



## Early Maturing Drought Tolerant Rice Variety BRRI dhan71 Suitable for Drought Prone Environment in Bangladesh

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author MAK planned the experiment and lead the research. Authors MAK and TLA designed & carried out the research. Authors TKH and MEH performed the statistical analysis. Authors TKH and RRM carried out the research on the field. Authors RRM and TKH collected the data. Authors RRM and MEH wrote the manuscript. Authors TLA and RRM managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Drought is the second most treacherous climate-related risk for rice production in rainfed lowland areas. To counter this climate vulnerability, a new rice variety with enhanced drought tolerance was developed. The promising line IR82589-B-B-84-3 was subjected to advanced yield trials to evaluate specific and general adaptability with standard check in on-station as well as on-farm conditions of Bangladesh following randomized complete block (RCB) design with three replications in wet (T. Aman) season. IR82589-B-B-84-3 was developed as a drought-tolerant rice variety BRRI dhan71, which plant height 108 cm and growth duration 115 days after proper evaluation by National Seed Board (NSB) Bangladesh. It was found that this variety is the higher drought tolerance (up to 28 days) during reproductive stage. It can produce 5.5 t/ha grain yield in standard condition and 4.0 t/ha grain yield in medium drought condition but 3.0-3.5 t/ha grain yield in severe drought condition.

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Grain yield is also not affected by water scarcity during reproductive stage where parch water table depth is more than 70-80 cm from the surface and reduced soil moisture (<20%). Thousand grain weight of the variety is 24 gm, amylose content is 24%. It has long, erect and deep green colored flag leaf. The results indicated that farmers can maximize net profit by cultivating BRR1 dhan71 because it required less input, early maturing than existing varieties, drought tolerant and they also get opportunity to cultivate Mustard, Barley, Potato and vegetables after harvesting it. Thus total productivity will be augmented and food security can also be sustained by the cultivation of BRR1 dhan71.

*Keywords: BRR1 dhan71; drought; rice; rainfed lowland and variety.*

## 1. INTRODUCTION

Rice is the staple food for more than three billion people in Asia, where more than 90% of the world's rice is produced and consumed [1]. It is grown worldwide in one hundred fifty four million hectares (m ha) and more than 45% of the area is in rainfed ecosystems, where yields are seriously affected by drought [2]. According to Ricepedia report, about sixty million hectares of rainfed lowlands supply about 20% of the world's rice production. The rice yield in these ecosystems is very low at 1.0-2.0 ton ha<sup>-1</sup> and is unstable due to erratic and unpredictable rainfall. With the changing climate, drought is becoming one of the major problem among other stresses which would affect rice production severely.

Drought is the most important source of climate-related risk for rice production in rainfed areas [3]. Drought affected about 100,000 hectares (250,000 acres) of land in Bangladesh particularly in Barindra tracts and other northern districts during July to September period. To maintain food security, development of drought tolerant varieties is needed for drought-prone Barind Tract and other affected areas. The drought tolerant rice varieties has also economic significance to other districts that are known drought hot spots – Kushtia, Magura, Chuadanga, and Jashore, where rain is scanty and unpredictable during the last week of September and in October when rice needs water critically. Worldwide, approximately 27 million ha of rice are grown in upland condition also face drought stress. To counter this climate vulnerability, it is necessary to breed new rice cultivars with elevate drought tolerance.

Drought mitigation, through development of drought-tolerant rice varieties with higher yields suitable for water-limiting environments will be a key work to raise rice production and ensure food security to three billion people in Asia. The progress in genetic improvement of rice for

water-limiting environments, however, has been slow and limited due to poor understanding of the inheritance, mechanisms of tolerance and lack of efficient techniques for screening breeding materials for drought tolerance [4,5]. Characterization of drought environment, matching phenology, high potential yield and inbuilt drought tolerance are vital for successful crop production in water-limiting conditions. Drought types, particularly timing and intensity, are important in determining specific plant traits required to improve drought resistance. Drought stress induces a series of complex responses beginning with stress perception, signal transduction and manifestation of responses at the cellular, physiological, and developmental levels. The set of responses observed depends upon the crop stage, severity and duration of the stress. When evaluating the usefulness of traits to increase grain yield, it is important to consider phenological development, which has an overriding effect on the grain yield under water limiting condition [6]. The reproductive development in plant is highly vulnerable to water deficit [7]. Yambao and Ingram, 1988 [8] reported yield reduction up to 70% upon imposing drought for 15 days at panicle initiation stage and 88% and 52% reduction when stressed at flowering and grain filling stage, respectively. Stress imposed during panicle initiation can delay or completely inhibit flowering, through inhibition of floral induction and development<sup>7</sup>. Within this period two sensitive peaks have been reported, one being the period around pollen mother cell meiosis and tetrad break up and the second is anthesis to initial stage of grain development. Pollen formation in rice is highly vulnerable to drought stress [9]. Stress at meiotic stage causes pollen sterility, failure of pollination, spikelet death or zygotic abortion, but female fertility is affected only under extreme stress.

Conventional breeding has been based on observed selection for yield. Most of the high-yielding varieties– IR36, IR64, MTU1010, BR11,

Swarna and Samba Mahsuri are grown in rainfed areas are preferred by the farmers due to their yield potential but are not tolerant to drought. These varieties give high yield during non-drought years, but there is drastic reduction when moderate drought appears and collapse completely in severe drought stress [10]. Other varieties which show some degree of resistance to drought reported from plateau region of Eastern India. Nam Sagui 19 is one of the important parental lines in breeding programs. Some of the successful cases of direct selection for grain yield under drought have been reported at IRRI [10,11]. This breakthrough resulted in the development of several promising breeding lines for the rainfed lowland and upland [12,13]. Some of the varieties of rice for grain yield under drought conditions has been also released through direct selection those are Sahbhagidhan (India), Sukha dhan-1, Sukha dhan-2 and Sukha dhan-3 (Nepal), BRRRI dhan56 (Bangladesh), Sahod ulan-3, 5, 6, 8 and Katihan-8 (Philippines), Tarharra 1 (Nepal). These varieties perform well under drought as well as favourable years.

Multilocation testing of elite breeding lines has also allowed a better understanding of the genotype x environment (G×E) interactions related to grain yield under reproductive-stage drought. In general, it has been observed that a majority of these lines perform best in their specific environments. A majority of these varieties were released in specific countries where they turned out to be the best performers. However, lines IR74371-70-1-1 and IR74371-54-1-1 were released under three different names in three countries—India, Bangladesh, Nepal, Philippines and Nigeria respectively—showing the stability of performance of these lines across environments. Regardless of the complexity of grain yield under reproductive- stage drought, lines selected under managed dry-season field experiments at IRRI were able to perform well in different countries [14]. The success of this breeding programme pointed the adaptability of lines across regions in shallow lowland environments of different countries, and this validates the earlier prediction that G×E interactions can be handled more accurately within the different topography (shallow lowland, medium lowland, or deep lowland) in the rainfed ecosystem [15]. The main objective of this study is to evaluate agronomic parameters of a drought tolerant rice variety BRRRI dhan71 under controlled and natural condition and it's suitability for drought prone rainfed lowland rice ecosystem. The multi-location yield trials in

multiple years demonstrated that BRRRI dhan71 is more drought tolerant rice variety than existing one.

## 2. MATERIALS AND METHODS

BRRRI dhan71 was developed from a single cross between IR55423-01 (NSIC RC 9) and IRRRI148, with the aim to develop a drought tolerant rice variety. The pedigree of BRRRI dhan71 is IR82589-B-B-84-3. The fixed line was introduced from IRRI in 2012 and conducted advanced yield trial in the different drought prone areas of Bangladesh until 2014. The promising line was subjected to Advanced Yield Trial (AYT) to evaluate specific and general adaptability with standard check BRRRI dhan56 in on-farm condition of six locations of Bangladesh following randomized complete block (RCB) design with three replications in T. Aman 2012 (July - December). After proper yield evaluation this material was subjected to Advanced Lines Adaptive Research Trial (ALART) to evaluate specific and general adaptability with standard check BRRRI dhan56 in the farmers' field condition in T. Aman 2013, conducted by Adaptive Research Division (ARD) of BRRRI. This genotype was tested for different physico-chemical properties, cooking qualities and find out best planting time, disease-insect resistance ability under natural condition, plant height, tillering ability were recorded from the ten random plants excluding border rows. Growth duration was counted from seedling to 80% grain maturity. Grain yield data was taken from 10 sq-m sample plot in each replication. In T. Aman 2014, IR82589-B-B-84-3 (BRRRI dhan71) was evaluated by the National Seed Board of Bangladesh (NSB) in the nine locations of farmers' field of Bangladesh under field trial name Proposed Variety Trial (PVT). Finally after proper evaluation the NSB team found IR82589-B-B-84-3 as a superior genotype in respect to drought tolerance has been released as BRRRI dhan71 in the year 2015. The agro-morphological data like growth duration, plant height, grain yield etc. were subjected to statistical analysis to determine heritability, least significant difference (LSD), mean, Additive Main effects and Multiplicative Interaction (AMMI) Biplot, Adaptation map [16].

## 3. RESULTS AND DISCUSSION

### 3.1 Advanced Yield Trial (AYT)

The agro-morphological characteristics of IR82589-B-B-84-3 (BRRRI dhan71) is shown in

Table 1. It has intermediate plant height and lodging tolerance. BRRI dhan71 has deep green, erect and long flag leaf which facilitates maximum solar light uptake. The advanced yield trial (AYT) of BRRI dhan71 with check variety BRRI dhan56 was conducted in five locations of Bangladesh. BRRI dhan71 showed the maximum yield (4.35 t/ha), followed by BRRI dhan56 (Table 1) in wet season (T. Aman) 2012. Although BRRI dhan71 gave the highest (303) panicle/m<sup>2</sup> than BRRI dhan56 (288). The 1000 grain weight of BRRI dhan71 showed significant variation with BRRI dhan56. High yield is the prime objective in developing modern rice varieties. BRRI dhan71 showed higher yield than the all other breeding lines at drought condition in T. Aman 2012 season. This higher yield of BRRI dhan71 was due to its genetic potentiality of producing higher and more drought tolerant capacity than BRRI dhan56.

### 3.2 Advanced Line Adaptive Research Trial (ALART)

IR82589-B-B-84-3 (BRRI dhan71), one advanced line and check variety BRRI dhan56 were evaluated in 08 locations (Gazipur, Rangpur, Joypurhat, Chapai Nawabgonj, Naogaon, Dinajpur, Rajshahi, Jhinaidah,) in the farmers' field of Bangladesh in T. Aman 2013. Results are showed in the Table 2. Significant variation was found for grain yield of the genotype. Highest grain yield was found for BRRI dhan71 (4.82 t/ha) followed by BRRI dhan56 (4.50 t/ha) in Rangpur. The result visualizes the higher yield potentiality of BRRI dhan71 over the check genotype. On an average BRRI dhan71 yielded 0.33 t/ha higher than BRRI dhan56 (Table 2). The genotype was almost disease free in some locations. The plant stature of the variety made the line lodging tolerant. Growth duration was found 3 days longer than the check variety BRRI dhan56 (Table 2). Farmers preferred BRRI

dhan71 for their better yield, early maturing and importantly lodging tolerance as well as higher drought tolerance.

### 3.3 Proposed Variety Trial (PVT)

Performance of the IR82589-B-B-84-3 (BRRI dhan71) at on farm trial, T. Aman, 2014 is shown in Table 3. Evaluation of the IR82589-B-B-84-3 (BRRI dhan71) at on farm trial was evaluated by the National Seed Board (NSB) of Bangladesh in T. Aman 2014 season. The highest yield of the genotype was found 5.97 in Kushtia followed by 5.83 t/ha in Rajshahi (Poba) and 5.20 t/ha in Lalmonirhat (Sadar). The grain yield indicated that the variety could produce more against drought stress. On an average BRRI dhan71 produced 5.05 t/ha yield whereas BRRI dhan56 produced 4.40 t/ha yield, that is BRRI dhan71 produced 0.65 t/ha more grain yield than BRRI dhan56 (Table 3 and Fig. 1). According to soil moisture and perch water table depth status BRRI dhan71 is more drought tolerant rice variety than BRRI dhan56 (Fig. 2). Growth duration of BRRI dhan71 was ranged from 104 days in Chapai Nobabgonj to 115 days in Gazipur depending on the agro climatic situation in the T. Aman season. Mean growth duration of the variety was found 111 days which is five days longer than the check variety BRRI dhan56.

### 3.4 Disease and Insect Reaction

BRRI dhan71 showed tolerance to major diseases and insects under the natural field condition in the field of plant breeding division. The variety showed a bacterial score 1-3, meaning it is highly tolerant to bacterial blight and sheath blight disease (Table 4). The variety is also tolerant to brown plant hopper for the dead heart and white head symptoms count. BRRI dhan56 also showed similar symptoms.

**Table 1. Morphological and agronomical characters of the proposed variety, T. Aman 2012**

Designation	Plant Height (cm)	Growth Duration (days)	Panicle per m <sup>2</sup>	1000 grain weight (gm)	Location wise grain yield (t/ha)				Mean
					Rangpur	Nilphamari	Lalmonirhat	Kurigram	
IR82589-B-B-84-3	110	115	303	24	4.8	3.7	4.3	4.6	4.35
BRRI dhan56 (Ck)	113	110	288	23	4.0	3.2	2.9	4.4	3.63
LSD (0.05)	7.8	1.6	12.6	0.59	0.66				

**Table 2. Performance of the proposed variety at different Zonal Trial, T. Aman, 2013**

Designation	Plant height (cm)	Growth duration (Days)	Location wise grain yield (t/ha)								Mean
			Gazipur	Rangpur	Joypurhat	Chapai nwabgonj	Naogaon	Dinajpur	Rajshahi	Jhainadah	
IR82589-B-B-84-3 (BRRIdhan71)	107	117	3.24	4.82	3.60	4.35	3.68	3.04	4.50	3.64	3.86
BRRIdhan56(Ck.)	106	114	2.61	4.50	3.00	3.99	3.52	3.22	3.91	3.51	3.53
LSD (0.05)	ns	2.5	0.35	0.29	0.45	0.26	0.14	0.17	0.41	0.15	0.22
Heritability%	0.85	0.93	0.88	0.85	0.91	0.94	0.90	0.95	0.91	0.89	0.86

### 3.5 Distinctive Characters

The candidate variety IR82589-B-B-84-3 (BRRIdhan71) differ with check variety BRRIdhan56 by penultimate leaf pubescence of blade, culm length, decorticated grain size and shape and amylose content. At 50% heading date time only 0.5% off-type was observed for both the lines. It indicated that the candidate variety IR82589-B-B-84-3 (BRRIdhan71) is uniform according to UPOV standard. In the test plots of two

consecutive seasons trials, no remarkable variation and segregation were noted which imply the stability of the candidate varieties. It was observed that BRRIdhan71 is more drought tolerant due to its long root. The root length of BRRIdhan71 is 67.2 cm where the root length of check variety BRRIdhan56 is 63.3 cm. The grain weight per plant also more than the check variety (Table 5). The leaf is deep green and plant is stronger under both controlled and natural drought stress condition (Fig. 3 and Fig. 4).

**Table 3. Performance of the proposed variety at on farm trial, T. Aman 2014**

Location	Proposed variety		Check	
	IR82589-B-B-84-3 (BRRIdhan71)		BRRIdhan56	
	Growth duration (Days)	Grain yield (t/ha)	Growth duration (Days)	Grain yield (t/ha)
Rajshahi (Godagari)	112	4.78	104	4.47
Rajshahi (Poba)	105	5.83	101	5.40
Rajshahi (Tanore)	106	4.57	99	4.21
Chapai Nobabgonj (Nachole)	104	4.61	99	3.48
Rangpur (Sadar)	110	4.80	105	4.40
Lalmonirhat (Sadar)	110	5.20	105	5.70
Kustia (Sadar)	120	5.97	119	4.69
Jashore (Sharsha)	114	4.73	110	3.92
Gazipur (Sadar)	115	4.93	112	3.33
Mean	111	5.05	106	4.40

**Table 4. Reaction of the proposed variety against major diseases and insects under natural field condition**

Designation	BB	ShB	Blast	DH	WH	BPH	WBPH
IR82589-B-B-84-3 (Proposed Variety)	1	3	0	1	1	0	0
BRRIdhan56 (Ck)	1	3	0	1	1	0	0

BB = Bacterial Blight, ShB = Sheath Blight, DH = Dead Heart, WH = White Head, BPH = Brown Plant Hopper, WBPH = White Backed Plant Hopper, Disease and Insect severity scale (0 – 9)

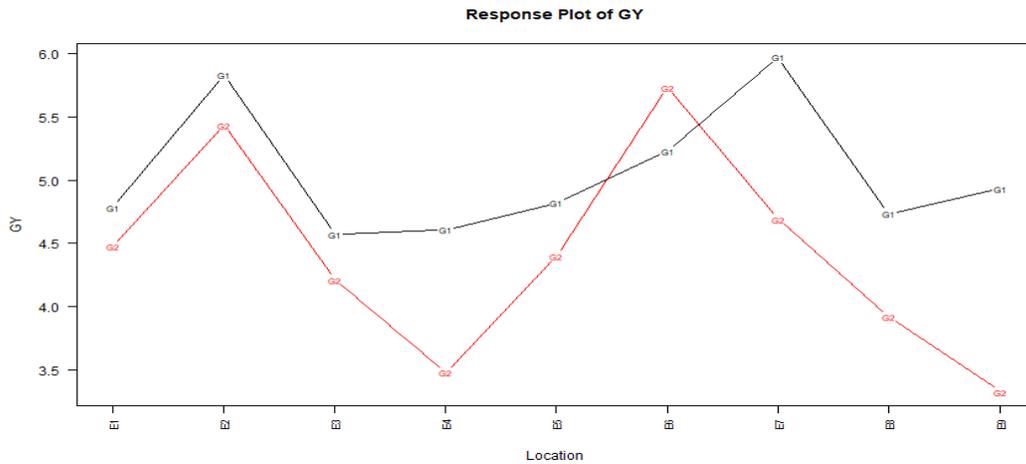


Fig. 1. Grain yield (GY) at ton/ha, comparison between proposed variety (G1) and check variety (G2) among multi-locations (E1-E9)

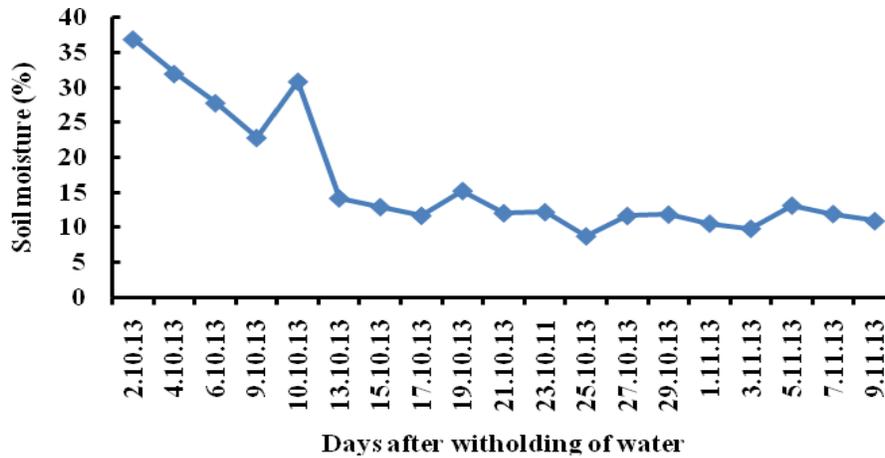


Fig. 2. Soil moisture percentage of the drum during IR82589-B-B-84-3 growing season, T. Aman 2013

### 3.6 Physico-chemical Properties

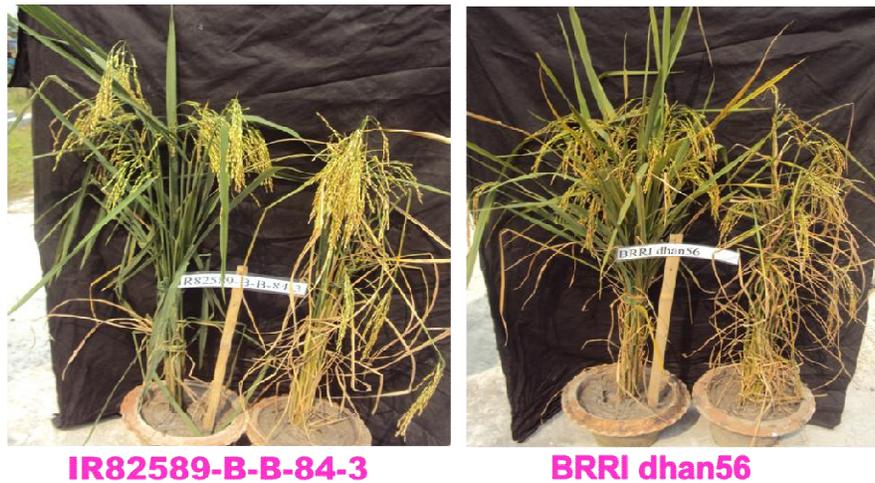
BRR1 dhan71 is a medium bold grain having length-breadth ratio 2.8 which is similar with BRR1 dhan56. The milling outturn of the variety is 70.4% with the head rice recovery 63.6% which is better than the other varieties (Table 6). But BRR1 dhan71 has 24.0% amylose where BRR1 dhan56 has 23.0% amylose. The paddy and husked rice of BRR1 dhan71 and BRR1 dhan56 as shown in Fig. 5.

Additive Main effects and Multiplicative Interaction (AMMI) model shows only environmental interaction for predicted potentiality of breeding line. According to AMMI

Biplot, the BRR1 dhan71 is the best performer in Kushtia (E7) followed by in Gazipur (E9), Jashore (E8) and Chapai Nowabgonj (E4). It will perform constantly in Rajshahi (E1, E3), and Rangpur (E5). BRR1 dhan71 will comparatively less perform in Lalmonirhat (E6) (Fig. 6). The What-won-where Biplot analysis indicates BRR1 dhan71 (G1) was higher yielder than BRR1 dhan56 (G2) among 08 trial locations and lower yielder in one location (Fig. 7). An Adaptation Map was constructed using data from nine farmer's field trial, the analysis predicts that BRR1 dhan71 is likely to be more adapted variety than the BRR1 dhan56 in eight locations and less adapted in 01 location (Fig. 8).

**Table 5. Evaluation of proposed variety under controlled drought condition, BRR I Gazipur, T. Aman 2013**

Designation	Root length (cm)	Cumulative root length(cm)	Root shoot ratio	Grain yield (g/plant)			% Sterility		1000 grain wt.	
				Control	Stress	% reduction	Control	Stress	Control	Stress
IR82589-B-B-84-3 (BRR I dhan71)	67.2	1776	0.130	49.67	11.95	75.9	14.2	65.7	23.74	17.18
BRR I dhan56	63.3	1063	0.141	48.17	8.51	82.3	18.0	72.1	21.73	18.03



**Fig. 3. Front view of IR82589-B-B-84-3 (BRR I dhan71) with BRR I dhan56 screened under controlled drought condition in BRR I**



**Fig. 4. BRR I dhan71 under rainfed condition**

**Table 6. Physicochemical properties of BRR1 dhan71**

Designation	Milling Yield (%)	Head rice yield (%)	Decorticated grain				ER*	IR*	Protein (%)	Amylose (%)
			Length (mm)	Breadth (mm)	L-B Ratio	Size and shape				
IR82589-B-B-84-3 (BRR1 dhan71)	70.4	63.6	6.5	2.3	2.8	MB	.5	3.4	7.0	24.0
BRR1 dhan56 (Ck.)	71.5	59.5	6.4	2.3	2.8	MB	1.5	3.5	8.0	23.0

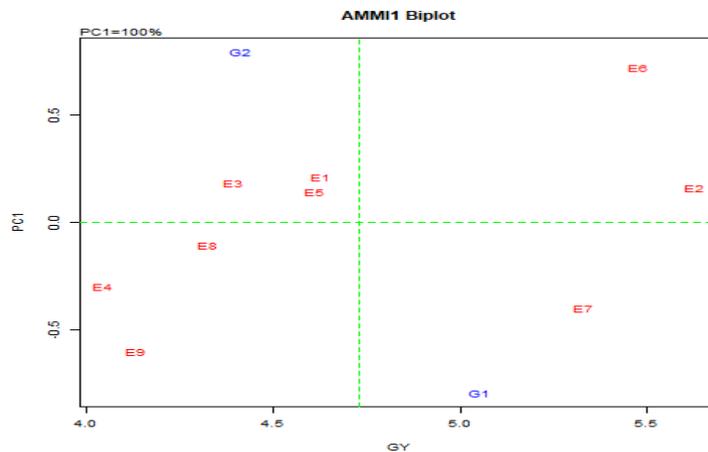
\* ER= Elongation Ratio and IR= Imbibition Ratio

The outcomes of multi-year and multi-locations advanced yield trials conducted in hot spot regions of drought under on-station and on-farm condition proved that the grain yield of the proposed variety is higher than the check variety (Table 1, Table 2, Table 3). The most important criteria for a drought tolerant breeding material are the root length. The root length and cumulative root length of proposed variety are longer than the check variety (Table 5). So, this proposed variety is a more potential genotype for cultivating in drought prone regions. In stress tolerance breeding identifying

best tolerant and the effective multi-location and multi-year on-farm trial are important consideration to release an advanced breeding line [17]. Some predictive analysis was done such as AMMI Biplot, What-won-where Biplot and Adaptation Map for understanding the suitable areas to cultivate proposed variety BRR1 dhan71 [18,16]. This study will be useful to develop breeding materials and drought tolerant rice variety in future. It will also impact on QTL mapping, Genome wide association mapping and SNP marker identification.



**Fig. 5. Comparative view of paddy and husked rice of BRR1 dhan71 and BRR1 dhan56**



**Fig. 6. AMMI Biplot analysis showing the environmental interaction to genotypes**

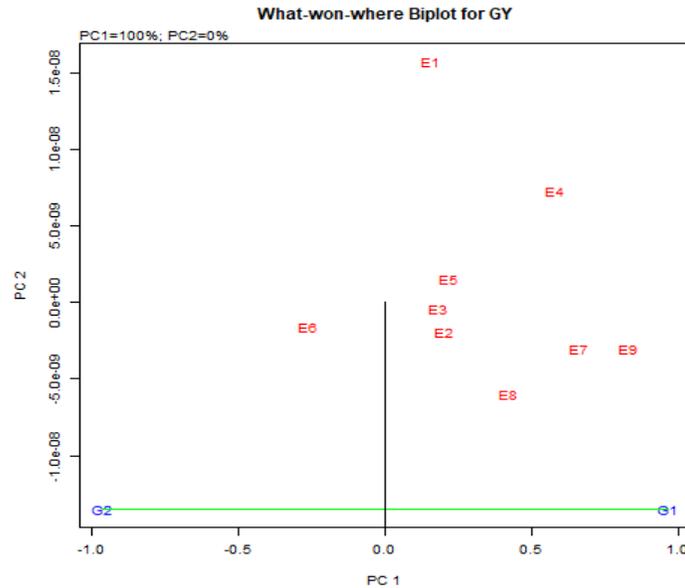


Fig. 7. What-won-where Biplot analysis shows the better performance of BRR1 dhan71 in each trial location

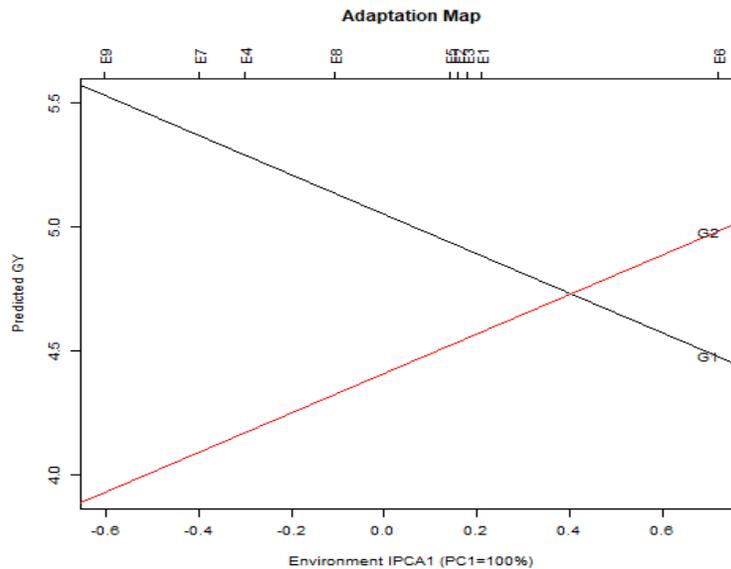


Fig. 8. An Adaptation map of BRR1 dhan71

#### 4. CONCLUSION

Drought tolerant high yielding rice variety at reproductive phase in rainfed lowland rice ecosystem is highly demanding. BRR1 dhan71 can give 0.5-1.0 t/ha more yield than BRR1 dhan56 at drought prone environments of Bangladesh. However, BRR1 dhan71 was finally

released as a high yielding and drought tolerant rice variety for drought prone areas of Bangladesh. Adaptability tests of this variety under multi-location trials in the farmers' field showed satisfactory performance with respect to grain yield and some yield contributing parameters. It is anticipated that this drought tolerant rice variety will contribute to the national

Gross Domestic Product (GDP) and also alleviate poverty from drought prone northern regions of Bangladesh.

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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