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Effect of Water Stress at Different Growth Stages on Yield and Yield Contributing Characters of Transplanted Aman Rice

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Abstract: A pot experiment with four transplanted aman rice varieties was carried out at the Bangladesh Institute of Nuclear Agriculture, Mymensingh during aman season, 2000 to find rice cultivar, which can be used as developing suitable variety for drought affected areas of Bangladesh. Moisture stress (30% FC) was maintained during booting, flowering and grain filling stage and 100% FC in the control plants. Plant height, tiller number, panicle number, panicle length, number of filled grains per panicle, 1000-grain weight, harvest index (HI), total dry matter (TDM) and yield were decreased with stress. However, varieties response was different for most of the characters and they had different degree of reduction. Among the four varieties, Binadhan4 produced highest yield, more tillers and panicles per plant, highest 1000-grain weight and medium TDM and HI under water stress condition. Shorna showed better yield but the highest TDM and medium HI. Brridhan33 showed medium yield and TDM but the highest 1000-grain weight and HI. Binashail showed the highest TDM and plant height. But it produced lower grain yield under stress condition. Binadhan4 and Binashail may be used as developing suitable varieties for drought -affected areas of Bangladesh.

Key words: Transplanted aman rice, water stress, growth stages and yield

Introduction

Bangladesh is an over-populated country and each year nearly 1.94 million people are added to its population of about 122 millions (FAO, 1999). Of this total people, rice is the first and staple food. Here, the total rice area is about 10 million hectare (ha) and it is about 75% of the total area of agricultural crops and 93% of the total area planted to cereals (CGIAR, 1997). Transplanted aman rice is generally cultivated in Bangladesh under rainfed conditions during the period of August to December and covers about 53% of the total rice area, which is equivalent to 5.3 million ha with a production of 10.3 million tons of rice (BBS, 2000).

Aman rice passes its vegetative stage during August to September when rainfall is sufficient. This crop suffers from moisture stress when the rainfall ceases by the first week of October. This crop passes its reproductive stages (panicle initiation, booting, flowering and grain filling) in October and November. The total rainfall in these two months is very irregular and often inadequate in Bangladesh which fails to meet the evapotranspirational demand of aman rice and thereby water stress develops and affects translocation of assimilates and grain development.

The performance of rice varieties under water stress conditions at different growth stages varies. Islam *et al.* (1994b) observed that yield losses resulting from water deficit are particularly severe when drought strikes at booting stage. Water stress at or before panicle initiation reduces the most potential spikelet number and stress during grain filling decreases translocation of assimilates to the grains, which decreases grain weight and increases empty grains (RRDI, 1999). However, how water stress affect the later part of growth stage in different rice varieties in Bangladesh is not clearly stated. Therefore, the present investigation has been undertaken to observe the effect of water stress on yield components and yield of some selected transplanted aman rice varieties. It also helps to find rice cultivar, which can be used as developing suitable variety for drought affected areas of Bangladesh.

Materials and Methods

The experiment was conducted in plastic pots at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from August to November 2000. The soil was sandy loam in texture having pH 6.7. The collected soil was dried under the sun. A total of 48 pots were prepared with 3.5 kg soils in each pot and were placed under polyethylene sheet.

Urea 576 mg, TSP 560 mg, MP 320 mg and Gypsum 66 mg per pot following 90-84-60-5 kg of N-P_2O_5-K_2O-S ha^{-1} were applied respectively as fertilizers. The whole amount of TSP, MP and Gypsum were mixed with the soil as basal dose at pot preparation. The Urea for a pot was equally applied in three installments to the soils at 7 days, 21 days and at tillering stage (35 days), respectively after transplanting.

Four transplanted aman rice varieties namely - Binadhan4, Binashail, Brridhan33 and Shorna were plant materials. Thirty days old seedlings were transplanted in each puddled pot on August 13, 2000. Each hill contained 3 seedlings. After 2 weeks the healthy one was allowed to grow and another two were uprooted.

The experiment was consisted of 16 treatments (4 varieties x 4 stress) replicated thrice i.e. 48 pots. Control and stress conditions are as follows.

i. Control condition i.e. 100% field capacity (FC) was maintained from booting to maturity.
ii. Stress (30% FC) at booting stage, varied between 60 and 75 days after transplanting (DAT)
iii. Stress (30% FC) at flowering stage, varied between 72 and 82 DAT
iv. Stress (30% FC) at grains filling stage, varied between 80 and 95 DAT

The experiment was laid out in Completely Randomized Design (CRD), where each treatment replicated 3 times.

The stress treatments as 30% FC were imposed at booting, flowering and grains filling stages and 100% FC was maintained from booting to maturity by adding measured amount of water (measured with a weighing balance, every day). At the seedling and tillering stages, similar moisture level (100% FC) was maintained in all pots. Field Capacity (100%) of the soils used in the experimental pots was determined through Gravimetric Method. This measured amount of water was multiplied by 0.30 to know the amount of water to maintain 30% FC during stress imposition period. At the end of each growth stage, stress was discontinued and hills were allowed to grow under 100% FC till maturity.

Intercultural operations such as weeding and application of pesticides were done as and when necessary.

At maturity, plants under control and stress treatments were harvested and agronomic parameters were recorded. Then the plant parts were separated into roots, stem, leaves and panicles. After separating the grains from the panicles, all the plant parts

were then oven dried at 60°C for 72 hours. The grains were allowed to sun dry. After drying, the data on yield components and yield was recorded. Then the data on physiological parameters were determined.

The collected data were analyzed statistically following two and three factors experiment in CRD with the help of MSTAT computer packages (Freed, 1992). The mean differences among the treatments and varieties were further assessed with Duncan's Multiple Range Test.

Results and Discussion

Plant height was significantly affected by water stress at booting, flowering and grain filling stage (Table 1) over the control. Among three growth stages, grain filling stage (89.02 cm) was affected highly followed by flowering stage (94.48 cm) and booting stage (96.34 cm). This result agrees with Islam *et al.* (1994b), who found that moisture stress reduced plant height under 20% soil saturation at booting and flowering stages. Similar result has also been reported by Islam (1999) and Islam and Gretzmacher (2000). Plant height varied depending on different varieties under water stress. The longest plant height was observed in variety Binashail (117.4 cm), which was significantly higher over Binadhan4 (91.32 cm) and Brridhan33 (87.14 cm) and Shorna (83.56 cm) shown in Table 2. Variety Binashail showed the longest plant than other two varieties. The shortest plant height was recorded in the variety Shorna. The interaction effect of varieties and stages of growth (at 30% FC) on plant height is presented in Table 3. Moisture stress at any growth stage reduced the plant height of all the varieties. Among varieties, Binashail produced the longest plant under stress at booting and it was the shortest in Binadhan4 under stress at grain filling stage. The decrease in height might be either due to inhibition of length of cells or cell division by water deficits.

The number of tillers per hill was the highest (10.58) under control which decreased significantly under moisture stress at different growth stages except that at flowering stage (9.83) (Table 1). This agreed with Murty (1987) and Islam *et al.* (1994a). Number of tillers per hill varied significantly among varieties (Table 2). Binadhan4 produced the highest (10.58) number of tillers per hill, which was similar to that by Shorna but significantly higher than that of Binashail (9.50) and Brridhan33 (8.83). Varieties and their growth stages under stress conditions showed significant interaction effect of tillers number per hill (Table 3). Shorna produced more tillers per plant but Brridhan33 produced less under stress at flowering stage.

The number of panicles per hill decreased significantly over the control, when moisture stress was imposed at booting stage. However, the number of panicles per hill due to stress at flowering and grain filling stage were not affected. This result agrees with Rice Research and Development Institute (1999) stated that water stress at or before panicle initiation reduces panicles number. Number of panicle per hill varied among the varieties due to soil moisture stress at different growth stages (Table 2). The highest number of panicles per hill was found in variety Binadhan4. Shorna showed the medium number of panicles and variety Binashail and Brridhan33 were the lowest (Table 2).

Panicle length was significantly decreased due to water stress at all growth stages in comparison to that of control (Table 1). Grains filling stage is highly affected than booting and flowering stages. Similar result was obtained by Islam *et al.* (1994a). The result also agrees with Ekanayake (1987). This might be due to the fact that moisture stress slowed down carbohydrate synthesis and or weaken the sink at reproductive stages. There were remarkable differences on panicle length among the varieties under stress (Table 2). Binashail maintained the longest panicle (23.37 cm) whereas Binadhan4 affected significantly and produced the shortest panicle. The interaction (Table 3) demonstrated that the panicle length was affected in all varieties at all growth stages where booting stage of Binashail was high stress tolerate and Binadhan4 was least tolerating at grain filling stage.

The number of filled grains per panicle decreased significantly with the moisture stress at booting, flowering and grains filling stages compared with control (Table 1). It was observed that water stress at grain filling stage was less harmful for filled grains than other stages (77.31/plant). Stress at flowering stage gave the lowest (71.24) number of filled grains per panicle. It was revealed that stress at flowering and booting stages were affected seriously. This result agrees with Islam *et al.* (1994a), O'Toole and Moya (1981) and Rahman and Yoshida (1985). Rice Research Development Institute (1999) reported that water stress at or before panicle initiation reduces the most potential spikelet number and at grain filling stage the percentage of filled grains decreased to 40%. Among varieties, Shorna produced the highest number of filled grains per panicle followed by Binashail and Brridhan33. The lowest number of filled grains per panicle was obtained from Binadhan4 (Table 2). Interaction showed that higher number of filled grains per panicle was found in the variety Shorna under stress at grain filling stage and lower in Brridhan33 under stress at booting stage. But in all cases, the highest value was recorded under control treatment (Table 3).

The formation of unfilled grains per panicle at stress at flowering stage was significantly higher than other treatments (Table 1). The results agreed with the report of Yambao and Ingram (1988). Different varieties showed significantly different results in the number of unfilled grains per panicle (Table 2). Binashail produced the highest number of unfilled grains per panicle followed by Shorna and Brridhan33. The lowest unfilled grains per panicle were found in Binadhan4. Interaction effect demonstrated that higher unfilled grains per panicle was produced by Shorna under stress at flowering but it was lower in Binadhan4 and Brridhan33 under stress at booting stage.

1000-grains weight indicated the reduction in grain size with moisture stress imposed at different growth stages (Table 1). Grains size was found significantly largest (24.67g) at control over other treatments. Similar results on 1000-grain weight under water stress at booting and flowering stages had been showed by Islam (1999) and Islam *et al.* (1994b). Stress at booting and grains filling stages had similar effect. Stress during different growth stages might decrease translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. Results showed that 1000-grain weight varied among varieties (Table 2). Variety Brridhan33 produced the largest grain size, which was similar to that in Binadhan4. The smallest grains size was found in Binashail. From this result, it can be concluded that moisture stress influenced the size of the grains and it varies with variety. The interaction effect between treatments and genotypes on 1000-grain weight is shown in Table 3. Weight of 1000-grains was lowered significantly over control in all cases. The lowest 1000-grain weight was recorded in Binashail under stress at flowering and grain filling stage. Water stress treatments had no effect on 1000-grain weight of Brridhan33.

Moisture stress at all growth stages reduced yield significantly over the control (Table 1). Islam (1999) also showed that stress at booting and flowering stages had the similar effect on grains yield. Irrespective of moisture stress applied at different stages of growth, there existed genotypic differences in yield (Table 2). Yield per plant was significantly greater in Binadhan4 (15.4 g) than in Shorna (14.9 g), Brridhan33 (13.5 g) and Binashail (10.7g) (Table 2). As translocation of assimilates of Binadhan4 was less affected by water stress, so it produced the highest grain yield. On the other hand, Shorna produced the lowest grain yield, because its translocation towards reproductive organs was severely affected by the stress. Interaction effect of genotypes and stages of growth indicated that water stress at any stage during reproductive growth reduced yield in all the genotypes. Among the four varieties, Binadhan4 performed best (15.6 g) under stress at booting stage followed by Shorna (12.4 g), Brridhan33 (11.6 g) and Binashail (10.4 g). Subjected to water stress at flowering

Table 1: Effect of soil moisture stress (30% FC) at booting, flowering and grains filling stages on some agronomic and physiological parameters of 4 transplanted aman rice varieties

Treatments	Plant height (cm)	Tillers/Hill (Number)	Panicles/Hill (Number)	Length of panicle	Grains/panicle (Number)		1000-grain weight (g)	Yield/hill (g)	Total dry matter /Hill (g)	Harvest index
					Filled	Unfilled				
Control (no stress)	99.63 a	10.58 a	9.33 a	21.44 a	96.86 a	32.80 b	24.67 a	16.90 a	42.38 a	0.41 a
Stress at Booting	96.34 b	9.42 b	8.67 b	20.33 b	75.03 c	31.56 b	23.69 bc	12.48 b	34.22 c	0.38 c
Stress at Flowering	94.48 c	9.83 ab	9.00 a	20.40 b	71.24 d	40.65 a	23.51 c	12.61 b	35.07 b	0.37 d
Stress at Grains filling	89.02 d	9.58 b	8.75 a	19.80 c	77.31 b	30.97 b	23.91 b	12.68 b	31.91 d	0.40 b
$LSD_{(0.05)}$	1.06	0.81	0.65	0.35	0.68	1.83	0.34	0.24	0.38	0.003

Common letter (s) within the column do not differ significantly at 5% level of significance analyzed by DMRT Values used in this table are the means of 4 varieties over 3 replications

Table 2: Growth and yield contributing performances of 4 transplanted aman rice varieties under soil moisture stress at booting, flowering and grain filling stage

Treatment	Plant height (cm)	Tillers/Hill (Number)	Panicles/Hill (Number)	Length of panicle	Grains/panicle (Number)		1000-grain weight (g)	Yield/hill (g)	Total dry matter /Hill (g)	Harvest index
					Filled	Unfilled				
Binadhan 4	91.32 b	10.58 a	11.08 a	19.30 c	64.88 d	18.65 d	27.29 a	15.41 a	32.43 b	0.48 b
Binashail	117.4 a	9.50 b	7.92 c	23.37 a	84.08 b	54.13 a	19.51 c	10.74 d	41.48 a	0.26 d
Brridhan 33	87.14 c	8.83 b	7.75 c	19.48 bc	76.74 c	24.22 c	27.46 a	13.56 c	27.86 c	0.49 a
Shorna	83.56 d	10.50 a	9.00 b	19.82 b	94.72 a	38.97 b	21.52 b	14.97 b	41.81 a	0.36 c
$LSD_{(0.05)}$	1.06	0.81	0.65	0.35	0.68	1.83	0.34	0.24	0.38	0.003

Common letter (s) within the column do not differ significantly at 5% level of significance analyzed by DMRT Values used in this table are the means of 3 replications over 4 treatments

Table 3: Soil moisture stress (30% of field capacity) effect on some agronomic and physiological growth parameters in different rice varieties

Varieties	Treatments	Plant height (cm)	Number/Hill		Length of panicles (cm)	Grains/panicle (Number)		1000-grain weight (g)	Yield/ Hill (g)	Total dry matter/Hill (g)	Harvest index
			Tillers	Panicles		Filled	Unfilled				
Binadhan4	Control	95.4 d	11.0 ab	11.3	20.3 de	66.1 l	19.2 g	27.8 a	16.8 b	36.1 e	0.46 e
	Stress at booting	94.2 de	10.7 abc	11.0	19.2 gh	65.7 l	13.7 h	27.0 b	15.6 c	33.2 f	0.47 d
	Stress at flowering	95.5 de	10.7 abc	11.0	19.6 efgh	59.6 j	24.4 f	26.9 b	14.1 e	30.0 ij	0.47 d
	Stress at grains filling	82.2 h	10.0 abcd	11.0	18.2 l	68.2 h	17.4 g	27.5 ab	15.2 cd	30.5 hi	0.50 d
Binashail	Control	124.8 a	10.3 abcd	8.0	24.8 a	123.5 a	63.3 a	20.5 de	14.8 d	51.3 a	0.28 j
	Stress at booting	124.1 a	9.0 cde	8.0	24.0 b	81.6 f	53.6 b	19.9 e	10.4 j	43.0 c	0.24 k
	Stress at flowering	116.2 b	9.3 bcde	8.0	22.6 c	60.0 j	55.3 b	18.9 f	8.7 k	40.8 d	0.21 l
	Stress at grains filling	104.7 c	9.3 bcde	7.7	22.1 c	71.3 g	44.3 c	18.8 f	9.1 k	30.9 gh	0.29 j
Brridhan33	Control	92.4 e	9.3 bcde	8.0	20.4 d	88.2 d	23.6 f	27.8 a	16.6 b	31.6 g	0.52 a
	Stress at booting	86.5 f	8.7 de	7.3	18.9 h	65.2 l	19.0 g	27.5 ab	11.6 l	23.9 l	0.48 c
	Stress at flowering	83.7 gh	8.3 e	8.0	19.7 defg	84.1 e	27.6 f	27.5 ab	12.6 gh	26.5 k	0.47 d
	Stress at grains filling	86.0 f	9.0 cde	7.7	18.9 h	69.4 h	26.7 f	27.1 ab	13.5 f	29.4 j	0.46 f
Shorna	Control	86.6 f	11.7 a	10.0	20.3 de	109.7 b	25.1 f	22.6 c	19.5 a	50.5b	0.38 g
	Stress at booting	79.8 l	9.3 cde	8.3	19.2 fgh	87.6 d	40.0 d	20.4 de	12.4 h	36.8 e	0.33 l
	Stress at flowering	84.6 fg	11.0 ab	9.0	19.8 defg	91.3 f	55.3 b	20.8 d	15.0 d	43.0 e	0.35 h
	Stress at grains filling	83.2 gh	10.0 abcde	8.7	20.0 def	100.3c	35.4 e	22.3 c	13.0 fg	36.9 e	0.35 h

Common letter (s) within the column do not differ significantly at 5% level of significance by DMRT Values used in this table are the means of 3 replications.

stage, Shorna produced the highest (15.0 g) grain yield followed by Binadhan4 (14.1 g), Brridhan33 (12.6 g) and Binashail (8.7 g). When stress imposed at grain filling stage, the highest (15.2 g) yield was found in Binadhan4 followed by Brridhan33 (13.5g), Shorna (13.0g) and Binashail (9.1 g) (Table 3).

Soil moisture stress at booting, flowering and grain filling stage decreased total dry matter (TDM) significantly (Table 1) over control. TDM was more affected by the stress at grain filling stage. The results are in confirmation with Gupta and O'Toole (1986) who observed reduced crop growth in rice as affected by the degree and duration of water deficit. TDM of varieties also differed significantly (Table 2). Shorna (41.8 g) and Binashail (41.4 g) produced similar total dry matter under the stresses. The second position ranked with Binadhan4 (32.4 g) followed by Brridhan33 (27.8 g). Interaction effect of genotypes and their growth stages showed that under stress at booting stage, Binashail performed the best (43.0 g) in TDM production followed by Shorna (36.9 g), Binadhan4 (33.2 g) and Brridhan33 (23.9 g) (Table 3). When stress imposed at flowering stage, Shorna performed best (43.0 g) followed by Binashail (40.8 g), Binadhan4 (30.0 g) and Brridhan33 (26.5g). Shorna produced the highest (36.9 g) total dry matter under stress at grain filling stage followed by Binashail (30.9 g), Binadhan4 (30.5 g) and Brridhan33 (29.4 g). The result agrees with Subbaiah (1985).

Harvest index (HI) values (Table 1) show that it decreased due to water stress at booting, flowering and grains filling stage. Stress at flowering stage caused the highest (0.37) reduction in HI followed by booting (0.38) and grains filling stages (0.40). These values were significantly lower than that of control. This might be due to the fact that water stress affected the translocation towards the grains of the plants, stressed at flowering and booting stages. HI values differed significantly among varieties (Table 2). The highest harvest index value was found in Brridhan33 (0.49) and the lowest in Binashail (0.26) under water stress treatments. Interaction effect (Table 3) shows that water stress reduced HI in most of the genotypes. In Binadhan4, higher HI (0.47) in stress treatments than control (0.46) indicated that water stress affected biological yield more than economic yield. HI values indicate the efficient translocation of assimilates towards sink. Lower HI values under stress at booting and flowering stages indicate that it was more harmful in translocation of assimilates towards the grains over grains filling stage. Different varieties showed different ability of translocation under moisture stress. This result is in conformity with Subbaiah (1985), who also observed varietal differences in the pattern of dry matter partitioning within the plant parts of the two varieties.

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