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Article

Effect of submergence durations on yield and yield contributing characters of hybrid and inbred *aman* rice

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Abstract: The trend of increasing submergence has a negative effect on the rice yield but among them, some of the genotypes show the excellent performance to give a satisfactory yield. The experiment comprised of two factors-factor a: submergence duration (4): control, 6 days, 10 days and 14 days and factor b: rice variety (6): hybrid (BRRI Hybrid dhan3, ACI Shankar and Heera-2) and inbred (BRRI dhan34, BRRI dhan46 and BRRI dhan51). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Significant variation was found on different yield contributing characters and yield with submergence durations. In all the varieties, the control treatment (0 days submergence) showed the highest values (except the number of unfilled spikelets panicle^{-1}) and was gradually decreased with increasing submergence duration from 6 days to 14 days. The lowest reduction due to submergence was recorded in BRRI dhan51, which was followed by BRRI dhan46. Attaining better yield, which was near about control, the varieties BRRI dhan51 and BRRI dhan46 proved them as relatively submergence tolerant compared to other varieties.

Keywords: submergence; hybrid; inbred; rice; yield

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of more than three billion people in the world; and most of them live in Asia (IRRI, 2009). It is cultivated under diverse ecologies ranging from irrigated to rainfed and upland to lowland deep water. Approximately 75% of the total cultivated land covering about 11.58 million hectares produces approximately 30 million tons of rice annually (BBS, 2008). The second largest part of the total production of rice comes of *aman* rice after *boro*. The yield of rice in Bangladesh is much lower than that of rice in other rice-growing countries of the world. The population of Bangladesh is still increasing by 2.3 million every year to its total of 150 million and may increase by another 30 million over the next 20 years (Momin and Husain, 2009).

Horizontal expansion of rice area in Bangladesh is not possible due to limited land resources, as land availability for crop production has been declining day by day because of population pressure and rapid urbanization. So, the only avenue left is to increase the production of rice vertically. Although the soil and climate of Bangladesh are favorable for rice cultivation throughout the year but per hectare yield of this crop is much below the potential yield level. The reasons are manifolds, some are varietals, some are technological and some are ecological. On the contrary every year thousands of hectares of lands are bared and remain uncultivated due to different reasons, we can increase our rice production by utilizing these lands among them flash flood in *aman* season is one of the main reasons for remaining rice fields uncultivated. Among the different biotic and abiotic stresses affecting rice production, submergence has been identified as the third most important constraint for higher rice productivity causes total yield loss (Sarkar *et al*., 2006). Flooding is one of the effects of climate change. An economic loss up to one billion US dollars has been estimated in South and south-east Asia due to loss of rice production caused by flash floods (Mackill *et al*., 2006). Scientists have estimated that 4 million tons of rice is being lost every year because of flooding (IRRI, 2008). The negative impact of submergence on

economic plants is mainly related to a poor gas exchange under water through impeding biochemical activities such as aerobic respiration and photosynthesis (Das *et al.,* 2005; Bailey- Serres and Voesenek, 2008; Colmer and Voesenek, 2009). Modification of morphology and anatomy of shoots and switching the energy conversion modes from aerobic to anaerobic respiration can ameliorate the negative effects of submergence (Fukao *et al.,* 2006; Mommer *et al.,* 2007). Zhang *et al.* (2015) found an increasing panicle number and decreasing grain number per panicle and seed-setting rate as the submergence duration and depth increased. Haque *et al.* (2015) found that a total grain per panicle was significantly influenced by the interaction effect of water levels and seedling number hill^{-1}. Elanchezhian *et al.* (2013) found that the range of grain yield in the control condition was 2.65–6.14 t ha^{-1}, whereas it varied from 0.13 to 3.18 t ha^{-1} under submergence stress. Submergence up to 14 days caused significant decrease in the survival of most of the rice genotypes, and the average survival was 59.71 % (Elanchezhian *et al.,* 2013).
Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time the total rice area will also shrink to 10.28 million hectares. Rice (clean) yield, therefore needs to be increased from the present 2.45 to 3.74 t ha^{-1} (BRKB, 2007). Therefore, it is an urgent need of the time to increase the production of rice through increasing the yield ha^{-1}. Among the various factors limiting rice yield, submergence is a very important one. Based on the facts, the experiment was under taken to study the effects of submergence on yield contributing characters and yield of different hybrid and inbred *aman* rice.

2. Materials and Methods

2.1. Experimental site

The experiment was conducted at the Research Field of Sher-e-Bangla Agricultural University, Dhaka-1207 during June 2017 to September 2017. The soil of the experimental field belongs to the general soil type, shallow red brown terrace soil with silty clay in surface and silty clay loam in sub-surface region. Soil pH was 6.7 and has organic carbon 0.45%.

2.2. Treatments and experimental design

The experiment consists of six rice varieties such as hybrid (BRRI Hybrid dhan3, ACI Shankar and Heera-2) and inbred (BRRI dhan34, BRRI dhan46 and BRRI dhan51) among them one BRRI (Bangladesh Rice Research Institute) released submergence tolerant check variety (BRRI dhan46) and four submergence treatments were 0 days or control, 6 days, 10 days and 14 days. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 4m x 3m. The spacing between block was 1 m and between plots 0.5 m. Seedlings of submerged plots were kept under 6 cm water by adding water with regular monitoring unless the specific durations were obtained. After the specific time being was over, the water was drained out from those plots.

2.3. Planting time and procedure

The seedlings were raised in seedbed and Eighteen days old seedlings were transplanted in the experimental plot. Various submergence treatments maintaining the standard spacing of 25 cm x 15cm with one seedlings hill^{-1}.The fertilizers were applied as per recommendation and other intercultural operations were done whenever necessary.

2.4. Data collection

Ten plants were selected randomly from each plot. Data on the following parameters were recorded during the period of experiment such as:- Number of effective tiller hill^{-1}, panicle length (cm), 1000 grain weight (g), filled spikelets panicle^{-1}, unfilled spikelets panicle^{-1}, total spikelets panicle^{-1}, grain yield (t ha^{-1}), straw yield (t ha^{-1}) and biological yield (t ha^{-1}).

2.5. Statistical analysis

All the collected data were tabulated and analyzed statistically using analysis of variance technique and subsequently, least significance difference (LSD at 5%) for comparing the treatment means, by MSTAT-C software (Gomez and Gomez, 1984).

3. Results and Discussion

The data on various yield parameters showed statistically significant variation due to rice varieties and different duration of submergence.

3.1. Effective tillers hill^{-1}

The highest number of effective tillers hill^{-1} (10.24 hill^{-1}) was recorded from the treatment combination of BRRI dhan51 when treated with no submergence whereas, the lowest number of effective tillers hill^{-1} (6.322 hill^{-1}) was recorded from the treatment combination of BRRI Hybrid dhan3 with submergence for 14 days. A decreasing trend in effective tillers hill^{-1} was shown by all the varieties as the duration of submergence increased. The number of the effective tillers is one of the major yield determinants. The genotype in which the reduction of effective tiller due to submergence is lower is considered as submergence tolerant because the high tillering ability is desirable for achieving maximum yield. Due to submergence the formation of tiller bud might hamper which decreased the tiller number. Hanada *et al.* (1990) suggested that the lack of oxygen for respiration or accumulation of ethylene might inhibit tiller bud formation and growth. However, the loss in tillers per unit area could not be compensated for in the sensitive genotypes because of the drastic decrease (up to 98 %) in survival (Singh *et al.*, 2014).

3.2. Panicle length

The largest panicle length (25.84 cm) was recorded from the BRRI dhan51 when combined with no submergence while, the lowest panicle length (22.78 cm) was recorded from BRRI Hybrid dhan3 when combined with submergence for 14 days. The results are conformity with Hushine (2004) who stated that panicle length was affected by the number of seedlings hill^{-1}.

3.3. Filled spikelets panicle^{-1}

The highest number of filled spikelets panicle^{-1} (108.24) was recorded from the treatment combination BRRI dhan51 with no submergence whereas, the lowest number of filled spikelets panicle^{-1} (38.17) was recorded from ACI Shankar with submergence for 14 days. Mahapatra (2017) found a significant difference among the cultivars as regard to number of grains panicle^{-1}.

3.4. Unfilled spikelets panicle^{-1}

The lowest number of unfilled spikelets panicle^{-1} (24.76) was recorded from BRRI dhan51 when treated with no submergence whereas, the highest number of unfilled spikelets panicle^{-1} (74.10) was recorded from treatment combination BRRI Hybrid dhan3 and submergence for 14 days.

3.5. Total spikelets panicle^{-1}

The higher number of total spikelets panicle^{-1} (135.46) was recorded from treatment combination of BRRI Hybrid dhan3 with no submergence and it was statistically similar (133.9) to BRRI dhan51. In contrast the lower number of total spikelets panicle^{-1} (100.7) was recorded from BRRI dhan34 when treated with submergence for 14 days. Due to submergence, the vegetative dry matter became lower. The injury level might higher and for this their maintenance cost was also higher which ultimately affect the reproductive growth and development. On the other hand, the chlorophyll content and gas exchange was lower; which might affect the current photosynthesis. As a result, all the spikelets did not get sufficient photosynthates and finally the filler grain number became lower. However, in Heera-2, the filled grain number plant^{-1} was less affected in every submergence treatment compare to other genotypes; indicates its submergence tolerance character.

3.6. 1000-grain weight

The maximum 1000-grain weight (26.58 g) was recorded from BRRI dhan51 when treated with no submergence while, the minimum 1000-grain weight (21.21 g) was recorded from ACI Shankar when treated with submergence for 14 days. 1000-grain weight decreased with increase in the duration of submergence in every variety. Decreased seed size in submerged treatment might be due to improper grain filling; though the difference was not significant. Nugraha *et al.* (2012) stated that the lowest 1,000-grain weight under submergence conditions was due to improper grain filling and uneven filling stage, therefore, at harvest the grains had different maturity stages thus lowered seed weight. Zhang *et al.* (2015) did not found any significant difference between control and submergence treated plant.

3.7. Grain yield

The highest grain yield (3.907 t ha^{-1}) was recorded from treatment combination of BRRI dhan51 when treated with no submergence whereas, the lowest grain yield (2.197 t ha^{-1}) was recorded from ACI Shankar when treated with submergence for 14 days. Grain yield decreased with an increase in the duration of submergence in every variety. If we calculate grain yield reduction (%), we can observe that highest reduction of yield was shown by ACI Shankar followed by BRRI dhan34 at 14 days submergence compare to control, while BRRI dhan46, BRRI dhan51 and BRRI Hybrid dhan3 showed better performances at the same submergence treatment. The relative grain yield indicated that at 6 days treatment BRRI Hybrid dhan3 was less affected and ACI Shankar was more affected. At 10 days treatment BRRI dhan51 was less affected and ACI Shankar was more affected. Whereas at 14 days treatment BRRI dhan46 was less affected and ACI Shankar was more affected compare to other. Reduction in grain yield due to submergence could be depended on injury, experienced by submergence treatment, as well as tolerant level of various genotypes. The higher the genotypes tolerance to flooding conditions, the higher the yield can be produced. Elanchezhian *et al*. (2013) found that the range of grain yield in control condition was 2.65–6.14 t ha^{-1}, whereas it varied from 0.13 to 3.18 t ha^{-1} under submergence stress. Wang *et al.* (2014) investigated the influence of slight submergence (2 and 4 d) on mid-season rice at the final phase of the tilling stage and found that the yields of the experimental groups were close to those of the control group.

3.8. Straw yield

The maximum straw yield (6.407 t ha^{-1}) was recorded from Heera-2 combined with no submergence whereas, the minimum straw yield (3.377 t ha^{-1}) was recorded from BRRI dhan34 and submergence for 14 days.

3.9. Biological yield

The highest biological yield (9.15 t ha^{-1}) was recorded from treatment combination BRRI dhan51 and no submergence whereas, the lowest biological yield (6.056 t ha^{-1}) was recorded from BRRI dhan34 which was statistically similar with BRRI Hybrid dhan3 (6.064 t ha^{-1}) when they were treated with submergence for 14 days.

Table 1. Effect of different submergence durations on number of effective tiller, panicle length, filled spikelets, unfilled spikelets and total spikelets of hybrid and inbred *aman* rice.

Submergence durations	Varieties	Number of effective tiller $hill^{-1}$	Panicle length (cm)	Filled spikelets $panicle^{-1}$	Unfilled spikelets $panicle^{-1}$	Total spikelets $panicle^{-1}$
Control or no submergence	BRRI dhan46	9.22 abc	25.34 abcd	104.9 ab	24.82 f	129.17 bc
	BRRI Hybrid dhan3	9.50 abc	25.77 ab	86.11 b	49.35 d	135.46 a
	BRRI dhan51	10.24 a	25.84 a	108.24 a	24.76 f	133.9 a
	Heera-2	9.28 abc	25.76 ab	67.93 b	54.48 cd	127.1 c
	ACI Shankar	9.00 abc	25.30 abcd	66.97 d	56.15 c	123.1 d
	BRRI dhan34	10.02 ab	25.73 abc	67.05 d	56.19 c	132.7 b
Submegence for 6 days	BRRI dhan46	7.92 cdefg	24.84 abcd	86.03 b	29.48 ef	112.6 f
	BRRI Hybrid dhan3	9.08 abc	24.74 abcd	63.55 d	63.19 b	126.7 c
	BRRI dhan51	8.98 abc	24.68 abcd	86.11 b	28.96 ef	113.0 f
	Heera-2	8.86 abcd	24.70 abcd	63.47 d	63.15 b	126.6 c
	ACI Shankar	7.70 cdefg	24.80 abcd	55.63 e	56.82 c	112.4 fg
	BRRI dhan34	8.76 abcde	24.64 abcd	55.71 e	56.86 c	112.8 f
Submergence for 10 days	BRRI dhan46	7.89 cdefg	24.81 abcd	81.27 b	30.82 ef	111.1 f
	BRRI Hybrid dhan3	8.27 abcdefg	24.24 abcd	52.48 ef	64.52 b	117.0 e
	BRRI dhan51	8.83 abcd	23.31 abcd	81.35 b	30.86 ef	116.9 e
	Heera-2	8.05 bcdefg	24.20 abcd	55.10 e	64.48 b	116.9 e
	ACI Shankar	7.67 cdefg	24.77 abcd	52.41 ef	56.82 c	105.3 i
	BRRI dhan34	8.61 abcdef	23.27 abcd	52.40 ef	56.86 c	108.1 hi
Submergence for 14 days	BRRI dhan46	6.90 defg	24.64 abcd	74.17 c	36.82 e	110.99 f
	BRRI Hybrid dhan3	6.32 g	22.78 d	39.12 g	74.10 a	123.5 d
	BRRI dhan51	8.82 abcd	23.11 abcd	74.25 c	32.89 e	107.13 i
	Heera-2	6.77 efg	24.07 abcd	52.40 ef	75.06 a	109.6 gh
	ACI Shankar	6.68 fg	24.60 abcd	38.17 g	68.82 b	117.0 e
	BRRI dhan34	8.60 abcdef	22.90 cd	48.25 f	68.86 b	100.7 j
$LSD_{0.05}$		1.766	2.47	4.938	5.224	2.991
CV (%)		2.82	1.92	1.61	3.67	2.49

In a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

Table 2. Effect of different submergence durations on 1000-garin yield, grain yield, straw yield and biological yield of hybrid and inbred *aman* rice.

Submergence durations	Varieties	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Control or no submergence	BRRI dhan46	23.05 cdefg	3.107 c	5.347 b	8.454 ab
	BRRI Hybrid dhan3	24.32 abcde	3.077 c	5.367 b	8.444 abc
	BRRI dhan51	26.58 a	3.907 a	5.247 b	9.150 a
	Heera-2	24.28 abcde	3.067 c	6.407 a	9.474 ab
	ACI Shankar	23.01 defg	3.537 b	5.421 b	8.964 abc
	BRRI dhan34	6.54 a	3.817 ab	5.307 b	9.124 a
Submergence for 6 days	BRRI dhan46	22.68 efg	2.677 def (86%)	4.517 cde	7.194 cd
	BRRI Hybrid dhan3	24.08 abcdef	3.047 c (99%)	4.640 cd	7.687 bcd
	BRRI dhan51	26.22 ab	3.597 b (92%)	4.977 ghi	8.574 ab
	Heera-2	24.04 abcdef	2.637 def (86%)	4.577 cde	7.214 cd
	ACI Shankar	22.64 efg	3.007 c (85%)	4.700 c	7.707 cd
	BRRI dhan34	26.18 ab	3.557 b (93%)	4.037 fgh	7.594 cd
Submergence for 10 days	BRRI dhan46	22.42 efg	2.597 def (84%)	4.387 cdefg	7.144 cd
	BRRI Hybrid dhan3	24.05 abcdef	2.667 def (87%)	3.977 ghi	6.644 cd
	BRRI dhan51	25.88 abc	3.387 b (87%)	4.767 efgh	8.154 ab
	Heera-2	24.01 abcdef	2.557 def (83%)	4.447 cdef	7.164 cd
	ACI Shankar	22.38 efg	2.627 def (74%)	4.037 fgh	6.664 cd
	BRRI dhan34	25.84 abcd	3.147 c (82%)	4.227 defgh	7.364 bcd
Submergence for 14 days	BRRI dhan46	21.25 fg	2.527 def (81%)	4.617 cde	6.984 cd
	BRRI Hybrid dhan3	22.41 efg	2.475 f (80%)	3.581 ij	6.064 d
	BRRI dhan51	25.68 abcd	3.127 c (80%)	4.317 cdefg	7.444 cd
	Heera-2	23.58 bcdefg	2.287 ef (75%)	4.717 cd	7.004 cd
	ACI Shankar	21.21 g	2.197 g (62%)	3.897 hi	6.354 d
	BRRI dhan34	25.64 abcd	2.687 de (70%)	3.377 j	6.056 d
LSD $_{0.05}$		2.47	0.185	1.4078	1.606
CV (%)		1.78	1.18	1.37	1.29

In a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4. Conclusions

The highest grain yield was found from the crop treated with no submergence in all the genotypes. On the contrary, submergence for 14 days resulted from the lowest grain yield. Less affected grain yield, straw yield and total biological yield in BRRI dhan46 and BRRI dhan51 due to submergence treatment indicated that these genotypes were more submergence tolerant than the other varieties of the experiment.

Conflict of interest

None to declare.

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