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Genotypic Differences in Nitrogen Uptake and Utilization of Wet and Dry Season Rice as Influenced by Nitrogen Rate and Application Schedule

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Abstract: Nitrogen accumulation, uptake and use efficiency of wet and dry season varieties were determined from field experiments conducted in 1996 to 1998 at the Bangladesh Rice Research Institute (BRRI) in Gazipur, Bangladesh. Four rice varieties were tested, Nsail and BR31 were planted in the wet season (WS) and HB6 and BR29 were planted in the dry season (DS). Nsail and HB6 are local, whereas BR31 and BR29 are modern varieties. The experiments were laid out in a two-factorial randomized complete block design with four replications. The two factors were nitrogen rate and its application schedule. Four N rates-0, 50, 100 and 150 kg N ha^{-1} were given. The rates of 50, 100 and 150 kg N ha^{-1} were given in three application schedules-two, three and four splits. Transplanting was done on the first week of August and first week of January for the WS and DS, respectively. Nitrogen uptake differed greatly among the varieties and nitrogen rates. The increase of total N uptake with N rate was almost linear for the modern varieties, whereas the traditional varieties showed a quadratic relationship between total N uptake and N level. Effect of N split application on N uptake was small, but the difference among the split applications were more pronounced when higher amont of N was applied. Genotypic difference in grain and straw N concentration of all the varieties was observed and increased with each increment of N fertilizer. Averaged across treatments and years, the highest grain N concentration was observed in BR31 and the lowest in BR29. The straw N concentration at different N rates were more pronounced in the wet season varieties, especially Nsail, which had the lowest straw N concentration when no N was applied but showed highest straw N concentration when 150 kg N ha^{-1} was applied. The agronomic fertilizer efficiency and the apparent N recovery percentage varied greatly among the varieties and decreased with higher N rates. The agronomic efficiency of the DS varieties was higher compared to the WS varieties. Across the years, the N recovery percentage of the tested varieties at different N rates and application schedules ranged from 20 to 40% for Nsail, 24 to 43% for BR31, 29 to 40% for HB6 and 35 to 51% for BR29.

Key words: Rice varieties, season, nitrogen concentration, nitrogen uptake

INTRODUCTION

Nitrogen fertility is an important component of rice cultivation system. There is a close correlation between nitrogen uptake and grain yield[1,2]. A significant variation in N uptake and N use efficiency among the varieties was reported by Borah and Deka[3]. Nitrogen uptake and N use efficiency, however, differed among the location, growing season, amount and timing of N application[4,5]. The nutrient uptake also affected by the dry matter production of the plant and its nutrient concentration[6]. In the present study, rice genotypes have been examined to N utilization efficiency in terms of N accumulation in grain and straw and N harvest at different N regimes and its application schedule in the dry and wet seasons.

MATERIALS AND METHODS

Field experiments were carried out from 1996 to 1998 at the Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. The soil was slightly acidic to neutral. The total N and organic carbon contents were very low. The available P and exchangeable K contents were medium (Table 1).

Four rice varieties were tested: Nizersail (Nsail) and BRRI dhan31 (BR31) were planted in the wet season (WS) and Habiganj boro6 (HB6) and BRRI dhan29 (BR29) in the dry season (DS). Among them, Nsail and HB6 are local varieties, whereas BR31 and BR29 are modern varieties. In each season, two separate experiments were laid out on adjacent fields for a traditional and a modern rice variety.

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Table 1: Physical and chemical properties of the topsoil in the experimental field at BRRI, Gazipur, Bangladesh

Soil parameters	Wet-season field	Dry-season field
pH (H_2O, 1:1)	6.60	6.90
Organic carbon (%)	0.73	1.03
Total N (%)	0.07	0.09
P available (mg kg^{-1})	9.80	10.50
K exchangeable (cmol(+) kg^{-1})	0.24	0.26
Textural class	Silty clay	Silty clay

Table 2: Total amount and timing of application for N-fertilisation treatments

Treatment	N amount kg ha^{-1}	Basal kg ha^{-1}	ET kg ha^{-1}	MT kg ha^{-1}	PI kg ha^{-1}	H kg ha^{-1}
1 (control)	0	-	-	-	-	-
2	50	-	25.0	-	25.0	-
3	100	-	50.0	-	50.0	-
4	150	-	75.0	-	75.0	-
5	50	10.0	-	20.0	20.0	-
6	100	20.0	-	40.0	40.0	-
7	150	30.0	-	60.0	60.0	-
8	50	12.5	-	12.5	12.5	12.5
9	100	25.0	-	25.0	25.0	25.0
10	150	37.5	-	37.5	37.5	37.5

Timing: Basal = before transplanting, ET = early-tillering stage, MT = mid-tillering stage, PI = panicle initiation stage, H = heading stage

The experiments were laid out in a two-factorial randomized complete block design. Each treatments were replicated four times. The two factors were-Nitrogen rates and its application schedules. Four N rates-0, 50, 100 and 150 kg N ha^{-1} were given. Nitrogen was supplied from prilled urea. The rates of 50, 100 and 150 kg N ha^{-1} were applied in three application schedules-two splits, three splits and four splits. The single treatments are presented in Table 2.

Transplanting was done on the first week of August and first week of January for the WS and DS, respectively. Three to four seedlings were transplanted per hill at a spacing of 20 x 20 cm. Fertilizers other than urea were applied one day before transplanting during the final land preparation. All plots received a blanket dose of 26, 33, 30 and 4 kg ha^{-1} $year^{-1}$ of P, K, S and Zn, respectively. Urea fertilizer was broadcasted according to the treatments. To keep the experimental fields weed and insect free, weeding and insecticide sprayings were done when necessary.

The grain and straw N concentrations were analysed with the Micro-Kjeldal distillation method[7]. The total nitrogen uptake at harvest was determined by adding N uptake by grain and straw. The N uptake by grain and straw was calculated by multiplying the grain and straw dry weight with their respective N concentrations using the following formula:

N uptake (kg ha^{-1}) = [Grain dry weight (kg ha^{-1}) x Grain N concentration/ 100] + [Straw dry weight (kg ha^{-1}) x Straw N concentration/ 100]

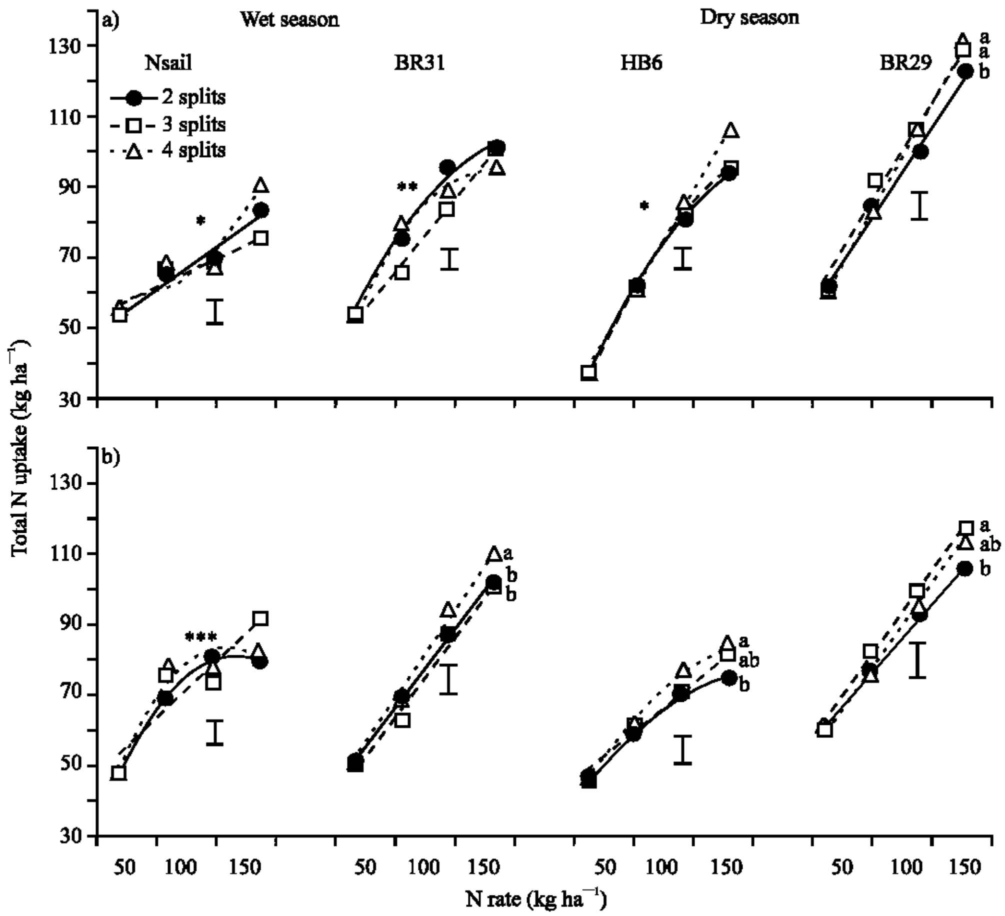
Nitrogen utilization by the crop was calculated through agronomic efficiency (kg rough rice per kg N applied) and apparent N recovery (quantity of nitrogen absorbed per unit of nitrogen applied). Data were statistically analysed with SAS, version 6.12.

RESULTS AND DISCUSSION

The total nitrogen uptake of the tested varieties as affected by N rate and number of splitting is shown in Fig. 1. In both years, differences in total N uptake were small between the control treatments. For the WS varieties, Nsail and BR31, the total N uptake amounted to approximately 50 kg ha^{-1}, whereas the uptake of the traditional DS variety HB6 was only about 40 kg ha^{-1} and that of the modern DS variety BR29 reached 60 kg ha^{-1}. Total N uptake of all varieties increased with each increment of N and reached up to 91 kg for Nsail, 110 kg for BR31, 106 kg for HB6 and 132 kg for BR29 in the 150 kg N treatment. In the second observation period, total N uptake by the DS varieties was less pronounced, whereas the WS varieties showed only small differences between the years.

Borrell *et al.*[1] and Inthapanya *et al.*[8] noted that nitrogen uptake at harvest affected by plant type, season, N rate and time of application. According to Yoshida[6], N uptake at harvest depends upon the total biomass production, its partitioning to grain and straw and their respective nitrogen concentration. Bacon and Heenan[9] reported that increasing N application increased both the dry matter production of grain and straw and their N concentration. These parameters jointly increased the N uptake at harvest. With a few exception, N uptake increased linearly with the increase of N rate in this study. This was in agreement with Bacon and Heenan[9]. They further reported that variation in timing of the fertilizer application had a minor effect on grain yield but a major effect on N uptake by the rice plant. Despite the grain yield reduction with the highest N rates in BR31 and HB6, N uptake increased at this N level in the present study. This was due to higher N concentrations of grain and higher straw yield. Similar findings were observed by Imaizumi and Kitamura[10]. They reported that high nitrogen rates did not always increase grain yield but increased N uptake and straw yield.

The increase of total N uptake was almost linear for the two modern varieties, whereas the traditional varieties showed a quadratic relationship between total N uptake and N level. The effect was stronger in the second year of observation, particularly for Nsail, which showed a strong tendency to lodge at N rate above 50 kg N ha^{-1}.

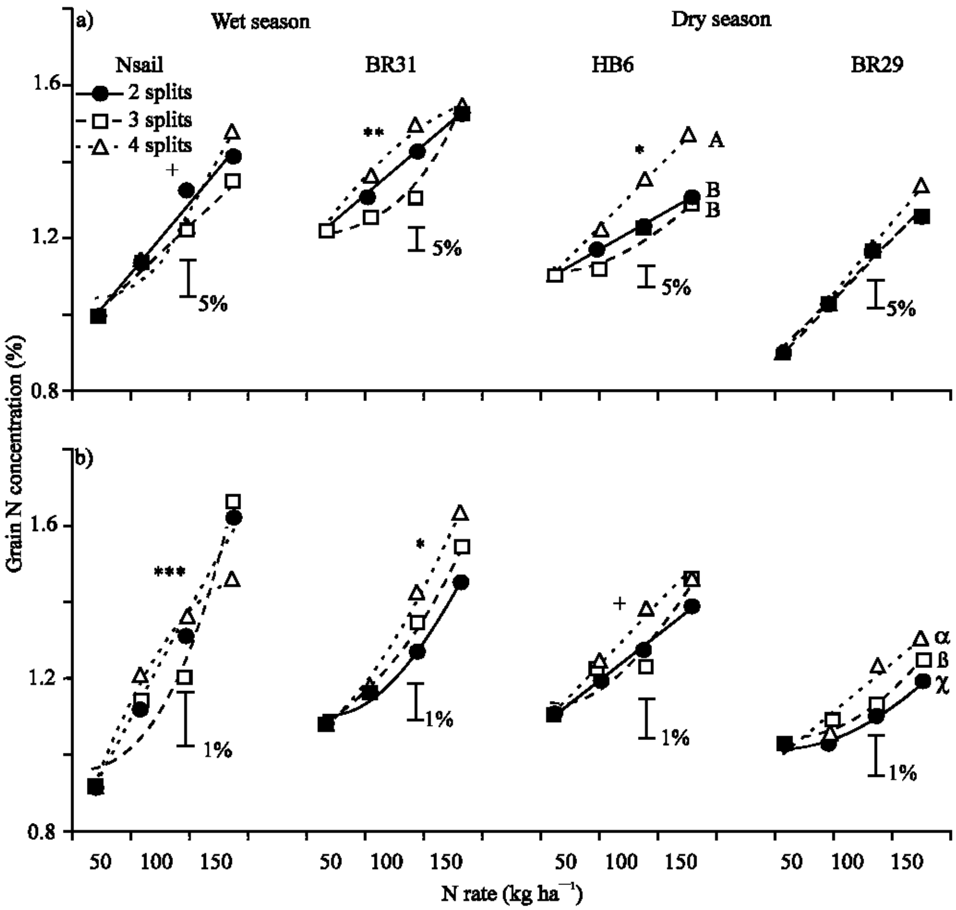


Error bars represent LSD values for N splitting within N rate at $p \leq 0.05$
*, **, *** indicate significant interaction between N rate and N splitting at $p \leq 0.05$, 0.01 and 0.001, respectively, other interactions were non significant at $p \leq 0.1$
a, b: splitting means across 50, 100 and 150 kg N with same letters do not differ significantly at $p \leq 0.05$; other splitting effects are either non significant or significant at a lower level than the N x splitting interaction

Fig. 1: Nitrogen uptake at harvest of four rice varieties as affected by N rate and splitting number at BRRI, Gazipur, a) 1996-97 cropping seasons b) 1997-98 cropping seasons

Effect of split application on N uptake at harvest was small. Differences between the various splitting treatments were more pronounced when higher amounts of N were applied. The trends, however, were inconsistent. Nevertheless, there was some evidence that the total N uptake of the modern DS variety BR29 increased when the nitrogen dressing was given in three doses. In the case of HB6, the 4-split treatment, however, produced a significantly higher total N uptake than the 2-split treatment at 150 N level. With regard to both WS varieties, no consistent trend was observed during two succeeding cropping seasons.

Grain N concentration as affected by N rate and split application differed among the varieties (Fig. 2). In the control plots, grain N concentration of the modern WS variety was higher than that of the traditional variety, whereas it was reserve between the DS varieties. Nitrogen concentration in the control ranged from 0.92 to 1.00% for Nsail, from 1.09 to 1.22% for BR31, from 1.10 to 1.11% for HB6 and from 0.9 to 1.03% for BR29. The grain N concentration of all varieties increased with each increment of fertilizer N, irrespective of the application schedule. Averaged across treatments and years, grain N concentration was the highest in BR31 and lowest in BR29. The concentrations were 1.37 and 1.13, respectively. The grain N concentration of both the traditional varieties was 1.28%. A significant difference of grain N concentration between the split applications was



Error bars represent LSD values and error levels for N splitting within N rate

+, *, **, *** indicate significant interaction between N rate and N splitting at $p \leq 0.1$, 0.05, 0.01 and 0.001, respectively, other interactions were not significant at $p \leq 0.1$

α,β; A,B: splitting means across 50, 100 and 150 kg N with same letters do not differ significantly at $p \leq 0.1$ and 0.01, respectively; other splitting effects are either non significant or significant at a lower level than the N x splitting interaction.

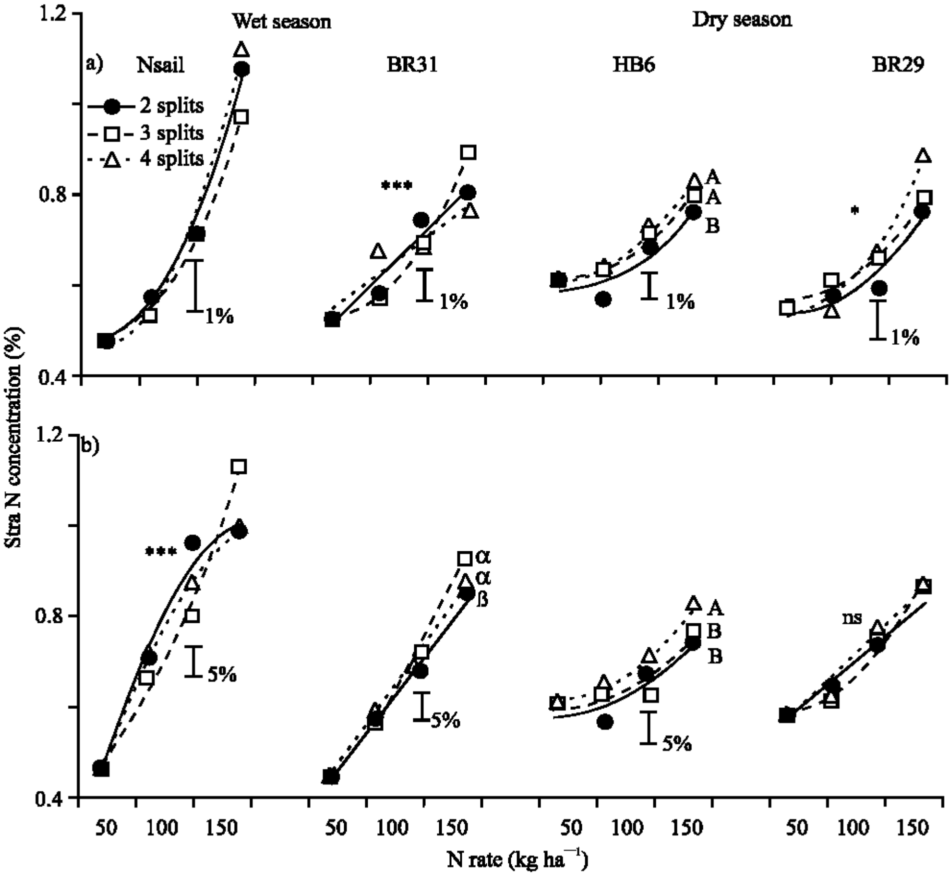
Fig. 2: Grain N concentration of four rice varieties as affected by N rate and splitting number BRRI, Gazipur, a) 1996-97 cropping seasons b) 1997-98 cropping seasons

observed. In most cases, the 4-split treatment showed a tendency towards a higher N concentration, regardless of the amount of applied nitrogen and the variety tested.

The straw N concentration of four rice varieties as affected by N rate and application schedule are presented in Fig. 3. In both years, the WS varieties showed lower N concentrations in the control than the DS varieties. The differences between the varieties, however, were more pronounced in the second year. In the control treatments, the straw N concentration varied between 0.46 and 0.48% for Nsail, between 0.45 and 0.52% for BR31, between 0.6 and 0.61 for HB6 and between 0.55 and 0.58% for BR29. The straw N concentration of all varieties increased with N levels, irrespective of N application schedule. The effect was more pronounced in the WS varieties, especially for the traditional variety, Nsail. In consequences, Nsail had the highest straw N concentration compared to other varieties in the 150 N treatment, although this variety had the lowest straw N concentration when no N was applied.

Effect of different splitting schedules on straw N concentration was small. No consistent trend was observed in Nsail. But for the other varieties, the 4-split application tended to increase N concentration of straw in most of the cases.

Genotypic variation in grain and straw N concentrations were observed among the different

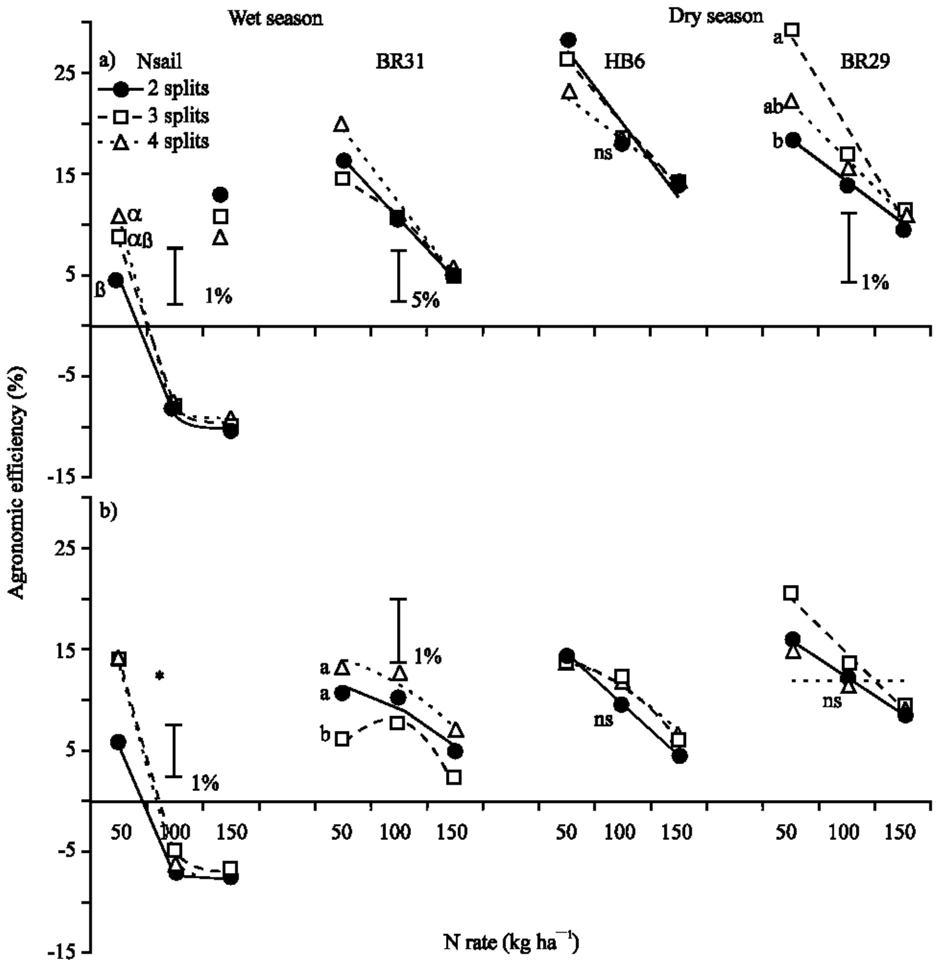


Error bars represent LSD values and error levels for N splitting within N rate, ns = non significant
*** indicates significant interaction between N rate and N splitting at $p \leq 0.001$, other interactions are non significant at $p \leq 0.1$
α, β; A,B: splitting means across 50, 100 and 150 kg N with same letters do not differ significantly at $p \leq 0.1$ and 0.01, respectively; other splitting effects are either non significant or significant at a lower level than the N x splitting interaction

Fig. 3: Straw N concentration of four rice varieties as affected by N rate and splitting at BRRI, Gazipur, a) 1996-97 cropping seasons b) 1997-98 cropping seasons

fertilizer management practices. Ladha *et al.*[11] observed a near-doubling in grain N concentration (0.78 to 1.48 N%) in IR72 grown under different fertilizer-N regime and plant population densities. According to Woperies *et al.*[12], grain N concentration varies between 0.8 and 1.8% depending on the nitrogen treatment. Grain and straw N concentration was also influenced by application schedule. In this study, nitrogen concentration in grain and straw at harvest increased when N was applied at heading stage. This was an agreement with Akita and Tanaka[13] and Ladha *et al.*[11]. They found that grain N concentration increased when N was applied at flowering stage. The percent of nitrogen in the grain is an indicator of the protein content. From a nutritional point of view, late top dressing has positive effects on the protein content of rice grains. According to van Keulen and van Heemst[14], the grain yield curve reaches a plateau at a higher N level, where increased uptake of nitrogen does not lead to higher grain yield. The additional nitrogen partly increases the protein content of the grain and partly remains in the straw. The greater straw N concentration at higher N level in Nsail compared to other varieties may be due to translocation hindrance of reserved and absorbed nutrients from stem to grain during the ripening phase resulting from lodging.

Grain yield, amount of N used and total N uptake at harvest were used to calculate the agronomic fertilizer efficiency and the apparent N recovery rate. Data are presented in Fig. 3 and 4. The agronomic efficiency of nitrogen applied to the traditional WS variety Nsail was



Error bars represent LSD values and error levels for N splitting within N rate, ns = non significant
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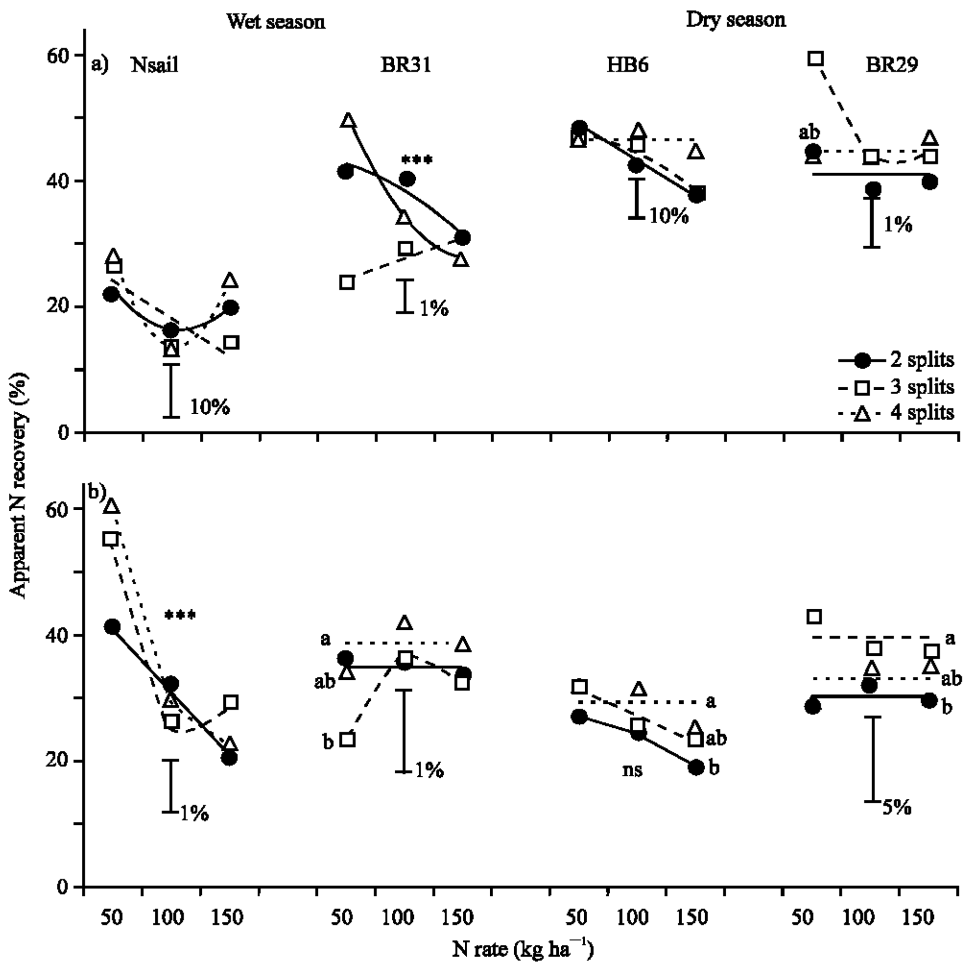
Fig. 4: Agronomic efficiency of four rice varieties as affected by N rate and splitting at BRRI in Gazipur, a) 1996-97 cropping seasons b) 1997-98 cropping seasons

very low in both years, even when a relatively low N amount of 50 kg ha^{-1} was applied. At higher N rates, the agronomic efficiency turned negative as the crop stands strongly suffered from lodging. In the first year of observation, the agronomic N efficiency of the modern DS variety BR31 was twice as high as of Nsail at a N level of 50 kg ha^{-1}. Applying higher amount of N reduced the agronomic efficiency strongly but without reaching negative values. Both DS varieties showed a similar tendency as the modern WS variety, but their agronomic N efficiency was about 40% higher at the 50 kg ha^{-1} N level in the first year. In the second year, the agronomic efficiencies of BR31, HB6 and BR29 were much lower than in the first year, particularly in 50 N treatment. In the dry season varieties, at a low N application level of 50 kg ha^{-1}, most of the treatments produced 20-30 kg rice grains with one kg of N in the first year and 15-20 kg in the following year. At the high N fertilization level of 150 kg ha^{-1}, the agronomic efficiency dropped to 10-15 kg in the first year and to 5-10 kg in the second year.



Error bars represent LSD values and error levels for N splitting within N rate, ns = non significant

*, **, *** indicate significant interaction between N rate and N splitting at $p \leq 0.05$, 0.01 and 0.001, respectively, other interactions were non significant at $p \leq 0.1$

α, β; a, b: splitting means across 50, 100 and 150 kg N with same letters do not differ significantly at $p \leq 0.1$ and 0.05, respectively; other splitting effects are either not significant or significant at a lower level than the N x splitting interaction

Fig. 5: Apparent N recovery of four rice varieties as affected by N rate and splitting at BRRI, Gazipur, a) 1996-97 cropping seasons b) 1997-98 cropping seasons

Significant splitting effects were restricted to the lowest input level and were highest for the modern DS variety where applying N in 3 doses instead of 2 doses improved the N efficiency from 18 to 29 kg rice per kg of applied N. In the case of two WS varieties, 4-split treatment showed a slight trend to improve the agronomic efficiency.

Averaged across the two years, the nitrogen recovery percentages at different N rates and splitting ranged from 20 to 45% for N sail, from 24 to 43% for BR31, from 29 to 40% for HB6 and 35 to 51% for BR29. There was a decreasing tendency of nitrogen recovery with higher N levels (Fig. 5). The effect, however, was more in case of lodging-prone variety Nsail compared to other non-lodging varieties BR31, HB6 and BR29. In the mean of N levels, 3-split was significantly superior to 2-split for the modern DS variety but inferior for the modern WS variety, whereas 4-split was superior to 2-split for the traditional DS variety. Borrell *et al.*[1] noted that N use efficiency was affected by variety, season and N application rate.

Farmers are more concerned with maximizing rice output per unit of applied N or in other words to increase agronomic efficiency. In this study, the efficiency of fertilizer N varied with variety, season, rate and application schedule which was also reported by Mikkelsen *et al.*[4]. The application of nitrogen fertilizer increased the grain yield of rice, but decreased the productive efficiency. The same result was reported by Carreres *et al.*[15]. The highest efficiency is usually obtained with the first increment of a nutrient, additional increments providing smaller increases[16,17].

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