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ORIGINAL ARTICLE

Growth and Yield of Basmati and Traditional Aromatic Rice As Influenced By Water Stress and Nitrogen Level

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Abstract

The experiment was done at the Bangladesh Rice Research Institute Farm, Gazipur during Boro season to determine the critical growth stage where water stress affect on yield reduction and to find out optimum level of nitrogen and to select stress tolerance nitrogen responsive rice variety. Water stress was imposed at i) vegetative stage, ii) reproductive stage, iii) grain filling stages and compared with iv) control (no water stress). Forty day-old seedlings of rice variety; BasmatiPNR, Basmati-D and Kalijira were transplanted on 15 December. Plant spacing was maintained at 20cm x15cm. Nitrogen was top dressed at 0, 70, 105 and 140 kg ha^{-1} at different growth stages. Increased spikelet sterility, resulting low grain yield. The highest grain yield was observed in stress free crop irrespective of nitrogen levels. However, grain yield increased with the increase of nitrogen levels irrespective of water stress. In the high fertilized crop, percentage of spikelet sterility increased with the increase water stress especially at the reproductive stage. Among the tested varieties the short stature Basmati PNR performed well by reducing spikelet sterility irrespective of nitrogen level and water stress conditions. *[J Sci Found, 2012;10(2):52-62]*

Keywords: Basmati rice, aromatic rice, traditional rice, nitrogen level, water stress

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Introduction

The cultivation of aromatic fine rice has given the priority along with coarse rice to meet up the food demands (Bhuiyan *et al.*, 2004). The Basmati fine rice and traditional aromatic rice has a great demand in the national level and in the international market. In fact aromatic long slender Basmati fine grain rice varieties are very popular in the world market (Yoshihashi, 2005). The aromatic rice has a wider acceptance in the market due to their test and aroma

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content. As a result their price is 2-3 times higher than the coarse rice (Biswas *et al*., 1992). Moreover, fine rice can be grown under wide range of environmental conditions (Begum *et al.*, 1999). Especially the traditional fine rice has more adaptability in adverse condition than the modern rice. For the cultivation of fine rice, it required less amounts of inputs especially nitrogen and water than modern coarse rice (BRRI, 2003).

Aromatic fine rice is recommended to grow in Aman season to get better quality. But the grain yield of rice grown in Aman season is generally lower than Boro crop due to climatic factors (BRRI, 2003a). To obtain higher grain yield of fine rice, sometimes farmers are interested to cultivate fine rice in Boro season. However, the growth and yield of Boro crop largely depends on the availability of inputs supply especially irrigation water and nitrogen (BARC, 2004). Crop growth stage especially at the reproductive stage is seriously affected due to water stress when pump failure or ground water level goes down below the pump layer consequently increases spikelet sterility and resulting drastic yield reduction (Okada *et al.*, 2002). However, the manipulation of irrigation water and nitrogen are essential to obtain higher grain yield of fine rice. Dobermann and Fairhurst (2000) reported that the application of water and nitrogen are the complementary inputs for the cultivation of rice. The technological information for growing modern coarse rice is available but in case of fine rice especially Basmati and traditional aromatic rice is still lacking. Based on the above facts the present study was undertaken to determine the critical growth stages of fine rice where water stress affect on drastic yield reduction and to find out the optimum level of nitrogen and to select nitrogen responsive potential fine rice varieties.

Methodology

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) Farm Gazipur in Boro season. Forty-day old seedlings of Basmati PNR, Basmati-D and Kalijira were transplanted with 2-3 seedling hill^{-1} spaced at 20 × 15 cm on 15 December. Water stresses was imposed at vegetative stage during 20-45 date after transplanting (DAT), at reproductive stage during 45-70 DAT, at grain filling stage during 70-95 DAT and compared with continuous standing water (no stress). The nitrogen was top dressed @ 0, 70, 105 and 140 kg N ha^{-1} in three equal splits at 20 DAT, 35 DAT and 50 DAT. The experimental area was laid out following split-split plot design, placing water stress in the main plot, N levels in the sub plot and varieties in the sub-sub plot. The unit plot size was 3m × 4m. Main plots were separated at a distance of 3 meter from each other to minimize se-page of water. To maintain water in the treated plot, levee was repaired regularly. Crop growth parameters were recorded at different growth stages and yield and yield components data collected during harvesting by following standard procedures. At the end of the stress period the soil moisture content (SMC) was determine by following gravimetric method. Soil samples were collected from each main plot at 0-10 cm, 11-20 cm, 21-30 cm depth of soil layers with 5 cm-diameter core sampler. Soil moisture content was computed by the following formula (IRRI, 1980).

$$SMC \frac{FW - DW}{DW} \times 100$$

where, *FW* = Fresh weight of the soil, and *DW* = dry weight of the soil.

The collected data were statistically analyzed following the procedures outlined by Gomez and Gomez (1984). Analysis of variance (ANOVA) for data of different parameters was done by computer package Irristat developed by IRRI (IRRI, 1992).

Results and Discussions

Plant Height, Tiller and Dry Matter: Plant height, tiller number and dry matter of rice varieties varied significantly at different growth stages due to variation of water stress, N levels and genetic potentiality of variety. Water stress imposed at the vegetative stage (20-45 DAT) hampered crop growth and development which reduced plant height (Fig. 1) number of tillers (Fig. 2) and dry matter (Fig. 3).

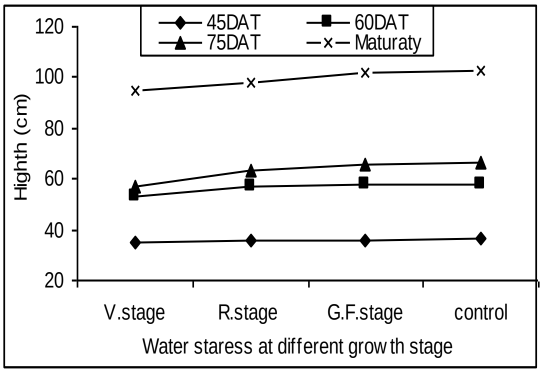

Fig 1: Plant height of fine rice at different DAT as affected by water stress (*Boro* season)

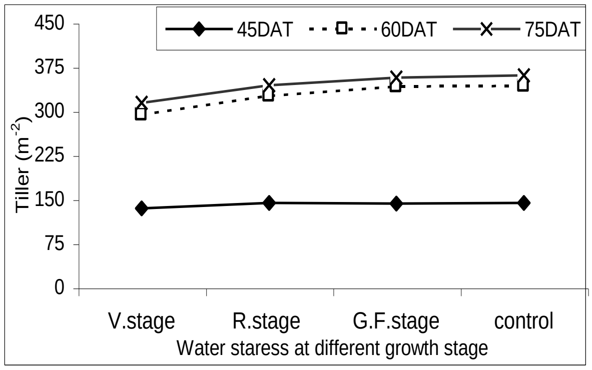

Fig 2: Tiller number of fine rice at DAT as affected by water stress (*Boro* season)

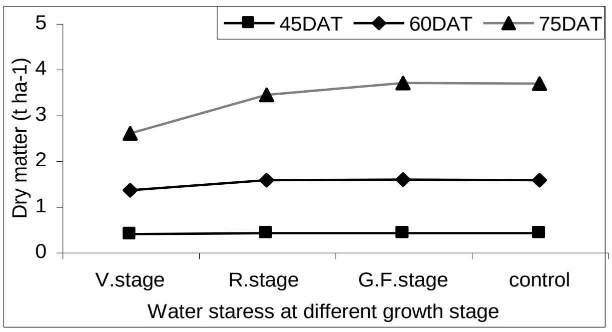

Fig 3: Dry matter of fine rice at different DAT height at as affected by water stress (*Boro* season)

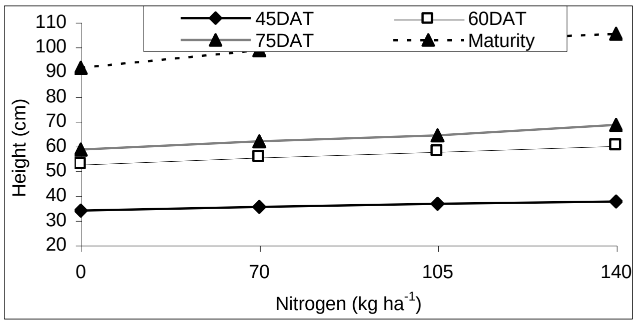

Fig 4: Effect of nitrogen on plant different DAT (*Boro* season)

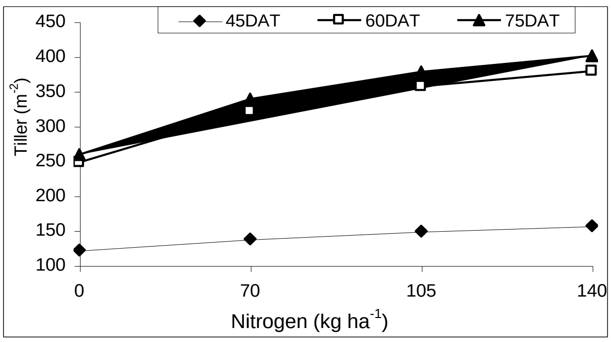

Fig 5: Effect of nitrogen on tiller production at different DAT (*Boro* season)

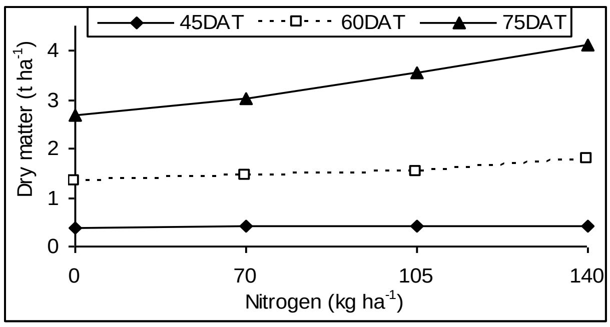

Fig 6: Effect of nitrogen on dry matter production at different DAT (*Boro*, season)

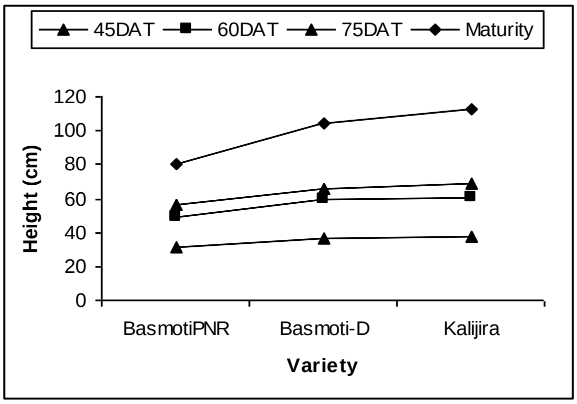

Fig. 7. Plant height of fine rice varieties at different DAT (*Boro*, season)

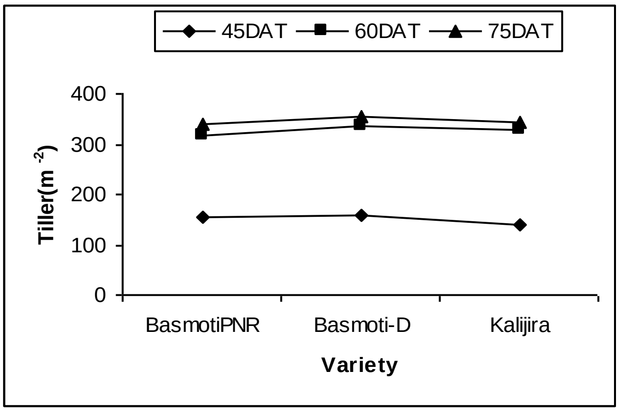

Fig: 8. Tiller production fine rice different DAT (*Boro*, season)

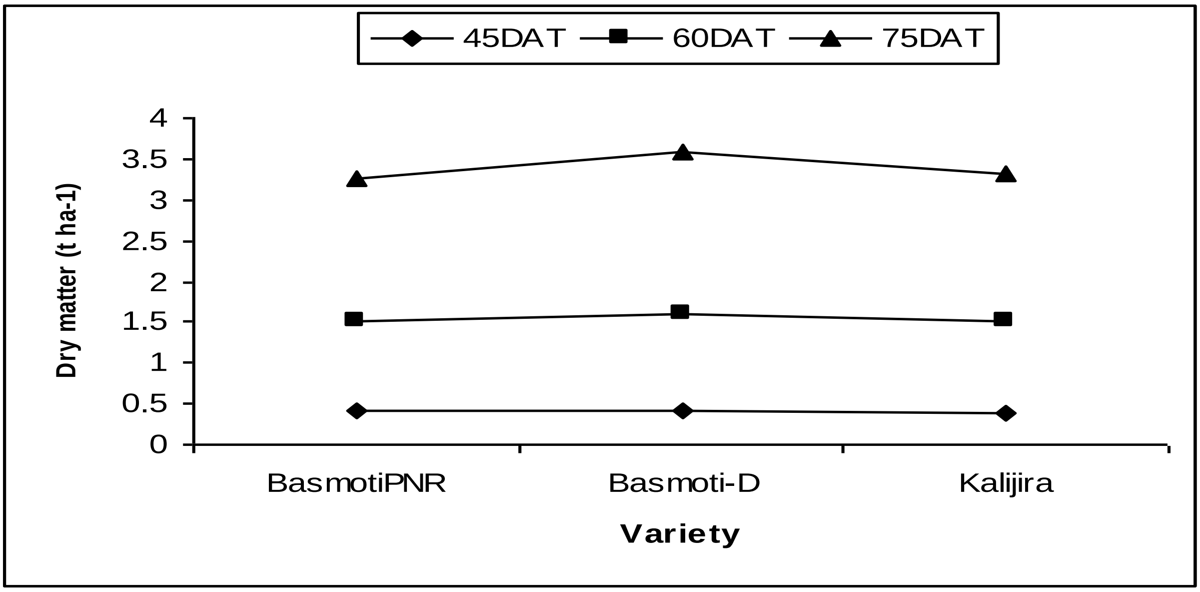

Fig. 9 Dry matter production of fine rice at different DAT (*Boro*, season)

In stress condition plant cannot absorb nutrients from the soil due to lack of available moisture, consequently crop growth became stunted. This was similar to the result of Siopongeo *et al.* (1989) where water stress at the vegetative growth stage showed shorter plant. Similarly, the supply of available nitrogen progressively increased the plant height (Fig. 4), number of tillers (Fig. 5) as well as dry matter (Fig. 6) irrespective of growth stages. These findings are in conformity with the results obtained by Mallick (1992) and Roy *et al.* (2004) where crop growth increased with the increase of N levels at different growth stages. Re-watering after stress period (at vegetative stage) the affected crop did not compensate or recovered completely those hampered during stress period with the supply of water after stressed period. Almost similar trend was also observed by Kumar (2002). Traditional aromatic rice Kalijira showed the significantly tallest plant followed by Basmoti-D, while the shortest plant was found in BasmatiPNR irrespective of water stress and N levels at different growth stages (Fig. 7). The findings of this study had the similarity with the results of Hossain *et al*. (2002). Taller plant of kalijira and Basmati-D produced higher number of tillers (Fig. 8) as well as dry matter (Fig. 9) at latter growth stages beyond 45 DAT irrespective of water stress and N levels. As the height of the plant is controlled by the genetic factors but it also varies due to management practices and input supply. Similar finding was reported by BRRI (2000). However, for the full expression of the genetic potentiality of variety it is better to provide necessary inputs such as water, nitrogen and to select potential variety. The interaction effect of N and varieties on plant height, tiller number and dry matter was insignificant at different growth stage.

Yield components

Yield components of rice parameters are varied significantly due to variation of water stress and N levels. Maximum number of panicle with longer in length was found in the plots where continuously standing water was maintained and applied higher doses of N. On the contrary, less number of panicles with shorter in length was observed in the crop field that was affected by water stress at the vegetative stage and N was absent (Table 1). Almost similar trend of response was observed in case of grains panicle^{-1} where more number of grains panicle^{-1} was found the crops which were grown in continuous standing water, followed by the crops that was affected by water stress at the grain filling stage and at the vegetative stage. Hossain *et al.* (2002) was also observed more number of panicle in stress free crop (Okada *et al.*, 2002). Higher percentage of spikelet sterility (38-40 %) was observed in the crop that was affected by water stress at the reproductive stage followed by the crop affected by stress at grain filling stage when higher doses of N was applied. On the contrary, less percentage of spikelet sterility was observed in the crop that was affected by water stress only at the vegetative stage (Table 1) and applied low level of N. Almost similar response was also found by IRRI (1994) in the crop that was affected by water stress at flowering stage. Moriwaki (1999) reported that excessive N application during meiosis stage reduced carbohydrate content resulting abnormal development of pollen grains, which increase in the number of empty spikelets and resulting lower number of grains panicle^{-1}.

Heavier individual grain was observed in the crops which was grown in continuous standing water condition irrespective of N levels, while; lighter individual grain was found in the crop affected by water stress at reproductive stage (Table 1). The findings of this study had the similarity with the result of Hossain *et al*. (2002).

Traditional variety Kalijira showed more number of panicle, grains per panicle and longer panicle while, BasmotiPNR exhibited less number of panicles per unit area irrespective of water stress (Table 2). The heaviest individual grain was found in BasmotiPNR, while lighter grain was observed in Kalijira irrespective of water stress and N levels. The variation of individual grain weight of rice varieties was probably due to genetic variability as supported by Yoshida (1981). The higher percentage of spikelet sterility was observed in Basmati-D, while, low sterility was found in BasmatiPNR irrespective of water stress and N levels (Table 3). Similar trend was also found by Hossain *et al.* (2002) where BasmatiPNR gave low number of empty spikelet in Boro season. The effect of interaction of nitrogen level and variety on yield components was insignificant.

Table 1: Effect of water stress and nitrogen on yield and yield components of Basmati and traditional aromatic rice in Boro season

Interaction		Panicle (m^{-2})	Panicle length (cm)	Grains panicle^{-1}	Sterility (%)	1000-grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	N-up take (kg ha^{-1})	
Water stress	Nitrogen (Kg /ha^{-1})								Grain	Straw
V. stage	0	208	18.79	66	20e	15.80	2.03h	2.25	16.10h	10.95
	70	247	19.22	70	23de	15.90	2.58fg	2.97	21.67ef	16.68
	105	288	19.56	71	25cde	16.02	2.91ef	3.44	25.90d	19.79
	140	300	19.48	74	26cde	16.06	3.24de	3.70	33.44bc	22.19
R. stage	0	226	18.70	66	28bcd	15.84	2.25gh	2.61	18.00gh	12.83
	70	286	19.15	64	34ab	16.00	2.65fg	3.49	22.35e	19.07
	105	313	19.60	64	38a	15.97	2.97ef	3.79	26.44d	21.93
	140	332	20.17	62	40a	16.08	3.19ef	4.22	33.20bc	25.30
G.F stage	0	227	18.97	68	24de	16.01	2.42gh	2.68	19.28fg	13.17
	70	292	19.54	69	28bcd	16.03	3.27cde	3.61	27.16d	20.15
	105	316	19.66	71	31bc	16.05	3.59bcd	4.04	31.89c	23.54
	140	335	20.21	68	34ab	16.06	3.69bc	4.22	36.09b	25.48
No stress	0	230	19.49	77	21e	16.02	2.59fg	2.77	20.54efg	13.46
	70	296	19.98	78	24de	16.13	3.47cd	3.75	27.62d	20.94
	105	323	20.38	76	26cde	16.14	4.00ab	4.17	34.82bc	24.00
	140	333	20.77	74	29bcd	16.18	4.22a	4.37	43.62a	26.05
Level of significance		NS	NS	NS	0.05	NS	0.05	NS	0.01	NS

*Figures in a column followed by different letters differ significantly but with common letter(s) do not differ significantly at 1 % and 5 % level of significance. NS=Not significant.

Grain yield

Grain yield of rice was varied significantly due to the variation of water stress and nitrogen levels. The highest grain yield was observed in the plots where continuous standing water was maintained and higher doses of N were applied. While, low grain yield (23%) in the crop affected by water stress at the vegetative stage compare to standing water and applied higher doses of N due to less number of panicles with shorter in length (Table 1). Similarly, the crop that was affected by water stress at reproductive stage reduced grain yield (24%) than that of continuous standing water condition at high level of N due to high percentage of spikelet sterility and less number of grains panicle^{-1}. Similarly, about 13 % yield reduction was found in the crop that was affected by water stress at the grain filling stage over control (no water stress) due to lighter individual grain and less number of grains per panicle. Water deficit at the grain filling stage adversely affect on grain development mainly due to shortage of moisture that impaired nutrient uptake. Due to water stress the topsoil layers desiccate first where most of the nutrients occupied and resulting nutrient can not absorbed by the plant, because in dry soil no transportation to the plant roots of N and mineral, takes place. The plant then experiences nutrient shortage because of necessary water is absorbed from deeper soil layer. Similar report was given by O`Toole *et al*. (1989). The maximum yield reduction was also observed by Bouman (2001) when water stress occurred at the reproductive growth stage. Kropff and Spitters (1991) reported that due to stress the dryness of soil especially the upper layer where most of the root remained and reduced nutrient movement and absorption in plant roots. Plant can uptake nutrient up to 14.75 % soil moisture content and excessive dryness due to shortage of water the wilting point started from 5.75-7.50 % moisture content in clay loam soil (Islam *et al.,* 1999).

The grain yield increased with the increase of N levels irrespective water stress. Maximum grain yield was observed in the plots where a higher dose N was applied and continuous standing water was maintained (Table 1). Probably, application of N promoted root growth, which aids in the extraction of larger proportion of soil N and enhanced crop growth resulted higher grain yield. Similar response was also observed by Miah and Panuallah (1999) in Boro season. But antagonistic response was found in the plot when high level N applied in stress affected crop. The rate of yield reduction was higher when higher level of N was applied in stress affected crop especially at reproductive stage. On the contrary, the rate of yield reduction was lower when less amount of N was applied in stress affected crop. However, grain yield decreased in control (without N) plot of stress affected at vegetative, reproductive, and grain filling stages was 22 %, 13 % and 7 % respectively than the control plot (without N) of standing water (Table 1).

Because, in stress condition the top soil layer dries up and nutrient cannot absorb by the plant. The plant then became experiences N shortage. The necessary water is absorbed from the deeper soil layer where N concentration is less. Similar response was also observed by Kropff and Spitters (1991).

Table 2: Effect of water stress and varieties on yield and yield components of Basmati and traditional aromatic rice in Boro season

Interaction		Panicle (m^{-2})	Panicle length (cm)	Grains panicle^{-1}	Sterility (%)	1000-grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	N-uptake (kg ha^{-1})	
Water stress	Varieties								Grain	Straw
V. stage	BasmatiPNR	250	19.61	60	22	19.89	2.75de	2.84	26.24e	19.42
	Basmati-D	259	19.00	59	25	17.87	2.80de	3.22	24.16ef	17.48
	Kalijira	266	20.13	91	21	11.19	2.68e	3.15	22.19f	16.10
R. stage	BasmatiPNR	270	19.72	54	32	19.86	2.84cde	3.18	26.43cde	18.77
	Basmati-D	289	19.31	53	37	18.01	2.59e	3.74	22.48f	20.17
	Kalijira	295	20.49	82	32	11.19	2.90bcde	3.55	24.82def	17.96
GF stage	BasmatiPNR	276	20.41	58	30	20.05	3.31ab	3.37	30.13ab	19.75
	Basmati-D	291	19.30	58	31	18.06	3.24abc	3.85	27.59bcd	20.80
	Kalijira	300	20.46	87	26	11.24	3.16bcd	3.67	26.05cde	18.87
No stress	BasmatiPNR	283	20.75	63	22	20.12	3.60a	3.56	32.73a	20.47
	Basmati-D	292	19.83	67	24	1818	3.56a	3.97	28.86bc	21.38
	Kalijira	304	21.27	95	21	11.28	3.30ab	3.76	27.31cde	19.37
Level of significance		NS	NS	NS	NS	NS	0.01	NS	0.01	NS

*Figures in a column followed by different letters differ significantly but with common letter(s) do not differ significantly at 1% levels of significance. NS= Not significant.

BasmatiPNR produced higher grain yield irrespective of water stress except that crop which was affected by water stress at vegetative stage (Table 2). In control (no nitrogen) or at lower level of N (70 kg N ha^{-1}) conditions Basmati-D performed well (Table 3). Beyond 70 kg N ha^{-1} BasmatiPNR showed higher grain yeld due to heavier individual grain. More number of grains $panicle^{-1}$ and low percentage of spikelet sterility of traditional variety Kalijira contributed to increase grain yield irrespective N levels. High percentage of spikelet sterility was observed in Basmati-D irrespective water stress N levels probably due to weak culms that prone to lodge. In continuous standing water condition grain yield of BasmatiPNR, Basmati-D and Kalijira increased 21 %, 27 % and 12 % than that of stress-affected crop at reproductive stage respectively (Table 2).

Table 3: Effect of nitrogen and varieties on yield and yield component of fine rice in Boro season

Interaction		Panicle number (m^{-2})	Panicle length (cm)	Grains $panicle^{-1}$	Sterility (%)	1000-grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Nitrogen	Varieties							
N_0	BasmatiPNR	219	19.35	57	23	19.81	2.28d	2.37
	Basmati-D	223	18.70	58	25	17.89	2.36d	2.76
	Kalijira	235	19.80	89	20	11.21	2.53d	2.64
N_{70}	BasmatiPNR	263	19.90	58	26	20.03	3.01c	3.21
	Basmati-D	274	19.08	59	29	17.94	3.09bc	3.63
	Kalijira	292	20.59	88	23	11.23	3.00c	3.46
N_{105}	BasmatiPNR	291	20.44	60	28	20.06	3.48ab	3.56
	Basmati-D	312	19.70	60	30	18.09	3.32abc	4.02
	Kalijira	319	20.88	90	27	11.22	3.24bc	3.90
N_{140}	BasmatiPNR	307	20.80	59	29	20.03	3.72a	3.82
	Basmati-D	322	19.96	60	33	18.20	3.41ab	4.35
	Kalijira	319	21.10	88	31	11.23	3.26bc	4.13
Level of significance		NS	NS	NS	NS	NS	0.01	NS

*Figures in a columns followed by different letters differ significantly but with common letter(s) do not differ significantly at 1 % levels of significance. NS= Not significant.

Straw Yield

The highest straw yield was recorded in the crop which was grown in continuous supply of water and applied higher amount N (Table 1). Water stress at vegetative stage (20-45 DAT) reduced plant height and tiller number, resulting lower straw yield than that of stress free crops. This fact well agrees with the results obtained by Hossain *et al*. (2002) and Mallick (1992). The high tiller productive variety Basmati-D produced maximum straw yield and short stature BasmatiPNR exhibited the lowest straw yield irrespective of water stress and N levels (Table 2 and Table 3).

N-Uptake in Grain and Straw

N-uptake in grain and straw varied due to the variation of water stress, nitrogen levels and genetic variability of variety (Table 1). Nitrogen uptake was higher both in grain and straw in the crop which was not affected by water stress at their growth stages and supplied higher level of nitrogen. N-uptake was lower in the crop that affected by water stress especially at the vegetative or at reproductive stages although the rate of N supply was high. Perhaps plants are not able to absorb the applied nitrogen due to the deficiency of water absorption in stress condition. This was similar to the results of Miah and Panaullah (1999) and this response was more pronounced under higher level of nitrogen. The N-uptake efficiency of Basmati PNR was higher both in grain and straw irrespective of water stress (Table 2). N-uptake increased with the increase of nitrogen rates both in grain and straw in stress and stress free conditions. The effect of interaction of water stress, nitrogen and varieties was insignificant on plant height, tiller number, dry matter production at different growth stages, grain and straw yield, and yield component parameters.

Conclusion

Thus, BasmatiPNR gave higher grain yield when crop grown in continuous standing water condition using with the appropriate amount of nitrogen (105-140 kg ha^{-1}). During water crisis period stress can be allowed only for few days at the vegetative stage up to certain extent. No stress period would be allowed even for a short period of time at the reproductive stage as water stress at the reproductive stage reduced grain yield drastically especially when crop is grown with higher level of N. The reduction of yield depends on the genetic resistance of variety against stress tolerance. Cultivation of stress tolerant varieties and identification the traits resistant to stress are important to increase yield of rice in water crisis situations.

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