Original Research Article

Development of Submergence Tolerant Rice Variety BRRI dhan79 for Flash Flood Ecosystem of Bangladesh

ABSTRACT

Tolerance to submergence stress is an important breeding objective for the areas where rice cultivars are subjected to complete inundation for a week or more. Submergence tolerance is an important trait for rice (*Oryza sativa* L.) in the flash flood-prone ecosystem. The trait is largely controlled by a major gene designated as Sub1 located on chromosome 9. Submergence of rice (*Oryza sativa*) by flash flooding is a major constraint to rice production in Bangladesh. Rice cultivars vary in their capacity to tolerate complete submergence. Quantitative trait loci analyses have revealed that a large portion of this variation in submergence tolerance can be explained by Sub1. Flooding has a dramatic effect on the growth and yield of crop plants because most of these economically important species are intolerant to flooding. A newly released submergence tolerant rice variety BRRI dhan79 suitable for the flash flood ecosystem of Bangladesh is an improvement over existing submergence tolerant rice varieties. The variety has satisfactorily been passed in the proposed variety trial conducted in the farmers' field. As a result, the National Seed Board (NSB) approved this variety for commercial cultivation in the wet season (Transplanted Aman season) in 2017. It has a modern plant type with 112 cm plant height and matures by 140 days (in case of three weeks submergence mature by 160 days). The important feature of this variety is the submergence tolerance up to three weeks with 50-60 cm water stagnation for 15-20 days after the receding flood during the vegetative stage. It can produce 5.5 t/ha grain yield (in case of three weeks submergence, produce 4.0-4.5 t/ha yield). The grain shape of the variety is intermediate medium. It has long grain length and erect flag leaf with deep green color. It is highly promising as a submergence tolerant rice variety for cultivation in the flash flood-prone area which helps farmers from huge economic loss and is contributing in sustaining food security.

Keywords: Submergence, wet season, Sub1, BRRI dhan79, vegetative stage, flash flood, stagnant water

1.INTRODUCTION

More than 2.0 million hectare areas of Bangladesh are affected by different grades of flash floods [1]. Submergence can result in yield losses of up to 100% depending upon different

factors of the environment. Submergence stress is estimated to affect about 20 million ha of rice-*growing* areas in Asia [2]. Traditional rice varieties grown under this environment were not high yielding having undesirable agronomic traits. Modern varieties with high yield potential and submergence tolerance are needed to increase the productivity of the submergence prone areas of rainfed lowland rice season. The discovery of comprehensive molecular linkage maps enables us to do the pyramiding of desirable traits to improve in submergence tolerance.

Submergence of rice (*Oryza sativa*) during the monsoon flooding season severely limits rice production in South and Southeast Asia, causing annual losses of over one billion U.S. dollars. Crop submergence due to flood or flash flood is an important hazard to the agriculture of Bangladesh; about 1 million hectares of cropland is highly flooded prone and 5 million hectares moderately prone. More than 18 districts of Bangladesh are more or less regularly affected by different grades of flash floods. Moreover, flash floods regularly affect rainfed lowland rice ecosystems. About 2.6 million hectares of rice lands of Bangladesh are affected by excess water for incessant rainfall in Monsoon season and periodically suffer from flash floods with complete submergence for 1-2 weeks or more covering about 24% of the total rice areas. This flood causes enormous damage to rice crop and irreparable yield loss (10-100%) depending on water depth, duration of submergence, the turbidity of the water, light intensity and age of the crop, etc. [3,4,5].

[2] Reviewed that plants require water for growth but excess water that occurs during submergence or waterlogging is harmful or even lethal. Among the rice-growing ecosystems, rainfed lowland is the most challenging one concerning the prevalence of many abiotic and biotic stresses. Submergence is the most important abiotic stress in the Rainfed Lowland Rice (RLR) ecosystem.

The Sub1 QTL on chromosome 9 accounts for 70% of the phenotypic variation for survival under submergence has been fine mapped on chromosome 9, and the cluster of genes underlying the QTL has been cloned [3]. This QTL has successfully been introgressed into a number of different varieties at the International Rice Research Institute (IRRI) and Bangladesh Rice Research Institute (BRRI) [1,2,6,7,8].

A large scale marker-assisted backcrossing (MABC) program was undertaken at IRRI to incorporate the *SUB1* gene into several popular rice varieties ("mega-varieties") that had many desirable attributes such as high yield and superior grain quality but were deficient in submergence tolerance. The *SUB1* gene conferred tolerance to complete submergence in rice for approximately 10 to 18 days. Using a high level of precision in MABC, the essential features of the mega-varieties (i.e. yield, grain quality, agronomic traits) were retained [1,2,6].

[6] Reported that flooding is a natural calamity that destroys the production of rice throughout the world especially in low-lying areas, but all economically important varieties are not tolerant to flooding. Identification of the *SUB1* QTL enables the scientist to introgress this QTL by MAB into the popular high-yielding varieties.

[6] Reviewed that by the use of MAB, *Sub1A* has been already inserted into modern varieties of different countries; BR11, Swarna, Sambha Mahsuri, IR64, CR1009 and Thadokkam 1 (TDK1) are some of the examples of those varieties.

[9] Reviewed that SSR markers, which were polymorphic between two parents, were generally used for the background confirmation of recurrent parent genome conformation also well combined with the Sub1 region originated from FR13A on chromosome 9. Normally newly developed Sub1 lines show more enhanced submergence tolerance compared to parents which are being obtained through phenotypic evaluation. These studies show the opportunities for the insertion of the Sub1 region from developed tolerant variety through MAB to produce tolerant varieties with a diverse genetic background. Furthermore, the effect of *SUB1* on other agronomical characteristics of the plant such as grain quality, growth, maturation, and grain production was determined in IR64-Sub1, Swarna-Sub1, and Sambha Mahsuri-Sub1. Further research of the above-mentioned submergence tolerant varieties and their original parents revealed that the insertion of the Sub1 gene does not alter yield performances including quality and yield of grain under normal non-flooded condition.

[10] Reported that complete submergence of susceptible varieties at the different growing stage considerably reduces the yield attributes like the number of panicles, the total number of grains per panicle, and grain filling percentage of the plant and also flowering and maturity may be delayed, resulting in a remarkable decline in yield. On the other hand, a Sub1 rice variety minimizes the total yield reduction by flood and produces more yield than the intolerant varieties at the submerged condition. One of the main advantages of using this approach is that the newly developed Sub1 varieties retain almost all agronomical characteristics of the recurrent parent, especially in terms of yield and quality. Sub1 varieties produced from FR13A-derived varieties have almost the same yield, agronomical, and grain quality characteristics as recurrent parent varieties when grown under regular conditions, but, when subjected to flooding for 1 to 2 weeks, Sub1 varieties showed a remarkable advantage in terms of yield than the susceptible ones.

[4] Reviewed that mega varieties that have *SUB1* gene, can be adopted by the farmer easily, besides, these new varieties can replace the traditional landraces with low yielding, and currently which has been used by the farmers in flood-prone areas. Some tolerant lines were evaluated and adopted in low-lying areas in more than ten countries in South and Southeast Asia, in field trials as the preferences of the farmers. The good yield performance of newly developed varieties, showing the better performance of Sub1 against flooding or submergence of rice. Those performances of the newly developed varieties have influenced a lot of rice improvement programs in Asia and Southeast Asia to perform rapid seed multiplication and dissemination schemes.

[11] Reported that a submergence tolerant high yielding variety was developed using BR11 as recipient parent applying foreground, phenotypic and background selection approaches. The recombinant selection was found essential to minimize linkage drag by BC_2F_2 generation. Without recombinant selection, the introgression size in the backcross recombinant lines (BRLs) was approximately 15 Mb on the carrier chromosome. The BRLs were found as submergence tolerant compared to the check varieties under complete

submergence for two weeks at Bangladesh Rice Research Institute (BRRI). The BRLs produced higher yield compared to the isogenic Sub1-line under controlled submerged condition. The Backcross Recombinant Line IR85260-66-654-Gaz2 was released as BRRI dhan52 in 2010 which was the first high yielding submergence tolerant variety in Bangladesh. BRRI dhan52 produced grain yield ranging from 4.2 to 5.2 t/ha under different flash flood-prone areas of Bangladesh in three consecutive seasons.

New high-yielding and adapted breeding lines derived from FR13A including IR49830 and IR40931 were developed at IRRI in the early 1990s. BRRI has developed two submergence tolerant rice varieties viz. BRRI dhan51 and BRRI dhan52 [11]. These two submergence tolerant varieties can withstand around two weeks of complete submergence under natural flash flooding situation. The challenge is to increase the level of flash flooding tolerance from 2 weeks to at least 3 weeks possibly through pyramiding another QTL conferring submergence tolerance along with *SUB1*. Modern rice varieties with an increased level of submergence tolerance are required to be developed as the currently available submergence tolerance varieties are sometimes died in the farmers' field where the intensity of stress taken place is more. The alternate source of *SUB1*QTL needs to be found out from the germplasm which will have the submergence tolerance as like as the reference resistant check FR13A but essentially will not possess the QTL *SUB1*. In this connection, [12] identified some germplasm having the similar properties of which the landrace Kalojoma is the most potential one.

The main objective of this study is to evaluate agronomic parameters of submergence and stagnant flood-tolerant rice variety BRRI dhan79 under the controlled and natural condition and its suitability for submergence prone flash flood ecosystem. The multi-location yield trials in multiple years demonstrated that BRRI dhan79 is more submergence tolerant rice variety than the existing one.

During the procedures of releasing breeding line BR9159-8-5-40-14-57 as a submergence tolerant variety BRRI dhan79, the yield and other parameters were observed which has been discussed very intensively in this study.

2. MATERIALS AND METHODS

BRRI dhan79 is developed through molecular marker-assisted backcrossing technique of a cross between two varieties BRRI dhan49 and BRRI dhan52 with a hope to develop a submergence tolerant rice variety in Bangladesh. The pedigree line of BRRI dhan79 is BR9159-8-5-40-14-57. The crossing was done in 2009 and advanced yield trials were conducted in the different submergence prone areas of Bangladesh until 2016.

A Participatory Variety Selection (PVS) trials were conducted to evaluate specific and general adaptability with standard checks BRRI dhan49 and BRRI dhan52 under the on-farm condition of flash flood-prone area at Badarganj, Rangpur; Kurigram and at controlled condition in Gazipur in Randomized Complete Block (RCB) design with three replications during T. Aman 2015. After proper yield evaluation, this material was subjected to Advanced Lines Adaptive Research Trial (ALART) to evaluate specific and general adaptability with standard checks BRRI dhan49 and BRRI dhan52 in the farmers' field condition of the flash

flood-prone area in T. Aman 2015, conducted by Adaptive Research Division (ARD) of BRRI. This genotype was tested for different physicochemical properties, cooking qualities, disease-insect reactions under natural conditions. Plant height, tillering ability were recorded from ten randomly selected plants excluding border rows. Growth duration was counted from seeding to 80% grain maturity. Grain yield data was taken from a 10 sqm sample plot in each replication. In T. Aman 2016, BR9159-8-5-40-14-57 (BRRI dhan79) was evaluated by the National Seed Board of Bangladesh (NSB) in the eight locations of farmers' field and two locations of controlled submergence condition in Bangladesh under field trial named Proposed Variety Trial (PVT) which were conducted in Randomized Complete Block (RCB) design with three replications. Finally, after proper evaluation, the NSB team recommended BR9159-8-5-40-14-57 as a superior genotype concerning submergence tolerance for releasing as BRRI dhan79 in 2017.

3. RESULTS AND DISCUSSION

Experimental PVS trial was submerged by natural flash flood for two times; 16 and 4 days and with 100 to 180 cm water height, respectively, along with 40-55 cm water stagnation at vegetative stage. BR9159-8-5-40-14-57 gave highest yield (4.10 t/ha) followed by BRRI dhan49 (2.36 t/ha) and BRRI dhan52 (2.31 t/ha). Farmers preferred BR9159-8-5-40-14-57, because of highest yield with highest survivability (80%) over other varieties (Table 1.a). PVS trial in Kurigram was flooded for 16 days by a natural flash flood with a 100 cm water level and 20-25 cm water stagnation at the vegetative stage. BR9159-8-5-40-14-57 produced similar yields as the check varieties and had a higher survival (61%) than the resistant check variety BRRI dhan52 (46%) (Table 1.b). PVS trial was submerged for 14 days at BRRI Gazipur in a controlled submergence condition with a water depth of 60 cm. After the waters had receded, BR9159-8-5-40-14-57 had a higher survivability (99%) than the check variety BRRI dhan52, however the yield was less as the grain type of the tested genotype was medium slender and small. Yield was significantly higher (4.10 t/ha) than the susceptible check variety BRRI dhan49 (0.38 t/ha) (Table 1.c). BR9159-8-5-40-14-57, BRRI dhan49 and BRRI dhan52 were evaluated in five locations (Rangpur, Sylhet, Lalmonirhat, Nilphamari and Jamalpur (Sadar) in the farmers' field of flash flood prone area in T. Aman 2015. In all locations the trials were submerged by natural flash flood. However, due to extreme flood water pressure BRRI dhan52 was fully damaged in Nilphamari. Average highest grain yield (3.48 t/ha) was found in BR9159-8-5-40-14-57 followed by BRRI dhan49 (3.26 t/ha) and BRRI dhan52 (3.15) (Table 2). BR9159-8-5-40-14-57 has erect flag leaf which facilitates maximum solar light uptake, 1000 grain weight of this variety is 22.5 gram and possesses intermediate medium grain shape (Fig. 1), high amylose content and late leaf senescence quality at maturity ensuring harvest of optimum yield (Table 3). On an average, the line BR9159-8-5-40-14-57 produced 5.37 t/ha grain yield which was significantly higher than the grain yield of BRRI dhan49 (4.12 t/ha). The growth duration of the proposed line was around 5 days earlier than BRRI dhan52. Though under 16 days of controlled complete submergence pressure at BRRI regional station Rangpur (Fig 3), the line produced similar grain yield compared to BRRI dhan52 (Table 4.a) but under 25 days of submergence pressure at BRRI Gazipur (Fig 2), the line produced 2.3 t/ha more yield than BRRI dhan52 and 3.1 t/ha more

grain yield than BRRI dhan49 (Table 4.a). Though there were no natural flash flooding in the farmers' field trials, but, importantly, in all the locations the proposed line produced more grain yield than BRRI dhan49 (Table 4.a). Under the controlled submerged condition, BR9159-8-5-40-14-57 showed higher survivability (%) under two to three weeks complete submergence (Table 4.b). This line has already been released as BRRI dhan79 in the 92th NSB Meeting on 5 April 2017.

Table 1.a. Performance of BR9159-8-5-40-14-57 (BRRI dhan79) in Participatory Variety Selection (PVS) trial conducted under natural flooding at Badarganj, Rangpur, T. Aman 2015

Sl#	Genotypes	Plant height (cm)	Growth duration (days)	Survival (%)	Grain yield (t/ha)
1	BR9159-8-5-40-14-57	105	165	80	4.10
2	BRRI dhan49 (Sus.Ck)	98	169	44	2.36
3	BRRI dhan52 (Res. Ck)	108	169	55	2.31
	LSD (0.05)	4.9	ns	18.3	0.69

Table 1.b. Performance of PVS trials conducted at Kurigram, T. Aman 2015

Sl#	Designation	Plant height (cm)	Growth duration (days)	Survival (%)	Grain yield (t/ha)
1	BR9159-8-5-40-14-57	77	165	61	4.35
2	BRRI dhan49 (Sus.Ck)	92	163	77	4.80
3	BRRI dhan52 (Res. Ck)	105	165	46	4.49
	LSD (0.05)	13.2	4.2	14.2	1.20

Table 1.c. Performance of PVS trials conducted at Gazipur (Tank), T. Aman 2015

Sl#	Designation	Plant height (cm)	Growth duration (days)	Survival (%)	Grain yield (t/ha)
1	BR9159-8-5-40-14-57	120	151	**99**	4.10
2	BRRI dhan49 (Sus.Ck)	116	149	8	0.38
3	BRRI dhan52 (Res. Ck)	127	157	83	5.64
	LSD at (0.05)	4.0	4.9	12.1	0.81

Table 2. Performance of the proposed variety at on farm trial under ALART (Flash Flood Submergence), T. Aman 2015

Location	Proposed Variety BR9159-8-5-40-14-57		Standard Check BRRI dhan49		Resistant Check BRRI dhan52	
	Growth duration (days)	Grain yield (t/ha)	Growth duration (days)	Grain yield (t/ha)	Growth duration (days)	Grain yield (t/ha)
Rangpur	136	4.00	135	4.15	145	3.55
Sylhet	145	3.36	147	2.45	152	2.39
Lalmonirhat	153	2.30	155	1.89	158	1.63
Nilphamari	141	2.83	141	2.60	-	-
Jamalpur (Sadar)	137	4.92	137	5.22	142	5.02
Mean	**142**	**3.48**	**143**	**3.26**	**149**	**3.15**

Table 3. Grain characteristics of BR9159-8-5-40-14-57 (BRRI dhan79) and check varieties

Designation	Milling Yield (%)	Head rice yield (%)	Decorticated grain				ER	IR	Protein (%)	Amylose (%)	1000 grain weight (g)
			Length (mm)	Breadth (mm)	L-B Ratio	Size and shape					
BR9159-8-5-40-14-57	71.7	63.3	5.5	2.3	2.3	IM	1.3	3.1	7.8	25.2	22.5
BRRI dhan49 (Standard Ck.)	70.0	65.0	5.4	2.0	2.7	SM	1.1	2.8	7.0	25.0	20.2
BRRI dhan52 (Resistant Ck.)	74.0	56.0	5.7	2.7	2.1	IM	1.5	2.8	7.3	26.8	25.4

*IR= Imbibition Ratio ER= Elongation Ratio IM=Intermediate Medium SM=Short Medium

Table 4.a. Performance of BR9159-8-5-40-14-57 (BRRI dhan79) in PVT trial conducted at ten different flash flood prone areas, T. Aman 2016

Designation	PH (cm)	GD (days)	Yield (t/ha)										
			L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean
BR9159-8-5-40-14-57	112	140	4.8	5.5	5.7	3.8	6.9	5.0	5.4	5.4	7.1	4.1	**5.37**
BRRI dhan49 (Standard Ck.)	110	141	4.5	4.8	5.4	3.7	6.7	4.7	5.2	4.8	0.4	1.0	4.12
BRRI dhan52 (Resistant Ck.)	128	144	5.4	5.6	6.3	4.2	5.5	5.4	6.1	5.1	7.2	1.8	5.26
LSD (0.05)						1.12							
Heritability						0.66							

L1=Mogholerbug, Sadar, Rangpur, L2=Aditmari, Lalmonirhat, L3=Kulaghat, Sadar, Lalmonirhat, L4=Palashbari, Gaibandha, L5=Batashar, Habiganj, L6=Dewanganj, Jamalpur, L7=Islampur, Jamalpur, L8=Dhobaura, Mymensingh, L9=BRRI-Rangpur (Control submergence-16 days submergence), L10=BRRI-Gazipur (Control submergence-25 days submergence)

Table 4.b. Survival % under controlled submergence condition PVT, T. Aman 2016

Sl#	Genotypes	Survival%	
		BRRI Gazipur Tank	BRRI Rangpur Tank
1	BR9159-8-5-40-14-57	77	95
2	BRRI dhan52 (Res. Ck)	23	57
3	BRRI dhan49 (Sus. Ck.)	15	4
4	Submergence	25 days with 80 cm water height	16 days with 99 cm water height

BR9159-8-5-40-14-57 (BRRI dhan79) showed tolerance to major diseases and insects under the natural and artificial inoculated condition. BR9159-8-5-40-14-57 (BRRI dhan79) showed

similar symptoms of check varieties against different major diseases and insects' infestation (Table 5 and Table 6).

Table 5. Reaction of BR9159-8-5-40-14-57 (BRRI dhan79) against major diseases and insects under the natural condition

Designation	Bacterial Blight	Sheath blight	Stem borer	Leaf folder
BR9159-8-5-40-14-57	5	7	5	7
BRRI dhan49 (Standard Ck.)	5	5	5	7
BRRI dhan52 (Resistant Ck.)	5	7	5	7

Disease and Insect severity scale (0 – 9)

Table 6. Reaction of BR9159-8-5-40-14-57 (BRRI dhan79) against major diseases and insects under the artificial inoculated condition

Designation	Bacterial Blight	Sheath blight	Brown Plant Hopper	White Backed Plant Hopper
BR9159-8-5-40-14-57	7	9	5	5
BRRI dhan49 (Standard Ck.)	7	5	7	7
BRRI dhan52 (Resistant Ck.)	5	9	9	9

Disease and Insect severity scale (0 – 9)

Distinguishing characters of the candidate variety BR9159-8-5-40-14-57 (BRRI dhan79) compared to the check varieties e.g. BRRI dhan49 and BRRI dhan52 are penultimate leaf: pubescence of blade, flag leaf: attitude of blade, culm: length, panicle: length, panicle: number of effective tillers in plant, grain: wt of 1000 fully developed grains (at 12%), decorticated grain: shape (length-breadth ratio), endosperm: content of amylose and other distinct special character (if any) (Table 7).

Table 7: Distinctness between BR9159-8-5-40-14-57 (BRRI dhan79) with check varieties

Sl#	Characteristics	BRRI dhan49 (Check Variety)		BRRI dhan52 (Check Variety)		BR9159-8-5-40-14-57		Remarks
		Code	State	Code	State	Code	State	
1	Penultimate leaf : pubescence of blade	3	Weak	5	Medium	3	Weak	Distinct
2	Flag leaf: attitude of blade	1	Erect	3	Semi-erect	3	Semi-erect	Distinct
3	Culm: Length	5	Medium	7	Long	7	Long	Distinct

4	Panicle: Length	7	Long	5	Medium	5	Medium	Distinct
5	Panicle: number of effective tillers in plant	7	Many	5	Medium	5	Medium	Distinct
6	Grain: wt of 1000 fully developed grains (at 12%)	5	Medium	7	High (24-27g)	5(23g)	Medium	Distinct
7	Decorticated grain: shape (Length-breadth ratio)	7	Medium slender	5	Medium	5	Medium slender	Distinct
8	Endosperm: content of amylose	3 (25%)	Intermediate (21-25%)	5 (26.8%)	High (>25%)	5 (25.2%)	High	Distinct
9	Other distinct special character (if any)	Non-Sub1 moderately submergence tolerant		Submergence tolerant		Submergence tolerant		Distinct

Uniformity: At 50% heading date-time only 0.5% off-type was observed. It indicated that the candidate variety BR9159-8-5-40-14-57 is uniform according to the UPOV standard.

Stability: In the test plots of two consecutive seasons trials, no remarkable variation and segregation were noted which implies the stability of the candidate variety.

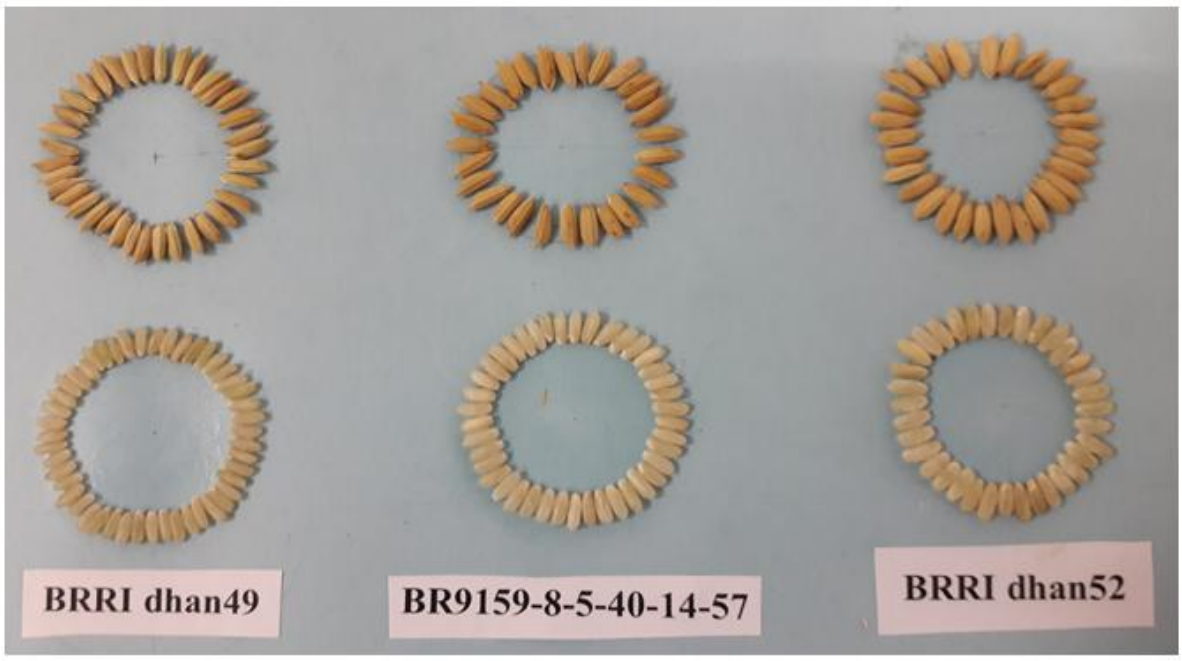

Fig. 1. Pictorial view of rice grain and dehulled grain of the proposed submergence tolerant line compared to the check varieties

Fig. 2. PVT-Submergence trial was submerged for 25 days at BRRI Gazipur, T. Aman 2016

Fig. 3. Mortality of BRRI dhan49 and survival with faster recovery of BR9159-8-5-40-14-57, PVT, BRRI R/S Rangpur, T. Aman 2016

4. CONCLUSION

To sum up, BRRI dhan79 was made available as submergence tolerant high yielding rice variety to satisfy the nation's desire. This variety's adaptability testing in the farmers' field under multiple locations trials demonstrated satisfactory performance in terms of submergence tolerance and some yield-contributing factors. BRRI dhan79 will be popular at farmers' level quickly and because of its high yielding along with submergence tolerance capability in flash flood ecosystem the total rice production will be increased.

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