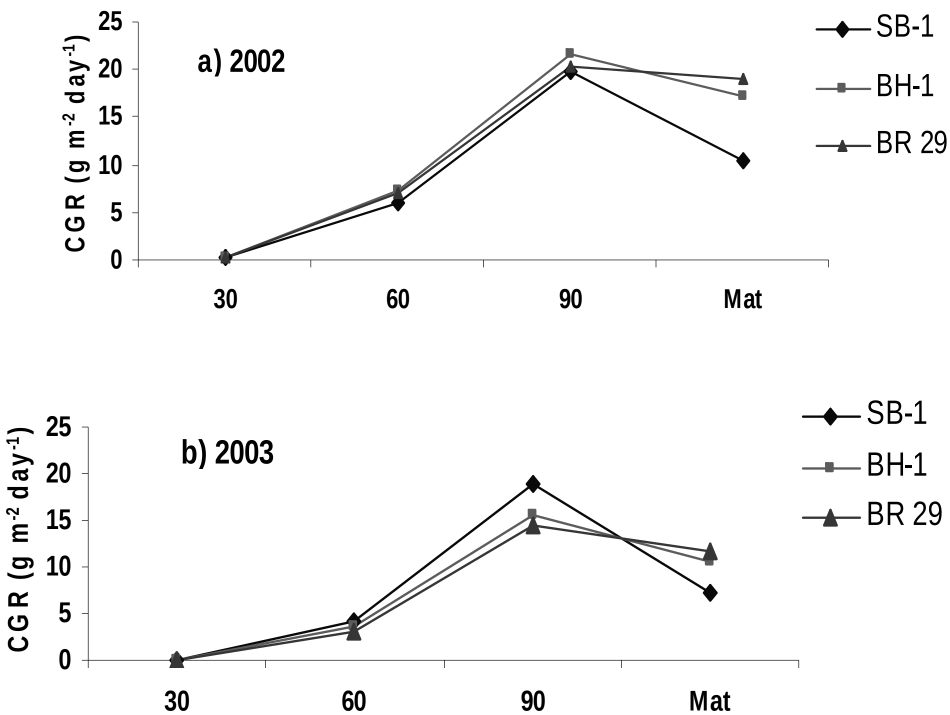
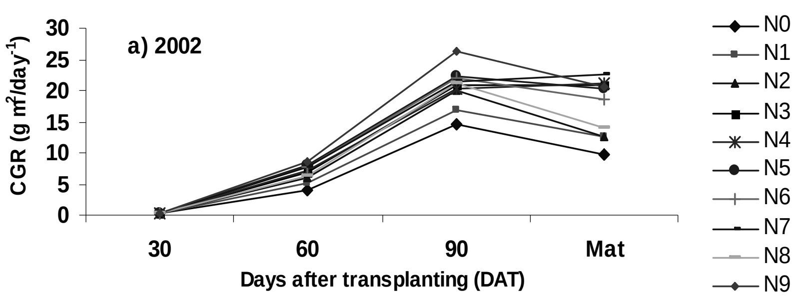


Fig. 3. CGR of different rice varieties in Boro season during 2002 and 2003
(SB-1= Sonarbangla-1, BH-1= BRRI hybrid dhan1 and BR29= BRRI dhan29)



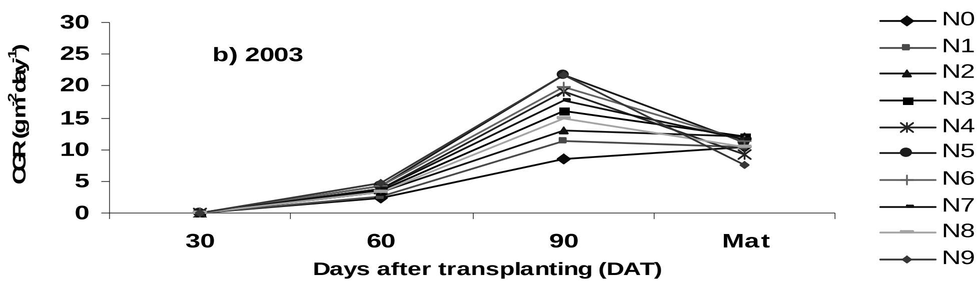


Fig. 4. CGR under different N management in Boro season during 2002 and 2003

[Ligend: N0 = Control, N1 = 40 kg N ha^{-1} at ET & PI, N2 = 80 kg N ha^{-1} at ET & PI, N3 = 120 kg N ha^{-1} at basal, MT & PI, N4 = 120 kg N ha^{-1} at ET, MT & PI, N5 = 160 kg N ha^{-1} at basal, MT, PI & FI, N6 = 160 kg N ha^{-1} at ET, MT, PI & FI, N7 = 30 kg N ha^{-1} at ≤ 35 SPAD with basal N8 = 30 kg N ha^{-1} at ≤ 35 SPAD without basal and N9 = USG @ 80 kg N ha^{-1}]

Sonarbangla-1 had the highest LAI at all the stages of growth, followed by BRRI hybrid dhan1, whereas BRRI dhan29 had the lowest leaf area index; which was due to low temperature in 2003. But Sonarbangla-1 and BRRI hybrid dhan1 performed better under low temperature condition. These results are also supported by Kaw and Khush (1985) who reported that rice hybrids have tolerance to low temperature and can continue normal growth. Irrespective of variety, highest LAI was observed in N_9 (USG), followed by N_5 and N_6 at all growth stages, whereas N_0 showed the lowest LAI in 2002 (Fig. 2a). In 2003, higher LAI was observed in N_9 (USG) followed by N_5, N_6 and N_7 at all growth stages, whereas N_0 showed the lowest LAI (Fig. 2b). The highest LAI obtained in N_9 (USG) was obviously due to uniform and adequate N-supply to the plants up to flowering stage.

3.4. Crop growth rate (CGR)

Figure 3a shows that CGR of all varieties were similar up to 90 DAT and their increasing trend was also similar in 2002. Crop growth up to 60 DAT was slow, perhaps because of cold weather. At 90 DAT, the trend reached the peak (22 g m^{-2} day^{-1}). For BRRI dhan29, CGR was stable at 22 g m^{-2} day^{-1} up to maturity, while for Sonarbangla-1 and BRRI hybrid dhan1, CGR was much lower (Fig. 3a). It indicated that maximum dry matter accumulation was obtained during 60-90 DAT for all varieties. CGR of Sonarbangla-1 sharply declined during 90 DAT to maturity, which was due to early leaf senescence as it is a short duration variety (Fig. 3a).

In 2003, CGR of all varieties was low and similar up to 60 DAT. Then CGR of all varieties sharply increased by 15-20 g m^{-2} day^{-1} during 60-90 DAT, when Sonarbangla-1 showed the highest CGR of 20 g m^{-2} day^{-1} (Fig. 3b). Then all varieties showed declining trend in CGR up to maturity, where Sonarbangla-1 had very sharp declining trend, which was due to leaf senescence, associated with early maturity as observed in the previous year (Fig. 3a). The CGR of the other 2 varieties decreased slowly during this period.

The CGR was higher and reached the peak (15-25 g m^{-2} day^{-1}) at 90 DAT in all N-treatments in 2002. Initially CGR was very similar during 0-30 DAT in all N- treatments. The highest CGR (25 g m^{-2} day^{-1}) was observed in N_9 during 60-90 DAT (Fig. 4a). It might be due to higher amount of dry matter accumulation resulted from uniform and adequate N-supply to the crop at this stage. After 90 DAT, CGR declined to 11-22 g m^{-2} day^{-1} in all N-treatments in 2002 (Fig. 4a). Reduction in CGR was due to leaf and tiller senescence at grain filling stage. In 2003, initially the CGR was similar during 0-30 DAT in all N-treatments then it reached the peak at 90

DAT, when the varieties were at heading to milk stage. The highest CGR was observed in N_9 during 30-60 DAT (5 g m^{-2} day^{-1}) and 60-90 DAT (21 g m^{-2} day^{-1}) (Fig. 4b). These faster CGR in N_9 and N_5 were attributed to higher plant height and leaf area resulted from adequate and uniform N supply to the plants. After 90 DAT, CGR declined in all N managements (Fig. 4b).

None of the varieties or N management showed negative CGR which was observed in T. Aman season as reported by Islam (2006), but all varieties showed declining trend after 90 DAT (heading stage). Roy (1999) also observed declining CGR during flowering to maturity in Boro season with BRRI dhan29.

4. Conclusions

Among the varieties, hybrids Sonarbangla-1 and BBRI hybrid dhan1 had better growth compared to the inbred BRRI dhan29. Among the N management practices, USG @ 80 kg ha^{-1} and 160 kg N ha^{-1} in 4 equal splits showed better growth performance. The USG and SPAD based N management with basal could save 80 and 40 kg N ha^{-1}, respectively, by showing similar growth performance with 160 kg N ha^{-1}.

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