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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 6 (22): 1864-1871, 2003
ISSN 1028-8880

Effect of Nitrogen Rate and its Application Schedule on Leaf Area Development and Crop Growth of Local and Modern Rice Varieties

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Abstract: The experiments were carried out from 1996 to 1998 at the Bangladesh Rice Research Institute in Gazipur. Four rice varieties-Nsail and BRRI dhan31 (BR31) in the wet season (WS) and HB6 and BRRI dhan29 (BR29) in the dry season (DS) were tested. Nsail and HB6 were local, whereas BR31 and BR29 were modern varieties. 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. The pattern of leaf area index (LAI) and crop growth rate (CGR) differed among the varieties. LAI and CGR of DS varieties were very low during early growth stages compared to WS varieties. LAI increased gradually and reached its peak around PI stage in Nsail, whereas for the other varieties, peaks were around heading stage. HB6 always showed a lower LAI than the other varieties. The yield-LAI relationship showed that the optimum LAI of the modern variety for achieving the highest yield ranged from 4 to 5, whereas the optimum range of the traditional DS variety was between 3 and 3.5. The LAI of the lodging-prone variety Nsail was above optimum throughout the growing season and the relationship between LAI and yield was negative. Nitrogen rate had a profound effect on leaf area development. Two-split treated plots of BR31 and 3-split treated plots of HB6 and BR29 showed the highest LAI around PI and heading stages in most of the cases. In Nsail, the CGR peaked before PI stage, whereas for BR31 and HB6 the peaks were reached around heading stage and declined thereafter. For the modern DS variety, an almost steady growth rate was observed. In most cases, the 3-split treated plots of BR29 showed higher CGR at PI and heading stages compared to the other split arrangements. Higher CGR after heading for the modern DS variety BR29 compared to other varieties may have led to a higher grain yield in BR29.

Key words: Rice varieties, nitrogen rate, leaf area index, crop growth rate

INTRODUCTION

Crop yield is the integrated result of events occurring throughout its entire life cycle. Mae (1997) indicated that leaf area index (LAI) is an important yield determining factor for rice cultivation which is promoted by nitrogen fertilization affecting average leaf size, number of leaves per shoot and number of shoots per hill. Horie (2001) reported that crop growth rate (CGR) also have a dececive effects on yield of rice. He also observed that the influence of CGR at different growth stages to yield varied considerably. Leaf area index and CGR are the growth attributes most closely related to the genotypic yield variation (Horie, 2001) and were affected by fertilizers especially nitrogenous fertilizers (Fageria *et al*., 1997). Hence to explore the full potentiality of a variety it is essential to understand fully the pattern of LAI and CGR of that specific variety. These growth parameters were also influenced by fertilizers, especially nitrogenous fertilizer. The present study was undertaken to have a clear understanding of the leaf area development and crop growth of local and modern varieties cultivated in the wet and dry season as influenced by nitrogen rate and its management practices.

MATERIALS AND METHODS

Field experiments were carried out from 1996 to 1998 at the Bangladesh Rice Research Institute (BRRI), Gazipur. The experimental site was located at 24°0' N and 90°30' E and 8.4 m above mean sea level, where the mean annual precipitation was 2,039 mm and the mean annual temperature was 25.7°C with a mean maximum and minimum temperature of 30.4 and of 21.1°C, respectively. The soil is slightly acid to neutral. The total N and organic carbon contents were very low. The available P and exchangeable K contents are 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) were planted in the dry season (DS). Out of these 4 varieties, Nsail and HB6 were local cultivars, whereas BR31 and BR29 were modern varieties. In each season, two separate experiments were laid out on adjacent fields for

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

Soil parameters	Wet-season field	Dry-season field
pH (H_2O, 1:1)	6.6	6.9
Organic carbon (%)	0.73	1.03
Total N (%)	0.071	0.097
P available (mg kg^{-1})	9.8	10.5
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 kgha^{-1}
1 (control)	0	-	-	-	-	-
2	50	-	25	-	25	-
3	100	-	50	-	50	-
4	150	-	75	-	75	-
5	50	10	-	20	20	-
6	100	20	-	40	40	-
7	150	30	-	60	60	-
8	50	12.5	-	12.5	12.5	12.5
9	100	25	-	25	25	25
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

a traditional and a modern rice variety. The experiments were laid out in a two-factorial randomized complete block design. The treatments were replicated four times. The two factors were: (I) Nitrogen rates and (ii) Nitrogen application schedules. 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 applied in three application schedules: (I) two splits (ii) three splits and (iii) four splits. The single treatments were presented in Table 2.

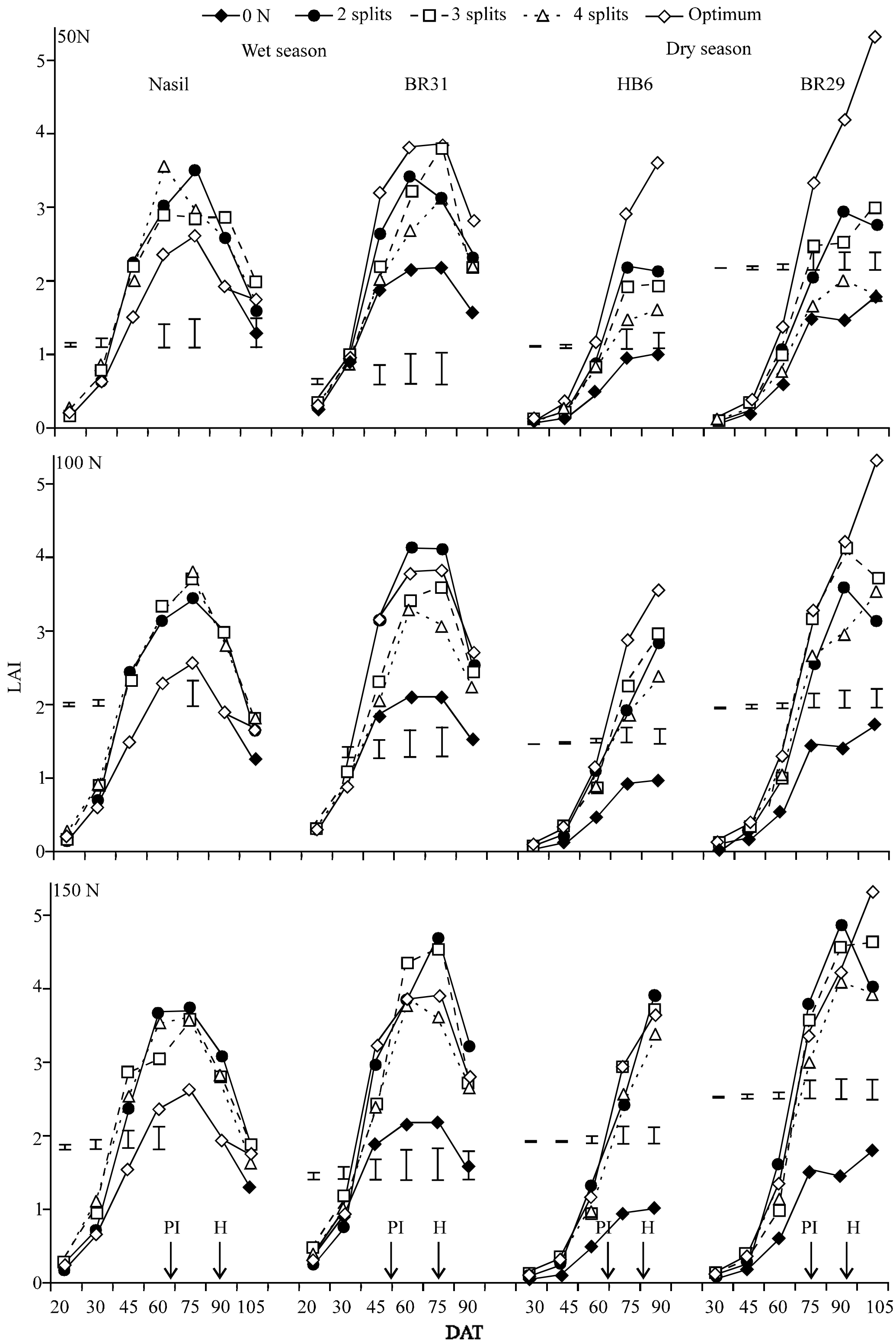
Transplanting was done on the first week of August and first week of January for the wet and dry season, respectively. Three to four seedlings were transplanted per hill at a spacing of 0.2 x 0.2 m. Fertilizers other than urea were applied one day before transplanting. All plots received a blanket dose of 26, 33, 30 and 4 kg ha^{-1} $year^{-1}$ of P, K, S and Zn, respectively. Nitrogenous fertilizer was broadcasted according to the treatments described in Table 2. To keep the experimental fields weed and insect free, weeding and insecticide sprayings were done when necessary.

Data on leaf area and crop growth rate were collected at 15 days interval starting from 30 days after transplanting (DAT) and continued up to heading stage. An additional sampling was done at 20 DAT for the wet season in the first year. Eight hills were uprooted from each plot for each sampling. The hills for each sample were marked randomly just after transplanting to avoid personal bias during sampling. The leaf area of a rice canopy is represented by leaf area index (LAI), which is a cumulative value of the total leaf area per unit land surface. To obtain dry weight, the samples (leaf and stem) were dried in a hot air circulating oven at 70°C for 72 h. Then crop growth rate (CGR) – dry weight increase rate per unit land area per unit time was measured. Data were statistically analysed with SAS, version 6.12.

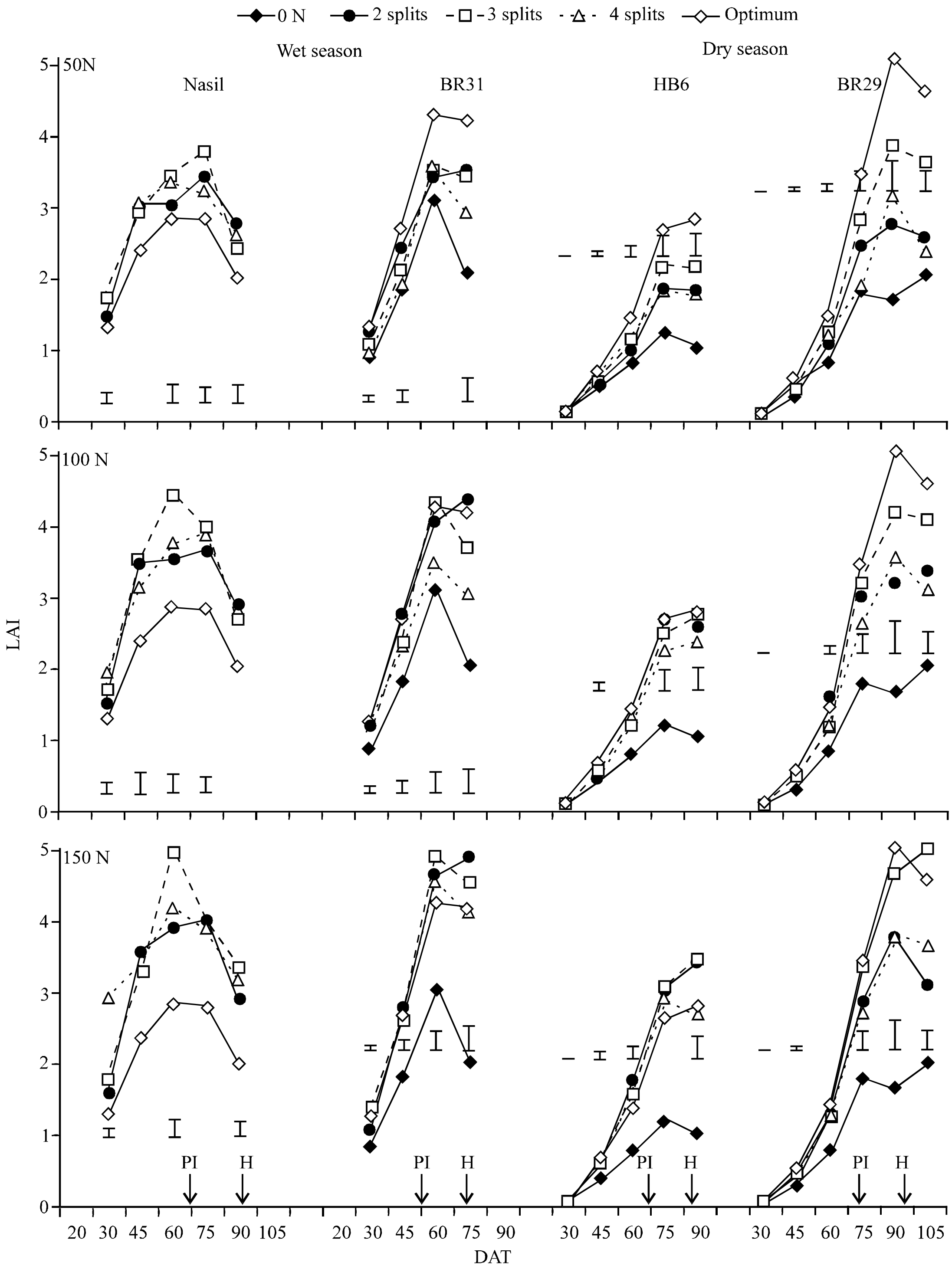
RESULTS AND DISCUSSION

Leaf area indices of DS varieties were very low during early growth stages compared to WS varieties (Fig. 1 and 2). As crop growth advanced, LAI increased gradually and peaked around PI stage in Nsail, whereas for the other varieties peaks were mostly found around heading stage. Among the varieties tested, HB6 always showed a lower LAI than the other varieties. The maximum LAI of Nsail ranged from 2.6 in the control treatment to 3.8 in the 150 N treatment for the first year and from 2.9 to 5.0 in the second year. Similar ranges were found for the other varieties in both years, but the traditional DS variety HB6 showed very low LAI values of 1.0 and 1.2 in the unfertilised control plots for both years.

The pattern of leaf area increase was different among the tested varieties. Leaf area index declined after attaining its maximum value with time. The decline was comparatively faster in the WS varieties than in the DS varieties. In Nsail, LAI peaked around PI stage and decreased considerably before heading stage. In BR31, although maximum LAI was attained at or just before heading stage, the increase of LAI from PI to heading stage was only small. In the DS varieties, however, LAI of both varieties increased steadily and a considerable increase was observed from PI to heading stage. Due to rapid growth of the WS varieties, LAI attained its peak at earlier growth stages than the DS varieties, coinciding with a period of higher temperature and low light intensity. Thus, a high respiration and a low net assimilation rate reduced crop growth. In consequence, this may have led to a faster decline of LAI in the WS varieties. Murata (1995) reported that LAI in a rice canopy reaches its maximum at the heading stage or shortly before that and decreased thereafter. He further indicated that the time and rate of changes in LAI lend to be specific to the variety and are affected by levels of N application. Fageria *et al*. (1997) reported that out of various factors the level of N fertiliser and how it is applied have the most marked effect on LAI by increasing the tiller number and the leaf size. Mae (1997) reported that leaf area expansion and dry matter accumulation are greatest during the period from panicle initiation stage to the late stage of spikelet initiation. According to Yoshida (1981), a large LAI is necessary to intercept the incident solar radiation. Miah *et al*. (1997) and Sharma and Singh (1999), however, reported that with the increase of LAI,

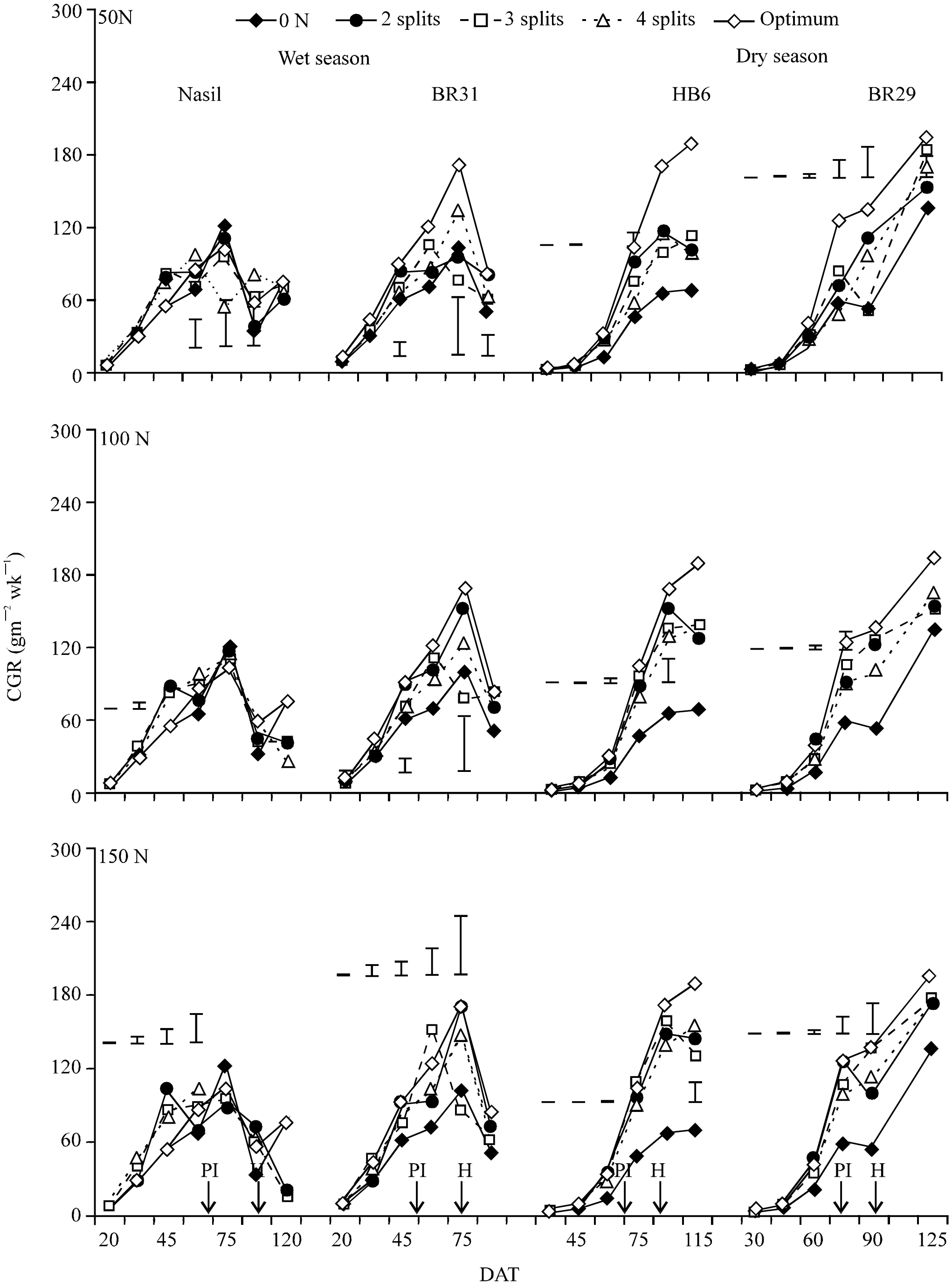


Error bars represent LSD values for N splitting within N rate at p≤0.1
PI = Panicle initiation stage, H = Heading stage
Fig. 1: Effect of N fertilisation on LAI of four rice varieties grown during the wet and dry season of 1996-97 at BRRI, Gazipur



Error bars represent LSD values for N splitting within N rate at p≤0.1
PI = Panicle initiation stage
H = Heading stage

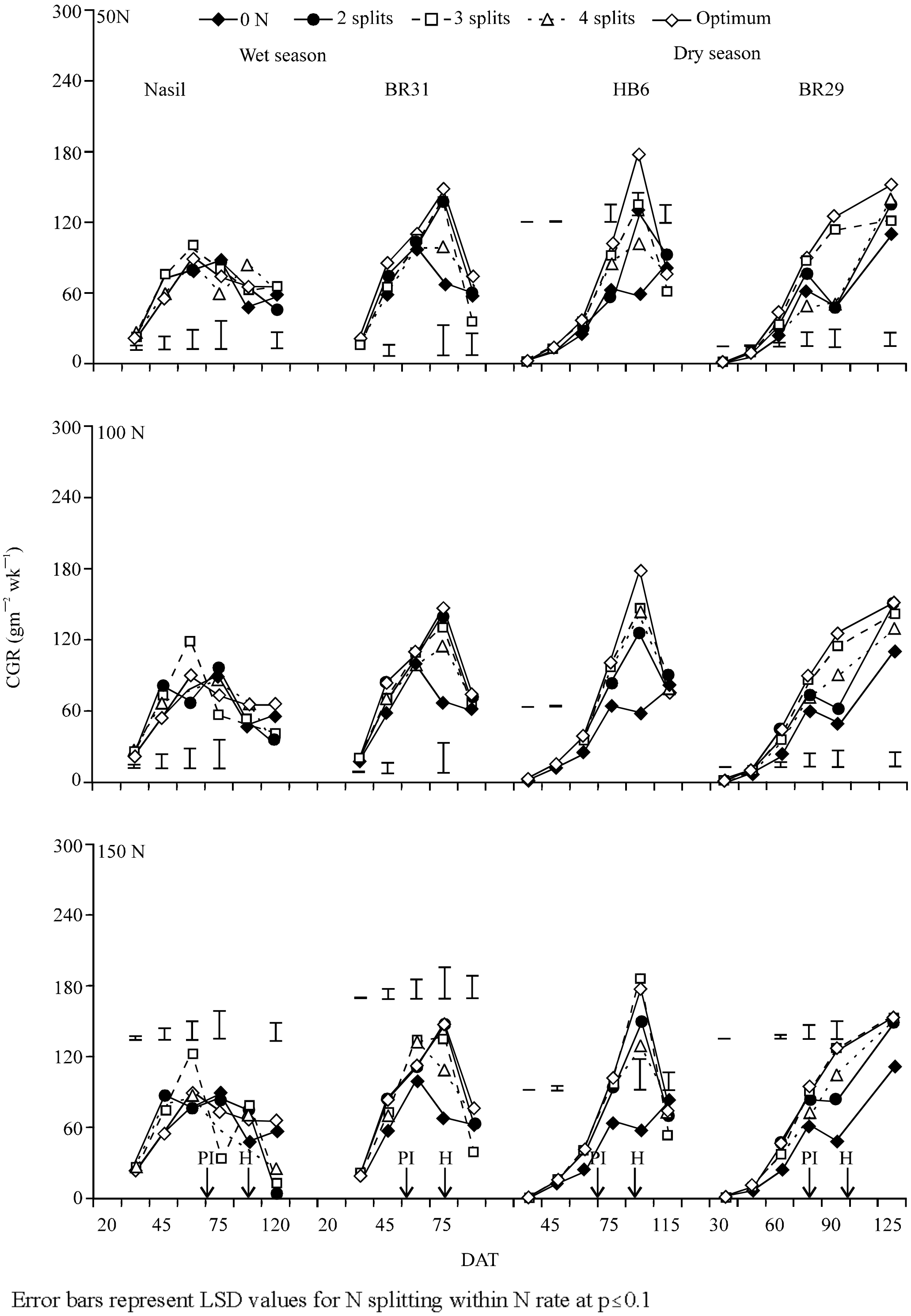
Fig. 2: Effect of N fertilisation on LAI of four rice varieties grown during the wet and dry season of 1997-98 at BRRI, Gazipur



Error bars represent LSD values for N splitting within N rate at $p \leq 0.1$

PI = Panicle initiation stage, H = Heading stage

Fig. 3: Effect of N fertilisation on crop growth rate of four rice varieties grown during the wet and dry season of 1996-97 at BRRI, Gazipur



Error bars represent LSD values for N splitting within N rate at $p \leq 0.1$
PI = Panicle initiation stage, H = Heading stage

Fig. 4: Effect of N fertilisation on crop growth rate of four rice varieties grown during the wet and dry season of 1997-98 at BRRI, Gazipur

light penetration inside the hill was restricted. Thus, photosynthetic rate decreased while respiration increased, resulting in a lower net assimilation rate.

Nitrogen rate had a profound effect on leaf area development (Kumura, 1995). Irrespective of N rates and splittings leaf area expanded after fertiliser application for all varieties. In most of the cases, 2- and 3-split treated plots produced a higher leaf area in all varieties, probably because 2- and 3-split treated plots received higher amounts of N fertiliser from tillering to PI stage compared to 4-split treated plots. This may have encouraged the rice plant to produce more tillers and consequently higher LAI. The yield-LAI relationship showed that the optimum LAI of the modern variety for achieving the highest yield ranged from 4 to 5, whereas the optimum range of the traditional DS variety was between 3 and 3.5. The LAI of the lodging-prone variety Nsail was above optimum throughout the growing season and the relationship between LAI and yield was negative. Murata (1995) indicated that excessive large leaf area could hamper dry matter production. With the increase in LAI, photosynthesis increases in an asymptote, whereas respiration may increase in proportion to the leaf area increase, as a result net dry matter increase as well as yield is reduced.

Crop growth rate of the tested varieties as affected by N rate and split application in two successive years are presented in Fig. 3 and 4. At early growth stages, CGR of WS varieties were much higher than that of DS varieties. Crop growth rate of the control treatment of Nsail started to increase after 20 DAT and the highest growth rates were observed during 60 to 75 DAT, being 122 g m^{-2} wk^{-1} in the first and 91 g m^{-2} wk^{-1} in the second year. Thereafter, the CGR declined. But in the fertilised plots, CGR increased up to 45 DAT and then remained almost constant up to around PI stage, afterwards CGR declined gradually. In the control plot of BR31, CGR increased with age and highest growth rates were attained during 60 to 75 DAT with 102 g m^{-2} wk^{-1} in the first year and during 45 to 60 DAT with 100 g m^{-2} wk^{-1} in the second year. In the fertilised plots, highest CGR were observed during 45 to 60 DAT for the 3-split treatment, during 60 to 75 DAT for the 2- and 4-split treated plots in the first year and during 60 to 75 DAT for all splittings, except the 4-split treatment plots at 150 N in the second year. In the case of HB6, CGR of the control treatment increased up to heading stage, reaching a value of approximately 65 g m^{-2} wk^{-1} and remained almost constant up to maturity. In the fertilised plots, CGR increased with crop age and the highest values were attained at heading stage, irrespective of N level and number of splittings in both years. The values, however, decreased during the ripening phase. In the case of BR29, a rapid increase of the CGR was mostly observed during 45 to 75 DAT (PI stage), thereafter the rates slowed down or declined slightly but increased again during ripening phase. In most cases, the 3-split treated plots of BR29 showed higher CGR at PI and heading stages compared to the other split arrangements.

The environment has a strong impact on crop growth, which is clearly revealed by the data presented above. In the dry season, the temperature was 19°C at the early growth stage of rice. At such a low temperature, the period of crop establishment after transplanting is prolonged and even after establishment the rice plants remained stunted. But in the wet season, the temperature was 29°C at early growth stages, being very favourable for rice growth. Hence, after transplanting the rice plants established rapidly and started to produce tillers. Consequently, LAI and CGR of the WS varieties were higher during early growth stages compared to the DS varieties. This was confirmed by De Datta (1981) and Yoshida (1981), who noted that temperature has a marked effect on growth of the rice plant. They reported that the optimum temperature for tillering stage was 25 to 31°C.

The pattern of CGR differed among the varieties. The CGR of the WS varieties were higher during early growth stages. In Nsail, the CGR peaked before PI stage, whereas for BR31 and HB6 the peaks were reached around heading stage. For the modern DS variety, an almost steady growth rate was observed. Higher CGR during the early growth stages of Nsail and BR31 might be associated with a decline of CGR in the later stages. The dry matter production is the balance between photosynthesis and respiration. IRRI (1968) reported that varieties with high growth rate during early growth stages promoted an excessive vegetative growth resulting in mutual shading and subsequently in lower growth rates at later growth stages. Akita (1989), Sharma and Singh (1999) explained that excessive biomass production during the early part of growth is mostly accompanied by the inevitable enhancement of respiratory losses and a decrease of CGR in consequence.

Higher CGR after heading for the modern DS variety BR29 compared to other varieties might have led to a higher grain yield in BR29. This is because, higher CGR during ripening stage is very important with regard to yield. Yoshida (1981) estimated that the contribution of accumulated carbohydrates, which were translocated to grain after heading ranged from 20 to 40%. The rest of the 60 to 80% of the grain carbohydrate derived from photosynthesis during the ripening phase.

In both years, higher CGR during ripening stage and consistently higher panicle number in the 3- and 4-split arrangements might have increased economic grain yield of Nsail at 50 N level. In case of BR31, the poor performance of 3-split treated plot in the second year could be explained by excessive and unproductive tiller production after the PI stage and with lower CGR during the ripening phase. The modern DS variety BR29 benefited from the 3-split application of N in respect of economic yield, either by a higher CGR or near optimum CGR from PI to heading stage.

The traditional WS variety Nsail has a very low N responsiveness and produced an excess leaf area, irrespective of splitting even at low N rates. But in the 3- and 4-split treatments, a smaller amount of N was applied in each dose as compared to the 2-split treatment. This may have resulted in a better balanced growth in the 3- and 4-split arrangements than that in the 2-split application which was reflected in a substantially higher panicle number at harvest and a higher CGR during the ripening phase. In case of BR29, a better performance of the 3-split treatment was reflected in higher leaf area and greater tiller number, consequently in a higher panicle number at harvest. In the 3-split arrangement, CGR was also greater either at heading stage or during ripening phase. All these parameters might increase yield in the 3-split treatment of BR29. Horie (2001) reported crop growth rate during the later half of the reproductive period (15 to 0 day before heading) was very critical affecting final spikelet number, potential single-grain weight and grain filling. He also indicated that a considerably large genotypic difference existed in CGR during this period, which was also found in these experiments.

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