Effect of Flooding on Germination, Yield and Yield Components of Aus Rice Cultivars

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ABSTRACT

In *Kharif I* season direct seeded local Aus rice cultivation is a common practice in the coastal non saline area of Bangladesh. The crop during this period is vulnerable to various abiotic stresses like tidal flood which goes for several days making uncertain germination and poor establishment of the crop. An experiment was carried out in pots to evaluate the effect of artificial flooding on germinability and yield contributing characters of thirty aus rice genotypes. The experiment was conducted in the Agronomy Field Laboratory of Patuakhali Science and Technology University, Dumki, Patuakhali during the period from April-July 2016. Two treatments *viz.* flooding and non-flooding were imposed on each variety. The experiment was laid out in randomized complete block design with two replications. The result of the experiment showed that varieties under non-flooding condition performed better over flooded condition. Germination was reduced by 31.58% in flooding situation. However, the cultivar Abdul Hai gave maximum germination (84.00%) under flooding condition. Flooding also reduced plant height, total number of tillers per hill, number of effective tillers, panicle length, number of filled grains panicle^{-1}, 1000 grain weight, grain yield, straw yield and harvest index by 1.96%, 23.07%, 28.34%, 4.13%, 8.41%, 4.50%, 11.86%, 7.48% and 3.48%, respectively. Flooding interaction with cultivars revealed that highest effective tillers per hill (39.50), grains panicle^{-1} (144.25), and 1000 grain weight (40.38 g), grain yield (76.17 g plant^{-1}), straw yield (116.53 g plant^{-1}) and harvest index (39.53%) were recorded in Abdul Hai. Correlations among characters under flooded condition showed that grains panicle^{-1}, grain yield, straw yield and harvest index were significantly and positively correlated with germination percentage. Hierarchical cluster analysis showed that five cultivars *viz.* BR2, Kali Haitta, Sada Jamai Babu, Abdul Hai and Halai had maximum mean germination percentage (72.20%) and mean grain yield (69.84 g plant^{-1}). These results suggests that variety Abdul Hai is more tolerant to submergence than other varieties.

Keywords: Germination, Flooding, yield, Cultivars, Aus rice

INTRODUCTION

Bangladesh is one of the vulnerable countries where crop production is most likely to suffer adverse impacts from anthropogenic climate hazard. Besides, due to the large share of the agricultural sector in the overall output of the country's economy, the study of climate change impacts on Bangladesh agriculture has achieved recent attention. Karim et al. (1996) conducted a simulation study to assess the vulnerability of food grain production (rice and wheat) in six locations of Bangladesh to potential climate change such as enhanced CO2, drought and temperature. The results of the study showed that increased levels of CO2 increased yields of rice in all locations Rimi et al. (2009) have conducted a study on the trend and prediction of future climate change scenarios with Global Climate Model (GCM) to examine the impacts of climate change on rice production. The study concluded that temperature variations had spectacular implications on crop yield. The production of Aus rice (summer crop) has decreased significantly with increasing maximum temperature, whereas the production of Boro rice (winter crop) has increased significantly with the increase of minimum temperature. The inter-annual fluctuation in the amount of winter season rainfall was littleRice(Oryza sativa L.) is the staple food for fifty percent population of the world (IRRI, 2015),and it is the staple food of South East Asian countries like Bangladesh, India, Srilanka etc. and people of these areas consume most of their daily calories from rice. In Bangladesh about 77% land (11.42 Mha) is under rice cultivation out of 14.94 Million ha (Mha) total cropped area. Rice is grown in the three crop growing seasons *viz.*Aus, Aman and Boro. Most of the rice area is covered by Aman rice (5.62 Mha) followed by boro (4.76 Mha) and aus is far behind from other two seasons (1.05 Mha) (Salam *et al.*, 2014). Aus and Aman seasons are rainfed but boro is irrigated which is not cost effective since considerable amount of electric power and fuel is used for irrigation. For instance, government of Bangladesh is trying to decrease Boro area and giving emphasis on increasing aus coverage. But the main drawback is that average yield of aus rice (2.16 T/ ha) is lower than aman and boro season. Beside this in the southern region of Bangladesh most of the farmers cultivate direct seeded or dibbled local aus rice whose yield potential is very low. Again, sub-soil water is mining for irrigation which exerts a negative impact on our natural resources.

Rice cultivation is affected by different types flash floods which are – 1) flash floods caused by hilly rivers in the north-eastern region of Bangladesh 2) flash flood caused by damage congestion due to construction of unplanned infra-structure, 3) monsoon floods caused by major rivers in flood plains of the country, and 4) coastal floods caused by tidal and cyclonic surges. However, very few studies have been done in Bangladesh to investigate the pattern and trend of rainfall, temperature, relative humidity, solar radiation, heat budget and energy balance on various ecosystem, and meteorological application on rice production.

Furthermore, although direct seeding is advantageous over transplanting in Bangladesh because of labor requirement (Tuong*et al*,. 1993), many prime quality and high yielding rice cultivars are not good performers in direct seeding, resulting in slow development of direct seeding technology in flood-prone area. For its wider cultivation in flood-prone areas, rice cultivars are required to have tolerance to low oxygen levels during germination and adaptability to direct seeding. Enhancement in the genotypic tolerance to anaerobic conditions during germination is much more inexpensive for poor farmers in developing countries and is more feasible for adoption on a larger scale than other management practices (e.g., coating seeds with calcium peroxide which supplies oxygen to the rice seeds under flooding conditions). Unfortunately, very limited success has been achieved from previous efforts to improve the tolerance of genotypes for anaerobic conditions during germination (Jiang *et al.*, 2004). For instance, Angaji *et al.* (2009) reported that tolerance to flooding during germination seems relatively rare in rice. After screening over 8000 gene bank accessions, elite breeding lines and genotypes, they identified few genotypes with greater ability to germinate under flooding condition; only 0.23% of all accessions were identified with a reasonably high level of tolerance in the initial screening. Subsequent evaluation in replicated trials reduced this number even further i.e., 0.06% (Jiang *et al.*, 2006). Information available on anaerobic aus rice production is limited, particularly under Bangladesh condition. Therefore, the present study was undertaken to achieve the following objectives.

1. To determine the effect of flooding on germination and yield of Aus rice.
2. To evaluate the interaction effect of flooding and cultivars on germination and yield of Aus rice.
3. To identify flood tolerant cultivar for germination and yield of Aus rice.

MATERIALS AND METHODS

Experimental site and period

The experiment was conducted in pot at the Agronomy Research Field (net house) of Patuakhali Science and Technology University (PSTU) during the period from April, 2016 to July, 2016.

Plant materials

Thirty aus rice varieties, local and high yielding, were used in the experiment. The seeds of local aus rice varieties were collected from local farmers and high yielding varieties were collected from Bangladesh Rice Research Institute (BRRI). Table 1 presents the list of thirty aus rice varieties.

Germination test

Germination test was done for each variety before go for the study. All of the varieties showed germination percentage not less than 95%.

Fertilizer application

Fertilizer doses were 77 kg N, 17 kg P, 17 kg K and 3 kg Zn hectare^{-1} (BARRI, 2007) which corresponded to 306 mg, 68 mg, 68 mg pot^{-1} of N, P, K and Zn respectively. Full doses of TSP, MOP and Zn and 50% urea were incorporated into the soil by hands before transplanting. Remaining 50% urea was applied at 15 days after submergence. Details presents in appendix Each pot contained 8 kg soil.

Table 1: List of aus varieties used in the experiment

Sl. no.	Name of the variety	Source of collection
1.	BR2	BRRI,Gazipur
2.	BR3	BRRI, Gazipur
3.	BR14	BRRI, Gazipur
4.	BR16	BRRI, Gazipur
5.	BR21	BRRI, Gazipur
6.	BR24	BRRI, Gazipur
7.	BRRI dhan26	BRRI, Gazipur
8.	BRRI dhan-27	BRRI, Gazipur
9.	BRRI dhan-28	BRRI, Gazipur
10.	BRRI dhan-42	BRRI, Gazipur
11.	BRRI dhan-43	BRRI, Gazipur
12.	BRRI dhan-48	BRRI, Gazipur
13.	BRRI dhan-55	BRRI, Gazipur
14.	BRRI dhan-65	BRRI, Gazipur

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15.	BINA dhan-7	BINA, Mymensingh
16.	BINA dhan-10	BINA, Mymensingh
17.	IRRATOM-24	BINA, Mymensingh
18.	Mansur IRRI	Local, Patuakhali
19.	Abdul High	Local, Mirjagang
20.	LalJamaiBabu	Local, Khulna, Satkhira
21.	SadaJamaiBabu	Local, Khulna, Satkhira
22.	Parija	Local, Rangpur, Dinajpur
23.	Manikmuri	Local, Barisal, Patuakhali
24.	Benamuri	Local, Barisal, Patuakhali
25.	Matichak	Local, Dumki
26.	Mahisur	Local, Barisal
27.	AusBoro(awned)	Local, Mirjagang
28.	Kali Haitta	Local, PatuakhaliSadar
29.	Halai	Local, Patuakhali
30.	Tepu	Local, Patuakhali

Pot preparation

Each earthen pot (26 cm diameter at the top, 19 cm diameter at the bottom and 30 cm height.) were used for this study. The pots were filled with soils mixed with fertilizer. The pots were filled with soils mixed with fertilizer. Then the soil was soaked with water and made puddle and kept for seven days to reduce volatile gasses.

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) with two replications. Each pot was considered as experimental unit and there were 120 pots in total. Each variety was tested with two treatments, flooding and non-flooding.

Seed treatment, seed sowing and seedling growing

Prior to go for germination, the seeds were treated with disinfectant @ 2% sodium hypochlorite for 15 minutes. Twenty five dry seeds of each variety were sown in each pot on 5 April 2016 and then treatments were imposed. Pots with flooding treatments were kept waterlogged at 10 cm depth for seven days and then drained out to allow germination. Non-flooding pots were kept wet to avoid drying. After next seven days germination percentage was calculated. When seedling establishment completed then one healthy seedling was retained per pot for recording yield components and yield per plant and rest others were removed.

Data collection

Data were recorded on dissolved Oxygen germination (%), plant height (cm), number of tillers per plant, number of effective tillers per plant, number of non-effective tillers per plant, length of panicle (cm), number of filled grains per panicle, number of unfilled grains per panicle, 1000 grain weight (g), grain yield per plant (g), straw yield per plant (g) and harvest Index (%). These were recorded as.

(a) Dissolved Oxygen: The average dissolved Oxygen was 4.008 ppmin flood treatment.

(b) Germination (%): Twenty five seeds per replicate were placed in the pot. Germination count was recorded every 2 days for 8 days after sowing (DAS). Since no germination occurred under flooded condition, germination % was counted on the 8th day after drain out of water.

(c) Plant height: Plant height was taken from the ground level to the tip of the main stem at harvest and was expressed in cm.

(d) Number of tiller plant^{-1}: The total number of tillers was counted from each of the sample plant and the average was taken.

(e) Number of effective tiller plant^{-1}: The number of panicle bearing effective tiller was counted from each of the sample plant and the average was taken.

(f) Number of non-effective tillers plant^{-1}: The number of tillers with shriveled panicle was counted from each of the sample plant and the average was taken.

(g) Panicle length: Recorded as the distance (cm) from the last node of the rachis to the tip of the main panicle which was randomly selected from each plant and the average was taken.

(h) Number of grain panicle^{-1}: The spikelet with grain was considered as filled grain and counted from one randomly selected panicle from each plant and the average was taken.

(i) Number of sterile spikelet's panicle^{-1}: The spikelet without grain was considered as sterile spikelet's and counted from one randomly selected panicle from each plant and the average was taken.

(j) 1000-grain weight: Thousand seed weight was taken from each plant and adjusted at 14% moisture content.

(k) Grain yield: Total grain weight (g) of each plant of each pot was taken after cleaning and sun drying the samples and the average was taken at 14% seed moisture content.

(l) Straw yield: Straw from each replicate was oven dried at 70 ^{0}c until the constant was obtained.

(m) Harvest index: Harvest index was calculated by using the following formula-

$$\text{Harvest Index (\%)} = \frac{\text{Grainyieldperplant (g)}}{\text{Straw yield per plant (g)}} \times 100$$

Data processing and statistical analysis

Raw data were processed using MS Excel and analysis of variance over genotypes and flooding treatments were done with R software package Agricolae. For classification of genotypes according to their relative tolerance to flooding were subjected to hierarchical cluster analysis using SPSS 16 software package.

RESULTS

Thirty aus rice cultivars were used to carry out screening of flood tolerant genotype(s). Plant showed variability in germination percentage, plant height, tillering pattern, and panicle length, no. of filled and unfilled grains per panicle, grain yield, straw yield and harvest index compared to non-submerged condition

Effect of flooding treatment on growth and yield of thirty T. aus cultivars on Germination.

Flooding treatment showed significant difference in germ inability of Aus rice. Germination percentage was higher in non-flooding treatment (81.77%) than flooding treatment (55.95%). There was about 31.58%

reduction in germination when flooding was imposed. Flooding treatment delayed the germination of Aus rice. No germination was observed under flooded condition. When water was drain-out after one week, germination was started. In an average, germination was delayed one week in flooding treatment compared non-flooding treatment.

Effect of cultivars: Cultivars showed significant variation in germination. Germination percentage was found highest in Abdul Hai (89.50%), which was similar to Sada Jamai Babu (85.75%) followed by Tepu (81.00%) and Matichak (80.25%), and lowest germination was observed in BR3 (53%).

Interaction effect of flooding cultivar and on germination of aus rice:

Flooding had significant effect on germ inability of different cultivars of aus rice. Maximum germination was observed from variety Abdul Hai (95.00%) at non-flooding condition, which was statistically similar to BRRI dhan 65 (94.50%) and BR 14 (94.00%), and lowest germination was recorded from Benamuri (61.00%) under non-flooding condition. When flooding was imposed maximum germination was recorded from Abdul Hai (84.00%) and lowest from Mansur IRRI (27.00%). But germination reduction due to flooding was lowest in BRRI dhan 27 (-4.96%) and highest in BRRI dhan 43 (-64.57%) (Figure 1).

Table 2: Effect of flooding and non-flooding treatments on germination, plant height, Total number of tillers, number of effective tillers, number of non-effective Tillers and panicle length of T. aus rice

Treatment	Germination (%)	Plant height (cm)	Total Number of tillers / plants	Effective tiller (no.)/ plant	Non-effective tiller (no.)/ plant	Panicle length (cm)
Flooding	$55.95_{(-31.58\%)}$	$131.40_{(-1.96\%)}$	$28.68_{(-23.07)}$	$22.50_{(-28.34)}$	$6.10_{(14.02\%)}$	$21.14_{(-4.13\%)}$
Non-flooding	81.77	134.03	37.28	31.40	5.35	22.05
t value	-14.58*	-15.53**	-10.38**	-10.60**	2.54**	-9.32**

*= significant at 5% level, **= significant at 1% level, ns = Non significant and parentheses showing percent reduction over non-flooding treatment.

Table 3: Effect of flooding and non-flooding treatments on number of filled and unfilled Grains plant^{-1}, 1000 seed weight, grain yield plant^{-1}, straw yield plant^{-1} and harvest index of T. aus rice

Treatment	Number of filled grains per panicle	Number of unfilled grains	1000 grain weight (g)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest Index (%)
Flooding	$89.37_{(-8.41\%)}$	$25.61_{(12.97\%)}$	$29.09_{(-4.50\%)}$	$53.12_{(-11.86\%)}$	$91.62_{(-7.48\%)}$	$36.38_{(-3.48\%)}$
Non-flooding	97.58	22.67	30.46	60.27	99.03	37.69
t value	-8.54**	3.01**	-9.49**	-13.75**	-14.22**	-8.67**

*= significant at 5% level, **= significant at 1% level

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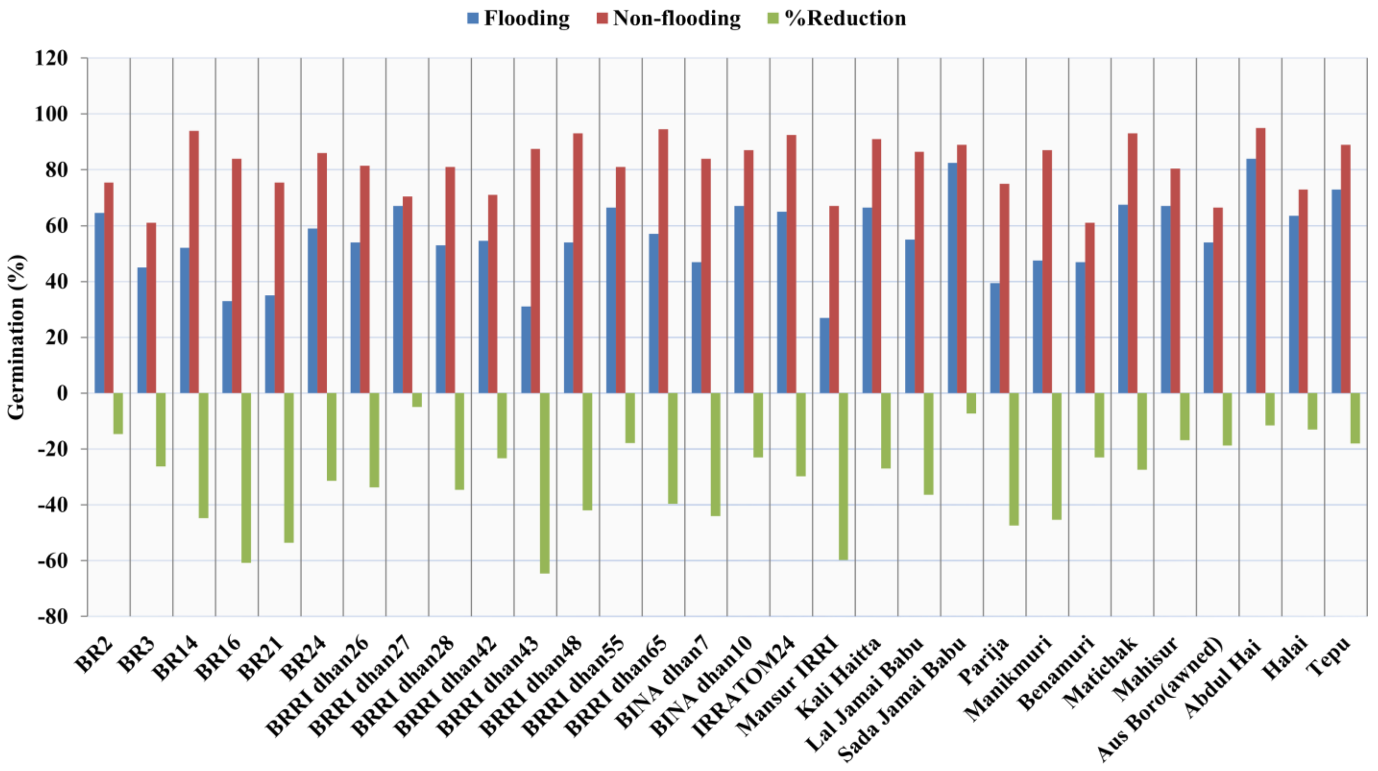

Figure 1: Germination percentage under flooding and non-flooding condition with percent reduction over non-flooding of aus rice

Effect of flooding

Panicle length varied significantly between flooding and non-flooding treatments. Non-flooding condition produced longer (22.05 cm) panicle than flooding condition (21.14 cm). Flooding reduced panicle length by 4.13%.

Effect of cultivar

Cultivars showed significant variation in panicle length. Longest panicle was produced from BINA dhan10 (22.73 cm) and BRRI dhan43 (22.72 cm), which was again statistically similar to Abdul Hai (22.41 cm) and BR 2 (22.40 cm), respectively.

Interaction effect of flooding and cultivars on length of panicle of aus rice

Significantly higher panicle length was observed in non-flooding condition. Highest panicle length (23.48 cm) was observed in BINA dhan10 which was statistically similar to Mansur IRRI (23.33 cm), BINA dhan7 (23.07 cm), BRRI dhan43 (23.07), Matichak (23.04 cm), Abdul Hai (23.03 cm) etc. Maximum reduction in panicle length was observed in Sada Jamai Babu (15.45%) and minimum in IRATOM24 (0.33%) though panicle length is significantly lower in both the varieties than highest one.

Number of grains panicle^{-1}

Effect of flooding

Number of grainspanicle^{-1}varied significantly due to flooding treatments. Significantly highest numbers of filled grains panicle^{-1} (97.58) was recorded from non-flooding condition than flooding condition (89.37),

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which was 8.41% less than non-flooding condition.

Effect of cultivars

Cultivars showed significant variations in the production of number of grains panicle^{-1}. Production of grains panicle^{-1} ranged from 55.58 to 146.78. Maximum number of grains panicle^{-1} (146.78) was produced from Abdul Hai followed by BR24 (135.85) and the lowest (55.58) from BR16.

Interaction effect offlooding and cultivar on number of grains plant^{-1}

Flooding and cultivars interaction showed significant variation in the production of grains panicle^{-1}. Highest number of grains plant^{-1} (149.30) was recorded from Abdul Hai under non-flooded condition. This variety also produced maximum (144.25) number grains plant^{-1} under flooded condition with 3.38% reduction.

Number of sterile spikelet panicle^{-1}

Effect of cultivar

The range of sterile spikelets panicle^{-1} production was between 6.58 to64.4. Benamuri produced highest number of sterile spikelets panicle^{-1}(64.4) followed by Manikmuri (44.68) while BR 3 produced lowest number of sterile spikelets panicle^{-1} (6.58).

Interaction effect of flooding and cultivar on number of sterile spikelets panicle^{-1}

Number of sterile spikelets panicle^{-1}in genotype Benamuri was significantly highest (73.00) in both flooding and non-flooding condition (59.75) and lowest sterile spikelets panicle^{-1} of 7 and 6.15 under flooding and non-flooding conditions, respectively was produced from BR3. BRRI dhan42 (4%) showed lowest reduction whilst Manikmuri (98.32%) showed highest reduction due to flooding stress.

Rice cultivar under flooding condition produced 4.50% less thousand grain weight than normal condition . Under non-flooding condition thousand grain weight was 30.46 g whereas under flooding condition it was 29.09 g.

Effect of cultivars

Thousand grains weight varied significantly among cultivars (Table 5). The range of thousand grain weight was between 20.9 g to 41.13 g. Variety Abdul Hai produced highest (41.13 g) thousand grain weight, while BR24 produced lowest (20.90 g) thousand grain weight.

Interaction effect of flooding and cultivars on thousand grain weight

There was significant effect of flooding and cultivars on thousand grain weight (Table 12). Variety Abdul Hai produced maximum thousand grain weight at both non-flooding (41.89 g) and flooding (40.38 g) condition. The lowest thousand grain weight was recorded from BR24 at both non-flooding (21.32 g) and flooding (20.47 g) condition, which was again statistically similar to BR21.

Table 4: Effect of cultivars on grain yield plant^{-1}, straw yield plant^{-1} and harvest index of T. aus rice.

Cultivars	Grain yield (g/plant)		Straw Yield (g/plant)		Harvest Index (%)	
BR2	68.99	C	109.01	cd	38.75	Bcde
BR3	41.90	R	78.71	r	34.50	Pq
BR14	62.55	Ef	102.83	f	37.84	Fgh

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BR16	44.25	Q	82.32	q	34.81	Op
BR21	47.96	Op	86.50	op	35.62	Mn
BR24	48.99	O	86.91	op	35.93	Lmn
BRRI dhan26	66.53	D	105.99	de	38.56	Cdef
BRRI dhan27	51.10	Mn	90.23	klm	35.94	Lmn
BRRI dhan28	51.02	Mn	88.49	lmno	36.56	Jkl
BRRI dhan42	46.16	Pq	84.99	pq	35.18	Nop
BRRI dhan43	45.27	Q	82.72	q	35.18	Nop
BRRI dhan48	49.35	No	87.36	mnop	36.09	Lm
BRRI dhan55	52.27	Lm	90.09	klmn	36.67	Jkl
BRRI dhan65	54.68	Jk	92.94	jk	36.99	Ij
BINA dhan7	53.47	Kl	90.99	kl	36.98	Ijk
BINA dhan10	39.14	S	76.52	r	33.75	Q
IRRATOM24	58.06	Hi	95.91	hij	37.70	Ghi
Mansur IRRI	69.69	C	109.61	c	38.86	Bcd
Kali Haitta	**73.46**	**B**	**113.65**	**b**	**39.26**	**Abc**
LalJamaiBabu	64.01	E	103.18	ef	38.28	Defg
SadaJamaiBabu	66.94	D	106.40	d	38.60	Cdef
Parija	56.24	Ij	94.85	ij	37.15	Hij
Manikmuri	59.09	Gh	97.11	ghi	37.82	Fgh
Benamuri	48.29	O	87.13	nop	35.53	Mno
Matichak	56.74	I	94.29	ij	37.56	Ghi
Mahisur	59.95	Gh	98.29	gh	37.88	Fgh
AusBoro(awned)	49.70	No	87.52	mnop	36.20	Klm
Abdul Hai	**79.05**	**A**	**120.26**	**a**	**39.66**	**A**
Halai	**75.40**	**B**	**115.93**	**b**	**39.40**	**Ab**
Tepu	60.67	Fg	99.01	g	37.99	Efg
$HSD_{0.05}$	1.97		3.05		0.79	
CV (%)	1.25		1.15		0.76	
Range	39.14-79.05		76.52-120.26		33.75-39.66	
SD (±)	10.35		11.27		1.57	

Table 5: Interaction effect of flooding and cultivars on percent germination and plant Height, and percent reduction over control of T. aus rice

Cultivar	Germination (%)				%Reduction	Plant height (cm)				%Reduction
	Flooding		Non-flooding			Flooding		Non-flooding		
BR2	64.50	n-q	75.50	ijk	-14.57	130.50	qr	134.75	p	-3.15
BR3	45.00	vw	61.00	pqr	-26.23	148.70	jk	150.50	ij	-1.20
BR14	52.00	tu	**94.00**	**a**	-44.68	128.50	rs	130.80	qr	-1.76
BR16	33.00	yz	84.00	e-h	-60.71	104.05	EF	105.50	EF	-1.37
BR21	35.00	xy	75.50	ijk	-53.64	138.75	o	142.75	n	-2.80
BR24	59.00	qrs	86.00	d-h	-31.40	128.45	rs	130.35	qr	-1.46

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BRRI dhan26	54.00	st	81.50	f-i	-33.74	130.58	qr	134.75	p	-3.09
BRRI dhan27	67.00	l-p	70.50	k-n	**-4.96**	155.50	gh	157.45	fg	-1.24
BRRI dhan28	53.00	stu	81.00	g-j	-34.57	116.00	zA	117.95	yz	-1.65
BRRI dhan42	54.50	st	71.00	klm	-23.24	124.50	tu	126.75	st	-1.78
BRRI dhan43	31.00	yz	87.50	b-f	**-64.57**	113.10	B	114.30	AB	-1.05
BRRI dhan48	54.00	st	93.00	ab	-41.94	112.00	B	117.95	yz	**-5.04**
BRRI dhan55	66.50	m-p	81.00	g-j	-17.90	105.20	EF	108.70	D	-3.22
BRRI dhan65	57.00	rst	**94.50**	**a**	-39.68	**103.50**	**F**	**104.70**	**EF**	-1.15
BINA dhan7	47.00	uv	84.00	e-h	-44.05	106.50	DE	109.10	CD	-2.38
BINA dhan10	67.00	l-p	87.00	b-g	-22.99	118.20	yz	119.95	wxy	-1.46
IRRATOM24	65.00	m-q	92.50	abc	-29.73	108.60	D	111.65	BC	-2.73
Mansur IRRI	**27.00**	**z**	67.00	l-p	-59.70	135.90	p	136.85	op	**-0.69**
Kali Haitta	66.50	m-p	91.00	a-d	-26.92	121.10	vwx	123.15	uv	-1.66
Lal Jamai Babu	55.00	rst	86.50	c-h	-36.42	128.50	rs	131.75	q	-2.47
Sada Jamai Babu	82.50	fgh	89.00	a-e	-7.30	117.90	yz	120.93	vwx	-2.51
Parija	39.50	wx	75.00	jk	-47.33	119.25	xy	122.10	uvw	-2.33
Manikmuri	47.50	uv	87.00	b-g	-45.40	145.25	lmn	147.65	kl	-1.63
Benamuri	47.00	uv	**61.00**	**pqr**	-22.95	162.75	e	167.35	bc	-2.75
Matichak	67.50	l-o	93.00	ab	-27.42	**169.55**	**ab**	**171.70**	**a**	-1.25
Mahisur	67.00	l-p	80.50	hij	-16.77	163.75	de	165.65	cd	-1.15
AusBoro (awned)	54.00	st	66.50	m-p	-18.80	149.75	jk	153.00	hi	-2.12
Abdul Hai	**84.00**	**e-h**	**95.00**	**a**	-11.58	143.50	mn	145.65	lm	-1.48
Halai	63.50	opq	73.00	kl	-13.01	158.15	fg	159.50	f	-0.85
Tepu	73.00	kl	89.00	a-e	-17.98	154.50	h	157.80	fg	-2.09
$HSD_{0.05}$	6.10					2.73				
CV (%)	2.05					0.48				

Effect of flooding

Flooding significantly affected grain yield plant^{-1}in direct seeded aus rice (Table 3). Significantly higher (11.86%) grain yield plant^{-1} was recorded from non-flooded (60.27 g) condition than flooded condition (53.12 g).

Effect of cultivars

The range of grain yield per plant was between 39.14 g to 79.05 g. Significantly the highest grain yield plant $^{-1}$ was obtained from variety Abdul Hai (79.05 g) and the lowest (39.14 g) from BINA dhan10 (Table 6).

Interaction effect of flooding and cultivars on grain yield plant^{-1}

Interaction effect of flooding and cultivar was significant (Table 13). Cultivar Abdul Hai produced highest grain yield at both non-flooding (81.94 g) and flooding (76.17 g) conditions, while BINA dhan10 gave lowest at both non-flooding (43.81 g) and flooding (34.48 g) condition.

Straw yield plant^{-1} Effect of flooding

Significant variation was found between flooding and non-flooding treatments in terms of straw yield (Table

3). Non-flooding condition produced 99.03 g straw yield plant^{-1}, which was 7.48% higher than flooding treatment (99.03 g) (Table 3).

Effect of cultivars

Straw yield plant^{-1} was found significant among direct seeded aus rice cultivars (Table 6). The range of straw yield plant^{-1} was 76.52 g to 120.26 g. The highest (120.26 g) straw yield per plant was recorded from variety Abdul Hai followed by Halai (115.93 g), Kali Haitta (113.65 g) and the lowest (76.52 g) from BINA dhan10.

Interaction effect of flooding and cultivars on straw yield plant^{-1}

Significantly the highest straw yield was found from Abdul Haiat both non-flooding (124.01 g) and flooding (116.52 g) condition with 6.04% reduction. The lowest (69.99 g) straw yield was noted from BR 3.

Harvest index (%) Effect of flooding

Harvest index varied significantly between flooding and non-flooding treatments but a narrow variation (3.48%) was observed (Table 3). Non-flooding treatment gave higher harvest index of 37.69%, while flooded treatment gave 36.38% harvest index.

Effect of cultivars

The range of harvest index was between 33.75% and 39.66%. Significantly the highest harvest index (39.66%) found in Abdul Hai, which was statistically similar to Halai (39.40%), Kali Haitta (39.26%) and the lowest (33.75%) harvest index was found from BINA Dhan10 (Table 6).

Interaction effect of flooding and cultivars on harvest index

Significantly the highest harvest index was recorded from variety Abdul Hai from both non-flooding (39.79%) and flooding (39.53%) condition with lowest difference (0.65). The lowest harvest index (32.80%) was found from BR 3 under flooding condition.

Table 6: Interaction effect of flooding and cultivars on grain yield plant^{-1}, straw Yield plant^{-1} and percent reduction over control of T. aus rice.

Cultivar	Grain yield plant^{-1} (g)				% reduction	Straw yield plant^{-1} (g)				% reduction
	Flooding		Non-flooding			Flooding		Non-flooding		
BR2	66.66	gh	71.32	def	-6.53	106.36	fgh	111.67	de	-4.76
BR3	**34.16**	**C**	49.65	v-z	-31.20	**69.99**	**B**	87.43	t-y	-19.95
BR14	61.16	j-n	63.94	hij	-4.35	99.85	klm	105.81	g-j	-5.63
BR16	38.13	B	50.38	u-z	-24.32	76.09	A	88.56	s-w	-14.08
BR21	44.33	A	51.60	t-w	-14.09	83.71	xyz	89.30	q-w	-6.26
BR24	43.52	A	54.46	q-t	-20.09	82.49	z	91.34	p-u	-9.69
BRRI dhan26	64.26	hi	68.81	efg	-6.61	103.39	h-k	108.60	efg	-4.80
BRRI dhan27	42.67	A	59.54	l-o	-28.33	82.71	yz	97.75	lmn	-15.39
BRRI dhan28	48.93	w-z	53.12	r-u	-7.89	87.02	t-z	89.96	p-w	-3.27
BRRI dhan42	44.28	A	48.04	xyz	-7.83	83.60	xyz	86.39	v-z	-3.23
BRRI dhan43	38.16	B	52.37	s-v	-27.13	75.87	A	89.58	q-w	-15.30

BRRI dhan48	47.79	yz	50.90	u-x	-6.11	85.92	w-z	88.80	r-w	-3.24
BRRI dhan55	48.40	xyz	56.14	pqr	-13.79	86.72	u-z	93.45	n-r	-7.20
BRRI dhan65	49.91	v-z	59.45	l-o	-16.05	88.17	s-x	97.72	lmn	-9.77
BINA dhan7	50.36	u-z	56.58	opq	-10.99	88.08	s-x	93.91	n-q	-6.21
BINA dhan10	34.48	C	**43.81**	**A**	-21.30	70.22	B	**82.83**	**yz**	-15.22
IRRATOM24	55.29	qrs	60.83	k-n	-9.11	92.30	o-s	99.52	klm	-7.25
Mansur IRRI	68.29	fg	71.09	def	**-3.94**	108.18	efg	111.05	def	**-2.58**
Kali Haitta	71.53	de	75.40	c	-5.13	111.63	de	115.68	bcd	-3.50
LalJamaiBabu	61.55	i-m	66.47	gh	-7.40	100.23	klm	106.12	ghi	-5.55
SadaJamaiBabu	62.72	ijk	71.15	def	-11.85	101.51	i-l	111.28	de	-8.78
Parija	50.65	u-y	61.83	i-l	-18.08	89.18	r-w	100.52	klm	-11.28
Manikmuri	56.95	opq	61.22	i-n	-6.97	94.35	nop	99.87	klm	-5.53
Benamuri	42.33	A	54.26	q-t	-21.99	82.62	z	91.63	p-t	-9.83
Matichak	54.15	q-t	59.33	l-o	-8.73	91.06	p-v	97.52	lmn	-6.62
Mahisur	58.49	nop	61.41	i-n	-4.75	96.44	mno	100.15	klm	-3.70
AusBoro(awned)	47.42	z	51.97	t-w	-8.76	85.55	w-z	89.48	q-w	-4.39
Abdul Hai	**76.17**	**bc**	**81.94**	**a**	**-7.04**	**116.52**	**bc**	**124.01**	**a**	**-6.04**
Halai	72.14	d	78.66	b	-8.29	112.27	cde	119.59	ab	-6.12
Tepu	58.71	m-p	62.63	ijk	-6.26	96.63	mno	101.39	jkl	-4.69
$HSD_{0.05}$	3.05					4.72				
CV (%)	1.25					1.14				

Relationship among yield and yield contributing characters

Relationship between morphological and yield contributing characters of direct seeded aus rice cultivars under flooded condition was studied through analysis of Pearson correlation between them. Correlation among 30 direct seeded aus rice cultivars at maturity stage is presented in Table 15. Among the associations, some were positively correlated and some were negatively correlated. In this relationship, number of grains panicle^{-1}, grain yield, straw yield and harvest index were significantly correlated with germination percentage. Thousand grain weight (TGW), grain yield (GY), straw yield (SY) and harvest index (HI) were positively and significantly correlated with number of effective tillers plant^{-1}.

Hierarchical cluster analysis

The cultivars were classified into four groups by cluster analysis based on percentage germination and grain yield per plant (Table 16 and Figure 3). Cultivars included in the group I were five genotypes (BR2, Kali Haitta, Sada Jamai Babu, Abdul Hai and Halai). Mean percentage germination and mean grain yield were 72.20% and 69.84 g plant^{-1}, respectively. Group II also included five cultivars (BR3, BR16, BR21, Benamuri and BRRI Dhan 43) with mean percentage germination and mean grain yield of 38.20% and 39.42 g plant^{-1}, respectively. Nineteen genotypes (BR14, BR24, BRRI Dhan 26, BRRI Dhan 27, BRRI Dhan28, BRRI Dhan 42, BRRI Dhan 48, BRRI Dhan55, Tepu, BINA Dhan7, BINA Dhan10, IRRATOM24, Lal Jamai Babu, Parija, Manikmuri, Matichak, Mahisur, AusBoro and BRRI Dhan 65) joined in group III with mean percentage germination and grain yield of 57.87% and 51.52 g plant^{-1}, respectively. Group IV included one cultivar (Mansur IRRI) and had mean percentage germination and grain yield 27.00% and 68.29 g plant^{-1}, respectively.

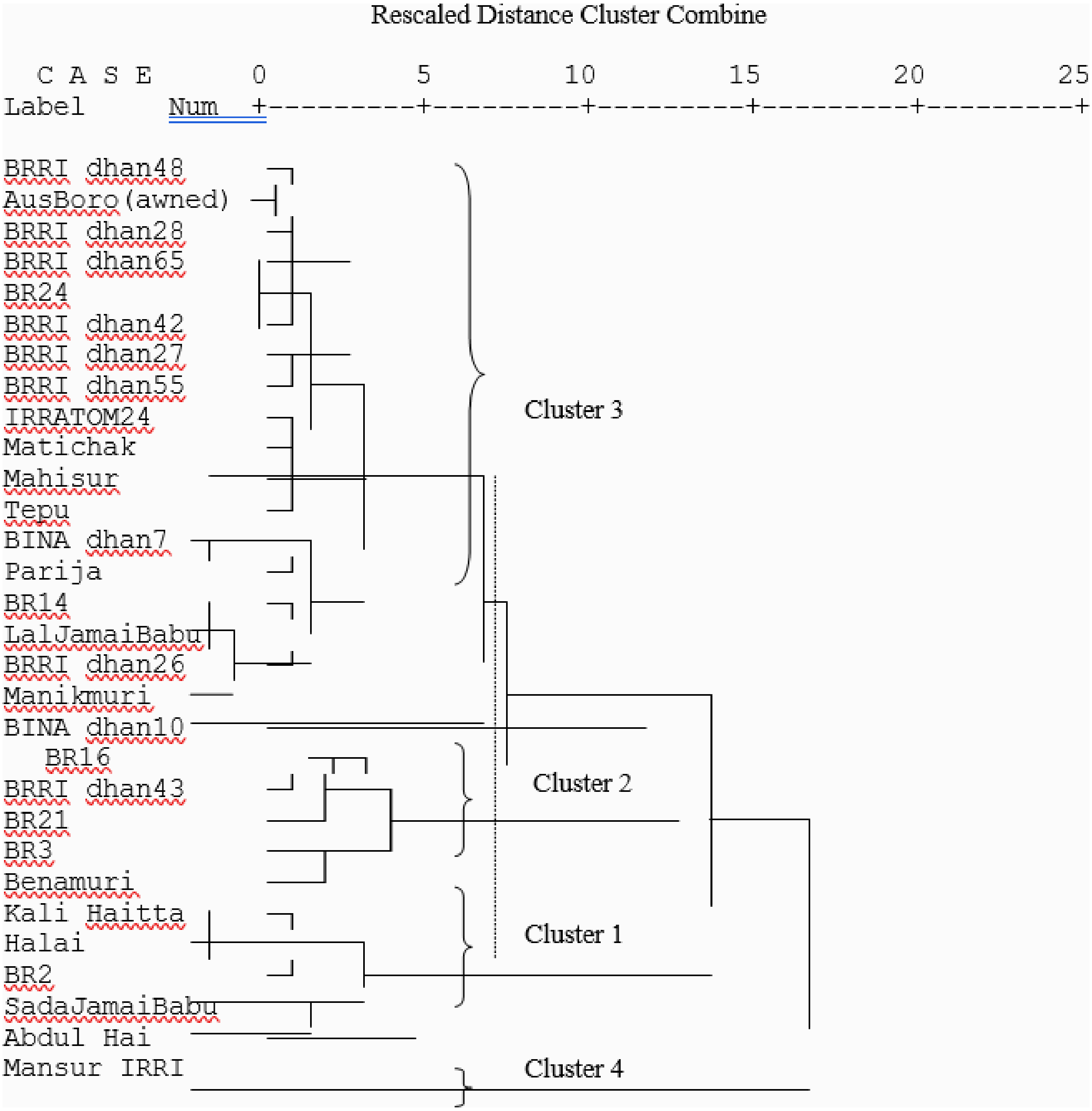

Figure 3: Dendogram using average linkage (Between Groups) based on germination (%) and grain yield (g plant^{-1}) under flooding condition. The dendrogram is showing the overall similarity/dissimilarity between varieties and cluster membership of the cultivars.

DISCUSSION

Coastal agriculture in Bangladesh has three rice cropping seasons which faces different kinds of submergence throughout the year. During *Kharif I* season Aus rice is cultivated when tidal flood is likely to occur. Farmers usually cultivate local aus rice varieties, most preferably in direct seeding method, which are vulnerable to damage due to tidal flood. The present study investigates the effect of submergence during germination and subsequent growth and yield of thirty aus rice genotypes in the pot culture.

Genotypes under study showed variability in relative tolerance to flooding. Flooding adversely affected genotypes from germination to growth and yield parameters. Under flooded condition about 31.58% reduction in germination happened, where more than 80% germination was observed in local variety Abdul Hai (84.00%) and Sada Jamai Babu (82.50%). When flooding occurs just after direct seeding, tolerant rice genotypes germinate faster and their coleoptiles grow at a relatively faster rate to emerge from flooded soils. These genotypes are also capable of forming roots and leaves in shallow water depths (Ismail *et al.*, 2009; Angaji*et al.*, 2010). In most plants, adequate supply of oxygen must be available during germination. In the lowlands, when cultivars are direct-seeded particularly when the seeds are covered with soil, lack of oxygen causes poor seedling emergence (Yoshida, 1981).

Panicle length under flooding (21.14 cm) condition was reduced by 4.13% than non-flooding condition (22.05 cm). Interaction between flooding and cultivars showed that highest reduction (15.45%) in panicle length occurred in Sada Jamai Babu.

Number of grains panicle^{-1} was higher in non-flooding condition (89.37), which was 8.41% higher than flooding condition. No of grains panicle^{-1} ranged between 55.58 to 146.78. Where maximum (144.25) no of grains panicle^{-1}was produced by Abdul Hai under flooded condition.

Grain weight of thousand seeds varied between 20.9 g to 41.13 g among the cultivars. Under flooded condition Abdul Hai produced maximum (40.38 g) thousand seed weight. Flooding reduced 11.86% grain yield per plant in aus rice. Among the varieties Abdul Hai produced highest (79.05 g) grain yield. In case of variety and flooding interaction under flooded condition highest (76.17 g) grain yield was recorded from Abdul Hai. This variety also produced highest straw yield (116.52 g) and harvest index (39.53%) under flooded condition. Srivastava et al. (2007) studied on six genotypes regarding their relative tolerance to submergence. They found under submerged condition panicle weight, grain yield hill^{-1} and biomass yield was lower than control.

Hierarchical clustering based on germination percentage and grain yield under submerged condition that showed there was four distinct clusters. Cluster I consists of five cultivarswith maximum mean germination percentage (72.20%) and grain yield plant^{-1} (69.84 g). Genotypes includes in cluster I are BR2, Kali Haitta, SadaJamaiBabu, Abdul Hai and Halai. Cluster II also had five members with average 38.20% germination and 39.42 g grain yield plant^{-1}. Cluster III being the largest group, consists of 19 cultivarswith mean percentage germination and grain yield of 57.87% and 51.52 g plant^{-1}, respectively. Finally, cluster IV had only one cultivars (Mansur IRRI) having lowest mean percentage germination and grain yield 27.00% and 68.29 g plant^{-1}, respectively.

SUMMARY AND CONCLUSION

A resilient rice-based food system is high challenges on Bangladesh's national policy agenda for food self-sufficiency and international commitments to sustainable development goals. Flood prone areas is the major challenges for adaptation of aus rice cultivation with climatic barriers. Rice is the main food item in Bangladesh which is grown in three crop growing seasons viz. aus, aman and boro. In *Kharif I* (April-July) season direct seeded aus rice is most popular to farmers of southern region of Bangladesh. Therefore, farmers increasingly rely on input providers for technology innovation and knowledge about new technology (Mottaleb, Rahut, and Erenstein, 2019). Additionally, the country's average plot/farm size is very small (less than a hectare) (Gautam and Mansur, 2019), meaning that one farmer's plot is likely to be contiguous to another farmer's plot. Therefore, farmers who do not have access to technology from either extension agents or input providers learn from their neighbors (Yamano et al., 2018). Floods, especially monsoon and flash floods, are the most common climatic events in Bangladesh.

(BinRahman and Zhang, 2016, Dewan, 2015). Each year, on average, one-fifth of the total 8.0 million hectares (ha) of cultivable agricultural lands are affected by floods.

However, the crop in this season is vulnerable to tidal flood submergence and substantial yield loss occurs. Moreover farmers of this area mostly prefer local variety, most of them are low yield potential. There are other high yielding varieties for the *Kharif I* season, but tolerance to submergence has not been tested yet. So, the central objective of the present study was to evaluate thirty cultivars, both local and high yielding, in relation to germination under submergence and subsequent growth and yield performance.

The experiment was conducted in the agronomy field laboratory of Patuakhali Science and Technology University (PSTU) during April –July, 2015. The experiment was laid out in RCB design with two replications. Twenty five seeds were sown directly to each pot and then the cultivars were exposed to flooding treatments for seven days and compared these with non-flooding treatments. After seven days water was allowed to drain out and kept for germination. One healthy seedling was retained per pot for evaluating further growth and yield parameters.

Submergence during germination adversely affected the agronomic traits and biomass production of the cultivars at varying degrees. Most of the cultivars performed better under non-flooded conditions. Flooding treatment reduced germination percentage by 31.58%, where variety Abdul Hai gave 84.00% germination under flooding condition. Flooding reduced plant height, total number of tillers hill^{-1}, number of effective tillers, panicle length, number of grains panicle^{-1}, 1000 grain weight, grain yield, straw yield and harvest index by 1.96%, 23.07%, 28.34%, 4.13%, 8.41%, 4.50%, 11.86%, 7.48% and 3.48%, respectively.

Cultivars versus flooding interaction revealed that the highest germination (84.00%), effective tillers (39.50), grains panicle^{-1} (144.25), 1000 grain weight (40.38 g), grain yield (76.17 g plant^{-1}), straw yield (116.53 g plant^{-1}) and harvest index (39.53%) were recorded in Abdul Hai.

Interrelationship among characters under flooded condition showed that grains panicle^{-1}, grain yield, straw yield and harvest index was significantly and positively correlated with germination percentage.

Four cluster were formed according to hierarchical cluster analysis. Cluster I consists of five cultivars *viz.* BR2, Kali Haitta, Sada Jamai Babu, Abdul Hai and Halai. The mean percentage germination and mean grain yield were 72.20% and 69.84 g plant^{-1}, respectively, which were higher than other clusters. These results suggests that variety Abdul Hai is more tolerant to submergence than other varieties. However, cultivars BR2, Kali Haitta, Sada Jamai Babu and Halai are from same cluster and more tolerant to submergence than the remaining cultivars. Climate change in Bangladesh is a serious concern since it adversely affects agriculture which is an important sector in the country. Therefore, the concerned authority should take appropriate policies to fight against the climate change impact on rice production to ensure food security for the ever increasing population of the country through implementing sustainable agricultural development. Last but not the least, national level data might not portray the real scenario of the regional variations of climate change and their effects on crop yield (Lobell et al., 2007). Therefore, future research in this field should focus on regional specific data analysis to capture the regional variations of climate change and to obtain a more comprehensive scenario of climate changes and their genetically improve varieties impacts on rice yield in Bangladesh. Moreover, researchers of this field may be extended by the government to go for further researches on adaptation of flood-tolerant ausrice varieties in the specific region of Bangladesh.

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