ZIBELINE INTERNATIONAL™ PUBLISHING

Big Data in Agriculture (BDA)

DOI: http://doi.org/10.26480/bda.01.2021.68.73

ISSN: 2682-7786 (Online)
CODEN: BDAIDR

RESEARCH ARTICLE

RESPONSES OF FOUR SUBMERGENCE TOLERANT RICE VARIETIES TO DIFFERENT SUBMERGENCE LEVELS

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ARTICLE DETAILS

Article History:

Received 20 May 2021
Accepted 23 June 2021
Available online 05 July 2021

ABSTRACT

The selections of suitable variety are very crucial for addressing future challenges and sustainably increase rice production in the flood-prone rice-growing environment. To find out the degree of tolerance of different submergence tolerant varieties under different submergence durations we conducted the present research from July to December, 2018. The experiment comprised of two factors namely, factor A, Submergence durations were S_0-control (no submergence situation), S_1, S_2,and S_3 allowing submergence up to 10 days after seedling establishment (DAE), submergence up to 15 DAE, and submergence up to 20 DAE, respectively and factor B- Submergence tolerant varieties were Binadhan-11, Binadhan-12, BRRI dhan52, and BRRI dhan79. The experiment was laid out in a split-plot design where submergence durations were assigned to the main plots and varieties were assigned to the subplots with three replications. The highest grain yield (4.09 t ha^{-1}) was obtained from no submergence situation with BRRI dhan52 followed by no submergence with variety Binadhan-11 (3.87 t ha^{-1}), submergence up to 10 days after seedling establishment (3.61 t ha^{-1}), and submergence up to 15 days after seedling establishment (3.35 t ha^{-1}) with variety BRRI dhan52. Among four submergence tolerant varieties, BRRI dhan52 showed better performance.Thus, it may be concluded that submergence up to 10 or 15 days after seedling establishment with variety BRRI dhan52 might be cultivated in flood-affected areas where rice plants remain 10 to 15 days under floodwater.

KEYWORDS

Submergence tolerance, Rice, Variety, Percent Yield reduction, Flood

1. INTRODUCTION

Rice is the agricultural commodity with the third-highest worldwide production and as a cereal grain; it is the most widely consumed staple food for a large part of the world's human population, especially in Asia and Africa. Bangladesh, an agro-based developing country, is well-known as a land of rice growers where rice plays a vital role in the livelihood of the people of Bangladesh (Miro and Ismail, 2013; Bangladesh Rice Research Institute, 2018). Among the three diversified rice growing seasons in Bangladesh such as a*us, aman, and boro*, *aman* rice covers approximately 50.56% of the country's total cultivated land area for rice production (Sayeed and Yunus, 2018; Childs, 2020). Being environmentally susceptible, Bangladesh experienced different natural calamities each year like drought and flood, etc (FAO, FAOSTAT, 2017). Among them, about 10% of rice production was damaged by severe floods in 2017 resulting in an increase in price of rice by 25% in that year. Submergence is the most important abiotic stress in Bangladesh and more than 2.0 M ha of land in Bangladesh is affected by different types of floods (Iftekkharuddaula et al., 2016; Iftekkharuddaula et al., 2015).

Submergence can result in yield losses of up to 100% depending on different environmental and floodwater conditions (Neeraja et al., 2007). Flooding can be classified on the basis of the height of the water column; as waterlogging, when it is superficial and covers only the root, or as submergence when water completely covers the plant (Sasidharan et al., 2017). Flash flooding which generally lasts less than a few weeks is caused by sudden heavy rain but the depth is not very deep and the deepwater flooding which lasts for several months occurs during the rainy season and the water depth reaches several meters (Kato et al., 2014). In Bangladesh rainfed lowland rice covers an area of 4.5 million hectares and is grown by transplanting *aman* rice from June-September at the peak period of monsoon rainfall. The seedling transplantation as well as at the early vegetative stage of the crop is often completely submerged by flash flood due to continuous rainfall as well as due to an onrush of floodwater from adjoining rivers.

Such flood may continue for a week or more inflicting heavy damage to standing crops. In some flooding-intolerant species, restricting submergence to the soil-based root system (water-logging) is sufficiently stressful to damage the whole plant severely and can even prove fatal (Jackson, 2004). Complete submergence at the vegetative stage of rice causes deterioration in the plant quality resulting in a poor stand and causes substantial yield loss. Due to incessant rainfall in the monsoon season in Bangladesh is unfavorably affected by excess water and periodically those go underwater with complete submergence for 1-2 weeks or more covering about 24% of the total rice areas. This flood caused enormous damage to rice crops and irreparable yield loss from 10 to 100% (Miro and Ismail, 2013). So, submergence caused by flooding is a major constraint in the case of transplanting aman rice establishment which affects plant growth and development and ultimately affects yield.

The reduction of yield depends on the genetic resistance of variety against stress tolerance and cultivation of stress-tolerant varieties is important to increase the yield of rice in water crises. The crop's level of tolerance also depends on the stage of plant development, submergence depth, duration

Quick Response Code	Access this article online	
	Website: www.bigdatainagriculture.com.my	**DOI:** 10.26480/bda.02.2021.68.73

Cite The Article: Suriaya Perveen, Md. Abdus Salam, Md. Ekram ul Haque (2021). Responses of Four Submergence Tolerant Rice Varieties To Different Submergence Levels. *Big Data in Agriculture, 3(2):68-73.*

of submergence, water, and air temperature, and the penetration of light through water (Liao and Lin, 2001). To face the challenge of flash flood-affected areas, submergence tolerant rice varieties have been developed by BRRI and BINA and those varieties are capable to yield well if they are under floodwater for about two weeks. Perfect evaluation of improved rice varieties with better yield potential in submergence ecology is one of the critical needs for sustainable rice production. If it is possible to grow rice cultivar without reduction of yield under submergence condition for a week or a couple of weeks will increase farmer's income. Thus, the impact of submergence stress can be reduced to a certain level. The present piece of research work was; therefore, undertake to find out the effect of submergence tolerant rice variety and level of submergence on the yield of *aman* rice.

2. Materials and Methods

2.1 Study area

We decided to conduct our research at the Agronomy Field Laboratory (AFL), Bangladesh Agricultural University, Mymensingh as AFL provides low land for rice cultivation in the *aman* season having good irrigation and drainage facilities. The duration of the experiment was July to December 2018. The study area falls under the Old Brahmaputra Flood plain (AEZ 9) (FAO and UNDP, 1988). The soil of the study area was more or less neutral in reaction (pH 6.5) and the land type was medium-high with silt loam in texture. The experimental site enjoys the humid tropical climate characterized by an average temperature ranging from 19.8 to 29.8^{0}C and the highest rainfall during the month of July (299.6 mm). The monthly meteorological data recorded during the study period are presented in Figure 1.

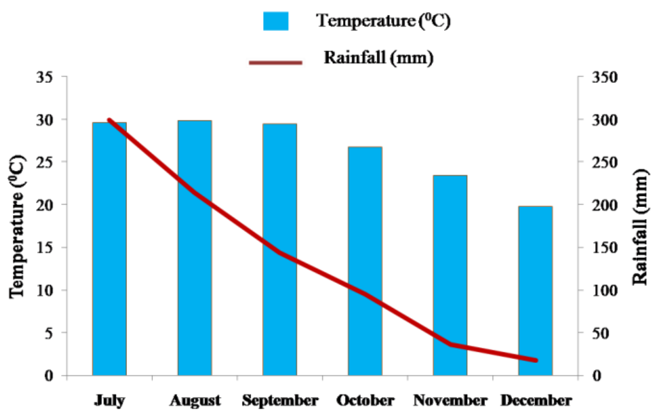

Figure 1: Distribution of monthly average air temperature, relative humidity, and rainfall of the experiment site during the period from July to December

2.2 Experimentation and Crop Husbandry

The experiment comprised of two factors, namely, factor A, four levels of submergence conditions were S_0-control (no submergence situation), S_1, S_2 and S_3 allowing submergence up to 10 days after seedling establishment (DAE), submergence up to 15 DAE and submergence up to 20 DAE, respectively and factor B- four submergence tolerant rice varieties were Binadhan-11, Binadhan-12, BRRI dhan52, and BRRI dhan79. The experiment was laid out in a split-plot design where submergence situations were assigned to the main plots and varieties were assigned to the subplots with three replications. Thus, the total numbers of unit plots were 48 (4×4×3). The distance maintained between the two main plots was 0.5 m. The size of each plot was 12 m2 (4.0m × 3.0m). Bunds of each plot were made as high as possible to reduce water loss from plots.

All plots were surrounded by polythene sheets except no submergence plots. Polythene sheets were placed in 1m depth and 1m above from the surface. In no submergence treatment (S_0), water drained out from the plot to avoid a submerged situation on that plot. In S_1, S_2, and S_3 treatment, water was kept within the plot allowing submergence up to 10, 15, and 20 days after seedling establishment, respectively. After this period, water was released from those plots to allow normal growth. Four submergence tolerant rice cultivars Binadhan-11 and Binadhan-12, BRRI dhan51, and BRRI dhan79 were used for the study. Seeds of Binadhan-11 and Binadhan-12 were collected from Bangladesh Institute of Nuclear Agriculture, Mymensingh.

Seeds of BRRI dhan52 and BRRI dhan79 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur. The seeds were sown on 20 July in a nursery bed and after 30 days (20 August 2018) seedlings were transplanted to the main fields. After laying out the mainland was fertilized with triple super phosphate, muriate of potash, and gypsum @ 60, 105, and 67 kg ha^{-1}, respectively as per fertilizer recommendation (Bangladesh Rice Research Institute, 2018). The urea @195 kg ha^{-1} was applied in three equal installments at 15, 30, and 45 days after transplanting. Weeding was done three times at 20, 45, and 60 days after transplanting. Submergence level treatments were imposed according to schedule.

2.3 Collection of Data

The plants were harvested at maturity on 11 December. Yield and other yield contributing parameters were recorded at the time of harvesting. From each plot, 1 m^2 area was harvested and five hills were collected to record different parameters. The harvested crop was brought to the threshing floor, then threshed by hand, cleaned, and dried in the sun for three to four consecutive days for achieving the safe moisture content of the seed. Straw was also sun-dried for three to four consecutive days to measure the dry weight. One thousand grains were counted and weighed to determine 1000-grain weight.

2.4 Statistical analysis

The recorded data were compiled and tabulated for statistical analysis and the analysis of variance was done with the help of a computer package program, SPSS 20.0. The mean differences among the treatments were adjudged by using Duncan's Multiple Range Test (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Effect of submergence tolerant variety and submergence duration on crop characters and yield components of rice

Different levels of submergence showed a significant impact on yield contributing components of *aman* rice (Table 1 and Figure 2). Most of the components like total tillers hill^{-1}, effective tillers hill^{-1}, grainspanicle^{-1}, sterile spikelets panicle^{-1}and 1000-grain weight were significantly affected by different submergence levels. The lowest number of total tillers hill^{-1}(7.25), effective tillers hill^{-1}(5.87), grains panicle^{-1} (118.58) and 1000-grain weight (17.50 g) were observed under submergence up to 20 days after seedling establishment and the highest number of total tillers hill^{-1}(8.90), effective tillers hill^{-1}(7.20), grainspanicle^{-1} (127.86) and1000-grain weight (19.15 g) were found under no submergence. The sterile spikelets panicle^{-1} was the highest (12.38) at submergence up to 20 days after seedling establishment and the lowest (10.88) was observed at no submergence. Plant height and panicle length were found non-significant under different levels of submergence.

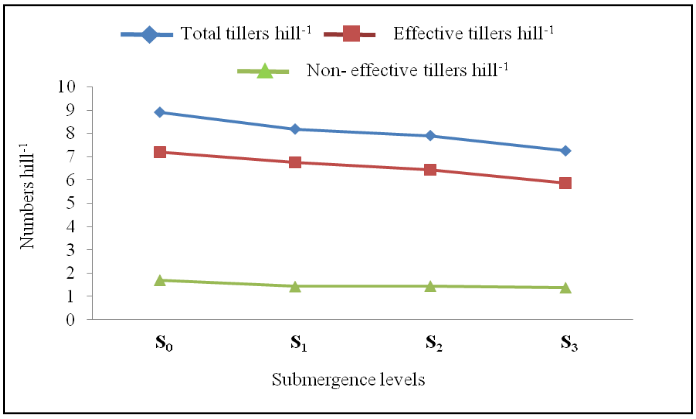

Figure 2: Effect of levels of submergence on total tillers hill^{-1}, effective tillers hill^{-1} and non-effective tillers hill^{-1} on T. aman rice

(S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment)

The varietal difference showed a significant influence on plant characters and yield components (Table 1 and Figure 3). The best performance was recorded from BRRI dhan52. The highest number of total tillers hill^{-1} (8.75), effective tillers hill^{-1} (7.07) and grains panicle^{-1} (126.93) were observed in BRRI dhan52 and the lowest number of total tillers hill^{-1} (7.55), effective tillers hill^{-1} (6.07) and grains panicle^{-1} (119.85) were found in BRRI dhan79 (V_4). The tallest plant (92.07 cm) was found in BRRI dhan79 and sterile spikelets panicle^{-1} was the highest (12.33) in Binadhan-12. The lowest 1000-grain weight (15.66) was recorded in BRRI dhan52 and the highest one (24.79 g) was observed in Binadhan-11.

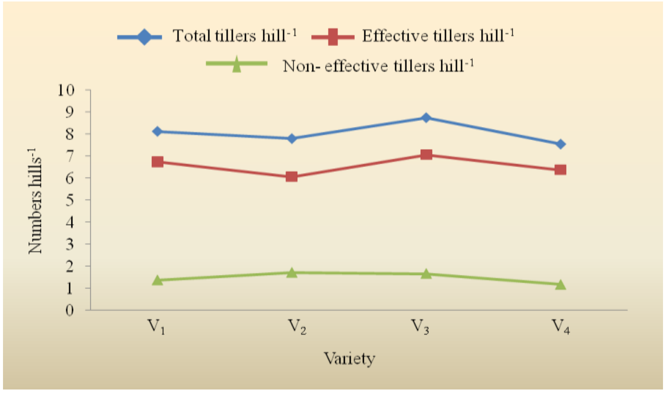

Figure 3: Effect of variety on total tillers hill^{-1}, effective tillers hill^{-1} and non-effective tillers hill^{-1} on T. aman rice

(V_1 = Binadhan-11, V_2 = Binadhan-12, V_3 = BRRI dhan52 and V_4 = BRRI dhan79)

Both the submergence levels and varieties had a significant impact on the yield components of rice (Table 2). The tallest plant (94.73cm) was found in BRRI dhan79 under submergence up to 15 days after seedling establishment condition but statistically identical to plant height of BRRI dhan79 under no submerge condition and BRRI dhan79 under submergence up to 10 days after seedling establishment condition. The maximum number of total tillers hill^{-1}(9.40) and effective tillers hill^{-1} (7.73) were recorded in BRRI dhan52 with no submergence condition which were statistically similar with BRRI dhan52 under submergence up to 20 days after seedling establishment. Number of grains panicle^{-1} showed the highest result from BRRI dhan52 under submergence up to 20 days after seedling establishment. With the increased level of submergence, number of sterile spikeletspanicle^{-1} was also increased. The heaviest thousand grain weight was observed from no submergence with Binadhan-11 which was statistically similar with submergence up to 20 days with Binadhan-11.

3.2 Effect of submergence tolerant variety and submergence duration on yield of rice

The yield of *T. aman* rice was significantly influenced by levels of submergence (Table 1 and Table 3). The lowest grain yield (2.37 t ha^{-1}) and straw yield (2.88 t ha^{-1}) were observed under submergence up to 20 days after seedling establishment and the highest grain yield (3.54 t ha^{-1}) and straw yield (3.94 t ha^{-1}) were found under no submergence (S_0). The varietal difference had a significant impact on the yield of *T. aman* rice (Table 1 and Table 4). The variety BRRI dhan52 produced the highest grain yield (3.51t ha^{-1}) which was followed by Binadhan-11 (3.14 t ha^{-1}). The best performance was recorded from BRRI Dhan52. The highest straw yield (4.14 t ha^{-1}) was also observed under BRRI dhan52 and the lowest grain yield (2.12 t ha^{-1}) and straw yield (2.63 t ha^{-1}) were found under BRRI Dhan79. In the case of the combination of submergence duration and variety, it showed significant influence on yield (Table 2 and figure 4). The highest grain yield (4.09 t ha^{-1}) was obtained from no submergence situation with BRRI dhan52 followed by no submergence with a variety Binadhan-11 (3.87 t ha^{-1}) and submergence up to 10 days after seedling establishment with variety BRRI dhan52 (3.61 t ha^{-1}).

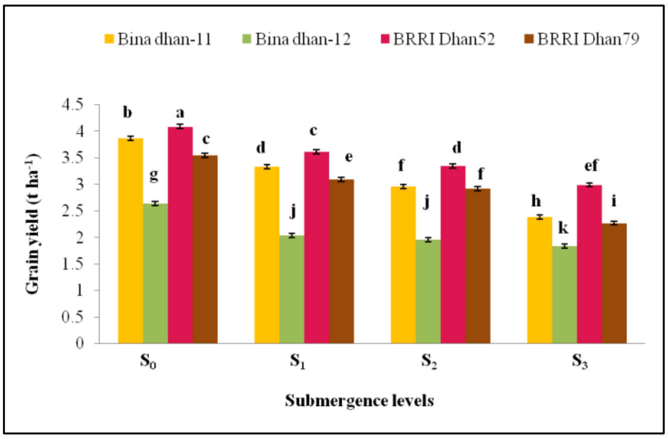

Figure 4: Interaction effect of different levels of submergence and varieties on grain yield of T. *aman* rice

(S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment)

Straw yield showed the highest result from no submergence with BRRI dhan52 which was followed by submergence up to 10 days after seedling establishment with variety BRRI dhan52 (4.31 t ha^{-1}). The lowest grain yield (2.27 t ha^{-1}) was found under variety BRRI dhan79 with submergence up to 20 days after seedling establishment and the lowest straw yield (2.22 t ha^{-1}) was observed from variety Binadhan-12 with submergence up to 20 days after seedling establishment.

Table 1: Effect of levels of submergence conditions and varieties on yield and yield contributing components of *T. aman* rice

Treatment	Plant height (cm)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikeletspanicle^{-1} (no.)	1000-grain weight.(g)	Straw yield (t ha^{-1})
Submergence duration						
S_0	81.62	20.55	127.86a	10.88c	19.15a	3.94a
S_1	82.48	21.11	124.29b	11.37b	18.77ab	3.56b
S_2	82.30	20.92	121.47c	11.79b	18.27b	3.40c
S_3	83.40	21.01	118.58c	12.38a	17.50c	2.88d
Level of sig.	NS	NS	1.00	1.00	1.00	1.00
SE(±)	1.46	0.190	0.439	0.078	0.188	0.039
Varieties						
V_1	79.13c	20.69	123.64b	11.35c	24.79a	3.66b
V_2	74.72d	20.88	119.85d	12.33a	13.83d	2.63d
V_3	83.88b	21.07	126.93a	10.90d	19.40b	4.14a
V_4	92.07a	20.94	121.78c	11.84b	15.66c	3.36c
Level of sig.	1.00	NS	1.00	1.00	1.00	1.00
SE (±)	1.46	0.190	0.439	0.078	0.188	0.039

*In a column figures having common letter(s) do not differ significantly as per DMRT NS= Not significant

S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment;
V_1 = Binadhan-11, V_2 = Binadhan-12, V_3 = BRRI dhan52 and V_4 = BRRI dhan79

Table 2: Effect of interaction of different submergence conditions and varieties on yield and yield contributing components of T. Aman rice

Submergence × Variety	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Straw yield (t ha^{-1})
S_0V_1	78.67b-e*	9.00ab	7.73a	1.27abc	20.03c	127.82b	10.51e	25.69a	4.07bc
S_0V_2	74.60cde	8.53a-d	6.67bcd	1.87a	20.56bc	125.20bcd	11.52b-e	14.53ef	3.07f
S_0V_3	80.47b-e	9.40a	7.53ab	1.87a	20.80abc	132.42a	10.22e	19.97c	4.73a
S_0V_4	92.73a	8.67abc	6.87bcd	1.80ab	20.80abc	125.99bc	11.27b-e	16.38d	3.88cd
S_1V_1	78.73b-e	8.20b-e	6.93bcd	1.27abc	20.89abc	124.30cde	11.11cde	25.27a	3.90cd
S_1V_2	77.80b-e	8.00c-f	6.33d-g	1.67abc	20.82abc	121.29efg	12.01a-d	14.19f	2.58g
S_1V_3	84.87a-d	9.00ab	7.20abc	1.80ab	21.90a	128.17b	10.95de	19.69c	4.31b
S_1V_4	88.53ab	7.53efg	6.53c-f	1.00bc	20.81abc	123.39c-f	11.41b-e	15.95d	3.45e
S_2V_1	79.80b-e	8.00c-f	6.47d-g	1.53abc	21.15abc	122.14d-g	11.64b-e	24.58ab	3.54e
S_2V_2	72.40e	7.60d-g	6.00efg	1.60abc	21.07abc	117.681hi	12.52abc	13.75fg	2.63g
S_2V_3	84.60a-d	8.73abc	7.00bcd	1.73abc	20.66abc	126.05bc	11.01de	19.07c	3.92cd
S_2V_4	92.40a	7.27efg	6.33d-g	0.93c	20.78abc	120.00gh	11.98a-d	15.66de	3.51e
S_3V_1	79.33b-e	7.33efg	5.87fgh	1.47abc	20.69abc	120.29fgh	12.12a-d	23.62b	3.11f
S_3V_2	74.07de	7.07fg	5.27h	1.80ab	21.08abc	115.21i	13.27a	12.86g	2.22h
S_3V_3	85.60abc	7.87c-f	6.53c-f	1.33abc	20.90abc	121.10fg	11.43a-d	18.87c	3.58de
S_3V_4	94.60a	6.73g	5.80gh	0.93c	21.37ab	117.73hi	12.69ab	14.66ef	2.58g
Level of sig.	1.00	1.00	1.00	0.05	0.05	1.00	.039	1.00	1.00
SE (±)	2.93	0.303	0.207	0.271	0.379	0.878	0.155	0.376	0.077

*In a column figures having common letter(s) do not differ significantly as per DMRT

NS= Not significant

S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment;

V_1 = Binadhan-11, V_2 = Binadhan-12, V_3 = BRRI dhan52 and V_4 = BRRI dhan79

3.3 Percent reduction of rice yield due to the submergence duration

Percent reduction of yield varied significantly by different levels of submergence (Table 3). The highest reduction over no submergence condition (33.0 %) was found from S_3 whereas the lowest reduction over no submergence condition (15.22 %) was found from ten days submergence after seedling establishment treatment (Table 3). Percent yield reduction differ from variety to variety (Table 4). The highest reduction over no submergence (19.61 %) was recorded from Binadhan-12 which was statistically similar with Binadhan-11(18.99 %). The lowest yield reduction (14.12 %) over no submergence was found in BRRI dhan52.

Table 3: Effect of submergence on yield and percent reduction of yield of rice

Treatment	Grain yield (t ha^{-1})	Yield reduction (%)
S_0	3.54a*	0.00d
S_1	3.02b	15.22c
S_2	2.80c	21.18b
S_3	2.37d	33.00a
Level of sig.	1.00	1.00
SE (±)	0.020	0.588

*In a column figures having common letter(s) do not differ significantly as per DMRT

NS= Not significant

S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment;

Table 4: Effect of varieties on yield and percent reduction of yield of rice

Treatment	Grain yield (t ha^{-1})	Yield reduction (%)
V_1	3.14b*	18.99a
V_2	2.12d	19.61a
V_3	3.51a	14.12c
V_4	2.96c	16.69b
Level of sig.	1.00	1.00
SE (±)	0.020	0.588

*In a column figures having common letter(s) do not differ significantly as per DMRT

NS= Not significant

V_1 = Binadhan-11, V_2 = Binadhan-12, V_3 = BRRI dhan52 and V_4 = BRRI dhan79

From Figure 5, it is evident that the highest percent reduction of yield (36.10) was recorded from S_3V_4 (submergence up to 20 days after seedling establishment × BRRI dhan79) which was statistically similar with S_3V_1 (submergence up to 20 days after seedling establishment × Bindadhan-11) treatment. The lowest yield reduction (11.69 %) was found from S_1V_3 (submergence up to 10 days after seedling establishment × BRRI dhan52) treatment which was statistically similar with S_1V_1 (submergence up to 10 days after seedling establishment × Binadhan-11) treatment.

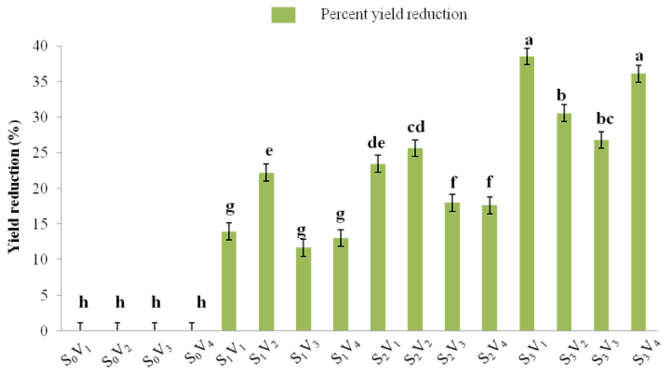

Figure 5: Interaction effect of submergence and varieties on yield and percent reduction of yield of rice

(S_0 = No submergence, S_1 = Submergence up to 10 days after seedling establishment, S_2 = Submergence up to 15 days after seedling establishment and S_3 = Submergence up to 20 days after seedling establishment; V_1 = Binadhan-11, V_2 = Binadhan-11, V_3 = BRRI dhan52 and V_4 = BRRI dhan79)

4. Discussion

Plant height was increased with increasing submergence duration to reach the air-water interface and the height of the plant was significantly influenced by variety due to varietal differences (Bailey-Seires et al., 2010; Jackson and Ram, 2003). The number of effective tillers hill^{-1} is one of the important yield contributing characters of rice plants. A decreasing trend in effective tillers hill^{-1} was shown by all the varieties as the duration of submergence increased. The formation of tiller bud might hamper due to submergence and it might cause a reduction of effective tillers hill^{-1} (Fukao et al., 2006; Haider et al., 2018). The lack of oxygen for respiration or accumulation of ethylene might inhibit tiller bud formation and growth. Panicle length was affected by submergence duration (Haque et al., 2015). The reduction of grains panicle^{-1} was occurred due to a lesser tiller number and other growth parameters that reduce the number of grains panicle^{-1}.

The number of grains per panicle drastically decreased under submergence compared to control (Hattori et al., 2011). Panicle number decreased due to the suppression of tiller growth or mortality of tiller either due to prevalence of lessening light below 50 cm water depth orlack of sufficient supply of oxygen (Nugraha et al., 2020). This result was also corroborated with the findings of Perata and Voesenek (Perata and Voesenek, 2007). Sterile spikelets panicle^{-1} was increased with the increased submergence duration. Due to submergence, all the spikelets did not get sufficient photosynthates, and finally, the filled grain numbers became lower. Grain yield decreased with an increase in the duration of submergence in every variety (Nishiuchi et al., 2012). From this study it could be said that the grain yield was positively correlated with the number of effective tillers hill^{-1}, the number of grains panicle^{-1} and negatively correlated with sterility percentage. In the case of percent yield reduction, it is observed that the highest reduction of yield was shown in BRRI dhan79 and Binadhan-11 up to 20 days submergence after seedling establishment compares to no submergence.

Reduction in grain yield due to submergence could be dependent on injury, experienced by submergence treatment, as well as the tolerant level of various genotypes. The higher the genotype's tolerance to flooding conditions, the higher the yield can be produced. These results showed similarity with the findings (Elanchezhian et al., 2013). A group researchers stated that 1000-grain weight decreased with an increase in the duration of submergence in every variety might be due to improper grain filling (Nugraha et al., 2020).

5. Conclusion

The current study showed that the submergence duration had significant effects on yield and yield contributing components of *aman* rice in Bangladesh. The highest grain yield was found from no submergence while submergence for 20 days resulted in the lowest grain yield. The varietal differences in grain yield are dependent on the genotypic ability to resist submergence. Less affected grain yield and straw yield in BRRI dhan52 and Binadhan-11 due to submergence treatment indicated that these varieties were more submergence tolerant than the other varieties of the experiment. The highest percent reduction of yield was recorded from submergence up to 20 days with BRRI dhan79 which was statistically similar with Bindadhan-11. The lowest yield reduction was found from submergence up to 10 days with BRRI dhan52 followed by submergence up to 15 days. From the results of the study, it may be concluded that submergence up to 10 or 15 days after seedling establishment with variety BRRI dhan52 might be cultivated in flood-affected areas in Bangladesh where rice plants remain 10 to 15 days under floodwater.

Authors' Contribution

1st author- Performing the field experiment, collection, analysis of data and writing of manuscript

2nd author- Design, formulation, supervision of the experiment and review of manuscript

3rd author- Planning of the experiment and supervision of experiment

Acknowledgement

We would like to show our gratitude to the Bangladesh Institute of Nuclear Agriculture (BINA) and Chief Farm Superintendent, Farm Management Section, Bangladesh Agricultural University, Mymensingh for their technical assistance during the course of this research

References

Bailey-Serres, J., Fukao, T., Ronald, P., Ismail, A., Heuer, S., Mackill, D., 2010. Submergence tolerant rice: SUB1's journey from landrace to modern cultivar, Rice, 3, Pp. 138-147.

Bangladesh Rice Research Institute. 2018. Adhunik Dhaner Chash (in Bengali), BRRI, Gazipur, Bangladesh, Pp.13.

Childs, N., 2020. RCS-20E, U.S Department of Agriculture, Economic Research Service,

Elanchezhian, R., Kumar, S., Singh, S.S., Dwivedi, S.K., Shivani, S., Bhatt, B.P., 2013. Plant survival, growth and yield attributing traits of rice (Oryza sativa L.) genotypes under submergence stress in rainfed lowland ecosystem. Indian J. Plant Physiol., 18, Pp. 326-332. DOI: 10.1007/s40502-013-0050-y

FAO and UNDP. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development Report No. 2. Agro-ecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization, Rome, Italy, Pp. 212-221.

FAO, FAOSTAT. 2017. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fukao, T., Xu, K., Ronald, P.C., Bailey-Serres, J., 2006. A variable cluster of ethylene response factor–like genes regulates metabolic and developmental acclimation responses to submergence in rice. Plant Cell, 18, Pp. 2021-2034. DOI: https://doi.org/10.1105/tpc.106.043000

Gomez, M.A., Gomez, A.A., 1984. Statistical Procedure for Agricultural Research. John Willey and sons. New york, Chichester, Brisbane, Toronto, Pp. 97-129, 207-215.

Haider, Z., Akhter, M., Mahmood, A., Saleem, U., 2018. Variation in expression of Sub1 gene and Association with submergence stress related traits in advance rice (Oryza sativa L.) genotypes as a tool of climate change adaptation. Am. J. Clim. Change, 7, Pp. 171. DOI: 10.4236/ajcc.2018.72012

Haque, M.M., Majumder, R.R., Hore, T.K., Biswash, M.R., 2015. Yield contributing characters effect of submerged water levels of boro rice (*Oryza sativa L.*). Sci. agric., 9, Pp. 23-29. https://doi.org/10.9734/jeai/2019/v41i630436

Hattori, Y., Nagai, K., Ashikari, M., 2011. Rice growth adapting to deepwater. Curr. Opin. Plant Biol., 14, Pp. 100-105. DOI: 10.1016/j.pbi.2010.09.008

Iftekharuddaula, K.M., Ahmed, H.U., Ghosal, S., Amin, A., Moni, Z.R., Ray, B.P., Barman, H.N., Siddique, M.A., Collard, B.C., Septiningsih, E.M., 2016. Development of early maturing submergence-tolerant rice varieties for Bangladesh. Field Crops Res., 190, Pp. 44-53.DOI: 10.1016/j.fcr.2015.12.001

Iftekharuddaula, K.M., Ahmed, H.U., Ghosal, S., Moni, Z.R., Amin, A., Ali, M.S., 2015. Development of new submergence tolerant rice variety for Bangladesh using marker-assisted backcrossing. Rice Sci., 22, Pp. 16-26.

Jackson, M.B., Ram, P.C., 2003. Physiological and molecular basis of susceptibility and tolerance of rice plants to complete submergence. Ann. Bot., 91, Pp. 227-241. DOI: 10.1093/aob/mcf242

Jackson, M.B., The impact of flooding stress on plants and crops, 2004.

Kato, Y., Collard, B.C.Y., Septiningsih, E.M., Ismail, A.M., 2014. Physiological analyses of traits associated with tolerance of long-term partial submergence in rice, AoB PLANTS, 6, plu058.https://doi.org/10.1093/aobpla/plu058

Liao, C.T., Lin, C.H., 2001. Physiological adaptation of crop plants to flooding stress. Proceedings of the National Science Council, Republic of China. Part B, Life Sci., 25, Pp. 148-157.

Miro, B., Ismail, A.M., 2013. Tolerance of anaerobic conditions caused by flooding during germination and early growth in rice (*Oryza sativa L.).* Front. Plant Sci., 4, Pp. 269. https://doi.org/10.3389/fpls.2013.00269

Neeraja, C.N., Maghirang-Rodriguez, R., Pamplona, A., Heuer, S., Collard, B.C., Septiningsih, E.M., Vergara, G., Sanchez, D., Xu, K., Ismail, A.M., Mackill, D.J., 2007. A marker-assisted backcross approach for developing submergence-tolerant rice cultivars. Theor. Appl. Genet., 115, Pp. 767-776.

Nishiuchi, S., Yamauchi, T., Takahashi, H., Kotula, L., Nakazono, M., 2012. Mechanisms for coping with submergence and waterlogging in rice. Rice, 5, Pp. 1-14.

Nugraha, Y., Vergara, G.V., Mackill, D.J., Ismail, A.B., 2020. Response of Sub1 introgression lines of rice to various flooding conditions. Indones. J. Agric. Sci., 14, Pp. 15-26.

Perata, P., Voesenek, L.A., 2007. Submergence tolerance in rice requires Sub1A, an ethylene-response-factor-like gene, Trends Plant Sci., 12, Pp. 43-46. DOI: 10.1016/j.tplants.2006.12.005

Sasidharan, R., Bailey-Serres, J., Ashikari, M., Atwell, B.J., Colmer, T.D., Fagerstedt, K., Fukao, T., Geigenberger, P., Hebelstrup, K.H., Hill, R.D., Holdsworth, M.J., 2017. Community recommendations on terminology and procedures used in flooding and low oxygen stress research. New Phytol., 214, Pp. 1403-1407. DOI: 10.1111/nph.14519

Sayeed, K.A., Yunus, M.M., 2018. Rice prices and growth, and poverty reduction in Bangladesh, FAO, Rome, Italy.