Mega Rice (*Oryza sativa*) Varieties of Bangladesh: A Comprehensive Review of the Breeding History and Production of BR11, BRRI dhan28, and BRRI dhan29

Biswajit Das
Department of Genetics and Plant Breeding, Bangladesh Agricultural University.
biswajit.23120705@bau.edu.bd

Abstract

Prior to the Green Revolution in the 1960s, rice cultivation in Bangladesh primarily relied on local landraces, which were characterized by low yield potential and undesirable agronomic traits. However, the establishment of the Bangladesh Rice Research Institute (BRRI) in 1970 marked a significant turning point, leading to steady advancements in rice production. To date, BRRI has developed 113 modern rice varieties (MVs), which now occupy 82% of the total rice cultivation area in Bangladesh. Despite this broad development, only a few varieties—BRRI dhan28 and BRRI dhan29 in the Boro season, and BR11 in Transplanted Aman—have achieved the status of mega varieties due to their widespread popularity and high yield potential. BR11, the most popular Transplanted Aman cultivar, produces approximately 6.0 t/ha, while BRRI dhan28 and BRRI dhan29 are the leading Boro rice varieties, especially in irrigated areas and haor regions. Together, these two Boro varieties account for 50% of the total Boro rice area. This review provides a comprehensive overview of these three mega varieties, focusing on their development, breeding history, pedigree, important progenies, favourable alleles, and their current status in Bangladesh's rice production landscape.

Keywords: Breeding, BR11, BRRI dhan28, BRRI dhan29, pedigree trees, progenies.

Introduction

Rice is the backbone of Bangladesh's agriculture; here, like in many other countries, 'food security' almost entirely depends on 'rice security' (Sarkar et al. 2021). Nearly, 36.4 million metric tons of rice were produced from almost 28.5 million acres of land, making it the most significant food crop in Bangladesh and accounting for 95% of all cereals consumed there. It alone contributes about 4.5% to the GDP (BBS, 2020).

Geographical and agronomic conditions of Bangladesh are favorable for rice cultivation. Rice is grown under diverse ecosystems such as irrigated, rainfed and deep-water conditions in the three distinct rice growing seasons, namely Aus, Aman and Boro which account for approximately 9%, 42% and 49% of total annual rice production, respectively (BBS, 2011). But before green revolution in 1960s, farmers mainly cultivated local landraces where yield potentiality was very low with some unexpected agronomic traits such as lodging tendency, low response to nitrogen fertilizer, low harvest index, and higher diseases infestation (Rahman et al. 2016). Across major rice producing countries of South Asia, green revolution started with the development of first semi-dwarf rice variety IR8 in the year of 1960 at International Rice Research Institute. (IRRI), Philippines. IRRI developed rice varieties and advanced breeding lines have contributed greatly to boost up rice production around the world. (Mackill and Khush 2018; Siddiq and Vemireddy 2021). In Bangladesh, rice breeding activities such as introduction, cultivar development and dissemination of those cultivars initiated through the establishment of Bangladesh Rice Research Institute (BRRI) in 1970.

As a result, since independence, there has been a three-fold increase in rice production in Bangladesh, which jumped from nearly 11 MT in 1971-72 to about 34.86 MT in 2014-15 (AIS, 2016). This has transformed the country from so called "Bottomless Basket" to a "Full of Food Basket". In recent years, the country has not only earned self-sufficiency in rice production, but also gradually entering into the export regime (BER, 2015). Kabir et al. 2015 rightly said, "Bangladesh has emerged as a global model for combating hunger and obtained great success in becoming a country of food surplus from a country lagged with chronic food shortages".

Till now, BRRI has developed 113 modern rice varieties for cultivation across different rice ecosystems (BRKB 2023). Among them, the cultivar BR11 is considered as most popular cultivar suitable for rainfed lowland area cultivated in Transplanted Aman (T. Aman) season. BR11 was released in 1980 as first mega variety of Bangladesh. It is well accepted to the farmers due to its good cooking quality (amylose 26%), higher yield (6.0 t/ha) and attractive phenotype (plant height 115 cm, 145 days growth duration).

The second mega rice cultivars of Bangladesh are BRRI dhan28 was released in 1994. BRRI dhan 28 is the most most popular cultivar for irrigated ecosystem during Boro season

(Iftekharuddaula *et al*. 2011). Gradually it became popular to farmers because of its good grain quality such as high amylose content (28%), medium slender grain and high yield (6.0 t/ha) with comparatively shorter growth duration (140 days). During dry season, the rice cultivar BRRI dhan28 occupies 23% of total rice growing areas (BRRI 2019).

The third mega rice cultivar of Bangladesh is BRRI dhan29 was also released in 1994. It is well accepted to single Boro areas because of its high yield (7.5 t/ha) with comparatively longer growth duration (160 days). During dry season, the rice cultivar BRRI dhan29 occupies 28% areas (BRRI 2019).

Recent climatic events have changed rice production scenario around the world. For example, old rice varieties have become susceptible to major diseases (such as blast) and often cause severe yield loss (Ahmed et al. 2023). In the future, higher genetic gain is required to meet the future challenges of crop improvement through accumulation of favorable alleles in the background of important popular rice varieties. Thus, future popular variety should possess resistance allele and other important agronomic traits. To increase secure rice production, we might use the breeding history of significant popular varieties and their important progenies to better understand the nature of parent selection, important progeny development, and subsequent usage in crop improvement programs in future.

2. Breeding history of mega variety BR11

2.1 Characteristics of BR11

The first mega variety, BR11, popularly known as 'Mukta' among the farmers of Bangladesh, once used to occupy 60-70% of the T. Aman acreage in the country. BR11 was released in 1980. According to Digital Herbarium of Crop Plants by BSMRSTU (retrieve from: http://dhcrop.bsmrau.net/br11/?doing_wp_cron=1689781433.3808770179748535156250) and Ahmed et al. 2023, the main features of this cultivar include :

- medium bold grain,
- high amylose content (26.0%),
- longer maturity period (145 days),
- high yield (6.0 t/ha),
- Moderately resistant to Tungro and tolerant to Yellow Stem Borer.

Fig. 1. Phenotype of BR11 (Source: knowledgebank-brri.org)

2.2 Development of popular cultivar BR11

The breeding line of BR11 is BR52-87-1-HR88. BR11, the first mega rice variety of BRRI, was developed through a cross between the IRRI variety IR20 and the IRRI breeding line IR5-47-2 and subsequent pedigree selection. Here, IR20 was used as female parent whereas IR5 was selected as male parent or pollen parent. The pedigrees of BR4 and BR10, on the other hand, are BR51-91-6 and BR51-46-5-HR65, respectively. These two lines resulted from a cross between IR20 and IR5-114-3-1. This information suggests that BR4 and BR10 are descended from the same parental mix as popular cultivar BR11. The BR4 and BR10 variants were released in 1975 and 1980, respectively. The grain in BR4 is moderately bold with a high amylose concentration. (25.0%), longer growth duration (145 days), and high yield (5.0 t/ha). BR10, on the contrary, provides similar agronomic characteristics as well as a greater yield (6.0 t/ha). Although BR4 and BR10 have a common ancestor, BR10 has a larger yield potential than BR4. In fact, IRRI developed IR20, which was praised for its effective cooking quality (intermediate amylose) and is resistant to salt, bacterial leaf blight, and blast. IR5 was also a good yielding rice cultivar with low blast resistance (Khush 2005). Actually, the cross between IR20 and IR5 resulted in the development of three rice varieties: BR4, BR10, and BR11. (Fig. 2). When BR11 was developed in 1980 for the rainfed lowland area of Bangladesh, its consistent production (6.5 ton/ha) became it the most popular T. Aman season variety in Bangladesh. It was also fairly resistant to tungro disease and to the yellow stem borer. Many researchers utilized it as a parent and standard check for fundamental investigations because of its popularity among farmers. Among Bangladesh's three rice growing seasons, Aman is distinguished by various rice growing regions, including favorable rainfed lowland with a broad variety of drought, salinity, submergence, and tidal flood-prone areas. These various rice growing conditions resulted in the emergence of region-specific rice variety development throughout the T. Aman season. (Ahmed et al 2023). As a result, rice breeders have endeavored to preserve the agronomic features of BR11 in newly established breeding lines.

2.3 Important progenies of BR11

In later decades, IR20 derived rice varieties BR11, BR4, and BR10 were extensively used as parents in the rice breeding program of Bangladesh. They also produced considerable amount of rice varieties with special agronomic characters such as photosensitivity, earliness, tidal flood tolerance. For example, two important T. Aman rice varieties BRRI dhan31 and BRRI dhan52 were developed in the background of BR11 (Ahmed et al 2023). The availability of genome-wide molecular markers for marker assisted selection enabled the transfer of important traits into popular varieties like BR11 through marker assisted backcrossing (Collard and Mackill 2008). The rice submergence tolerance gene *SUB1* was introduced by marker assisted backcrossing into BR11 along with several other popular varieties of major rice growing areas (Septiningsih *et al*. 2009; Iftekharuddaula *et al*. 2011). The cross between BR11 and CR146-7027-224 led to develop BRRI dhan57 which is noted for long slender grain with drought avoidance character for its shorter maturity period (100-105 days) in T. Aman season (Fig. 2). The rice variety BRRI dhan44 is an excellent example of a tidal flood tolerant variety. It was developed directly from a cross between two improved cultivars BR10 and BRRI dhan31(developed from BR11) under same pedigree tree. Again, cross between BRRI dhan44 and one IRRI line IR75862 produced two rice varieties namely BRRI dhan76 and BRRI dhan77 with improved tidal flood tolerance and better agronomic characters (Fig. 2). Above pedigree history clearly indicates that IR20 derived three rice cultivars BR4, BR10 and BR11 acted as key parents in developing most of the T. Aman rice varieties of Bangladesh.

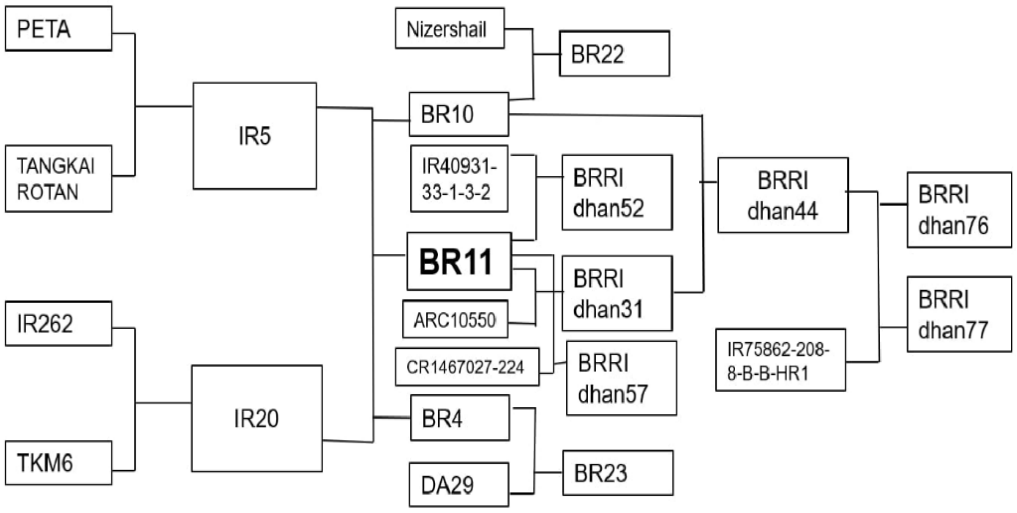


Fig. 2. Breeding history and pedigree tree of BR 11 and its relatives (Ahmed et al 2023).

2.3 key features of BR11 and their progenies

From the BR11 group, eight rice varieties were developed: BR22, BR23, BRRI dhan31, BRRI dhan44, BRRI dhan52, BRRI dhan57, BRRI dhan76, and BRRI dhan77. All developed progenies in this group were selected as T. Aman cultivars and released between 1988 and 2016 (Ahmed et al 2023). There was a significant variance in plant height, growth duration, and yield among BR11 progenies. It varied from 115 to 140 cm in height, 140 to 163 days in growth duration and 5.0 to 5.5 tons per acre in yield. It is worth noting that no progeny exceeded its founder father BR11 regarding grain output (Table 1).

Table 1. Agronomic characters and release year of improved rice varieties developed from popular cultivar BR11 group (Adapted from Ahmed et al 2023).

Variety name	Growing Season	PH (cm)	GD (days)	Yield (t/ha)	Release year	Group	Remarks	Reference
BR11	T. Aman	115	145	6.0	1980			(BRRI, 2020)
BR22	T. Aman	125	150	5.0	1988	BR11	Photosensitive	
BR23	T. Aman	120	150	5.5	1988	BR11	Photosensitive	
BRRI dhan31	T.Aman	115	140	5.0	1994	BR11	Stagnant flood tolerant	
BRRI dhan44	T. Aman	130	145	5.5	2005	BR11	Tidal submergence	
BRRI dhan52	T. Aman	116	155	5.0	2010	BR11	Submergence tolerance	
BRRI dhan76	T. Aman	140	163	5.0	2016	BR11	Tidal submergence	
BRRI dhan77	T. Aman	140	155	5.0	2016	BR11	Tidal submergence	

Note: PH: plant height, GD: growth duration or maturity days

3. Breeding history of popular cultivar BRRI dhan28

3.1 Characteristics of BRRI dhan28

In Bangladesh, BRRI dhan28 is regarded as one of the most popular Boro rice types because to its high yield, short maturation period, and high grain quality. According to Digital Herbarium of Crop Plants by BSMRSTU (retrieve from: http://dhcrop.bsmrau.net/rice-variety-brri-dhan-28/) and Ahmed et al. 2023, the main features of this cultivar include:

- medium thin grain,
- high amylose content (28.0%),

- shorter maturity days. (140 days),
- Moderately resistance to blast,
- high yield (6.0 t/ha).

Fig. 3. Phenotype of BRRI Dhan 28. (Source: knowledgebank-brri.org)

3.2 Development of popular cultivar BRRI dhan28

BRRI dhan28 rice developed by crossing IR28 and Purbachi (Fig. 4). In the 1980s, the most notable IRRI cross was IR2061, which was created by combining three breeding lines IR833, IR1561, IR24, and one wild rice *Oryza nivara*. IRRI created three varieties from this cross, IR28, IR29, and IR34, which were well adaptable throughout major rice growing countries. (Ahmed et al 2023). Furthermore, advanced lines derived from that cross aided rice breeding in the development of high yielding varieties (Khush and Virk 2005). IR28 was directly released as a variety in Bangladesh in 1977 with the label BR6. IR29 was also released as a rice variety in China and the Philippines. In India, Indonesia, Madagascar, Myanmar, the Philippines, and Tanzania, IR34 was introduced as a rice variety. However, one advanced line, IR2061-465-4-5-5, derived from the same pedigree tree as IR28, IR29, and IR34, brought about the world's most adaptable popular rice variety IR64 when combined with the IRRI line IR5657-33-2-1 (Khush and Virk. 2005; Mackill and Khush 2018). IR64 is a semi-dwarf indica rice cultivar with a short development period and strong resistance to brown plant hopper and green leaf hopper (Cohen et al. 1997; Khush 2005). It has good blast disease resistance (Roumen 1992; Bastiaans and Roumen 1993; Grand et al. 2012). Due to Tungro sensitivity, IR64 was not directly introduced as a variety in Bangladesh. To summarise, the foregoing pedigree tree clearly shows that BRRI dhan28 and IR64 descended from the same pedigree lineages as IR28, IR29, and IR34 (Fig. 4).

3.3 Important Progenies of BRRI dhan28

The pedigree history revealed that two rice varieties, BRRI dhan63 and BRRI dhan81, were created through a cross between Amol-3 and BRRI dhan28, with BRRI dhan28 serving as the male parent. Recently, BRRI dhan28 was found to be more compatible with wild rice *Oryza rufipogon*.

BRRI dhan96 was created by backcross mating between BRRI dhan28 and *Oryza rufipogon* (Accession no. IRGC103404). BRRI dhan28 was backcrossed twice to restore its background for improved agronomic and grain quality attributes. The higher yield advantage of newly produced varieties revealed that wild rice has the ability to introduce yield-related features into current Bangladeshi rice varieties (BRRI 2019). Pedigree history revealed that BRRI dhan28 and IR64 were derived from the same parental lineage in our study, has had a significant impact in the development of major rice cultivars in Bangladesh. For instance, BRRI dhan36 (Fig:2). As a result, IR64 may offer better potential for producing Bangladeshi rice varieties. In keeping with this, IR64 was developed by crossing IR64 and IR35293-125-3-2-3, while BRRI dhan55 was created by crossing IR64 with wild rice *Oryza rufipogon*. BRRI dhan36 and BRRI dhan55 were the progenitors of IR64 in this context. When treated with cold water in a greenhouse, BRRI dhan36 exhibited moderate cold resistance at the seedling stage (Khatun et al. 2016). The IR2061 combinations served as the common parent in the development of IR64 and BRRI dhan28.The pedigree information indicates that same ancestors of IR64 laid foundation in the development of popular rice variety BRRI dhan28 and several. subsequent rice varieties.

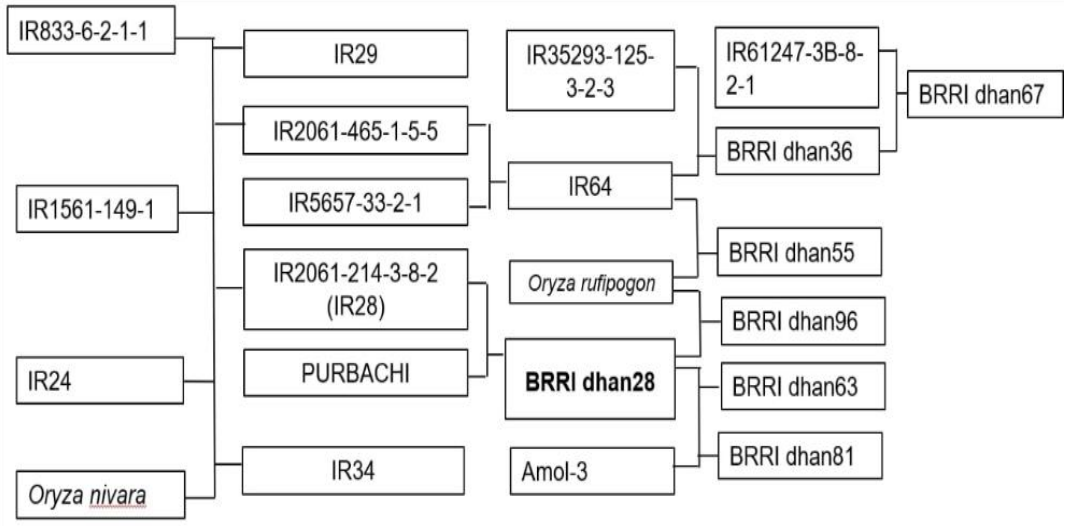


Fig. 4. Breeding history and pedigree tree of BRRI dhan28 and its relatives (Ahmed et al 2023).

3.4 key features key features of BRRI dhan28 and their progenies

The popular cultivar BRRI dhan28 was released in 1994. A total of six rice varieties namely BRRI dhan36, BRRI dhan55, BRRI dhan63, BRRI dhan67, BRRI dhan81, and BRRI dhan96 have been developed from BRRI dhan28 group (Table 2). In this group, all developed rice varieties were Boro cultivar and released between 1998-2020. Aside from that, there was considerable variation in plant height, growth duration and yield. It ranged from 86-100 for plant

height, 140-146 days for growth duration, 5.0-7.0 t/ha for yield. Except BRRI dhan36, most of the developed rice varieties surpassed the grain yield of its founder parent BRRI dhan28.

Table 2. **Agronomic characters and release year of improved rice varieties developed from BRRI dhan28 group (Adapted from: Ahmed et al 2023).**

Variety	Season	PH (cm)	GD (days)	Yield (t/ha)	Release year	Group	Reference
BRRI dhan28	Boro	90	140	6.0	1994		
BRRI dhan36	Boro	90	140	5.0	1998	BRRI dhan28	
BRRI dhan55	Boro	100	145	7.0	2011	BRRI dhan28	
BRRI dhan63	Boro	86	146	6.5	2014	BRRI dhan28	(BRRI, 2020)
BRRI dhan67	Boro	100	145	6.0	2014	BRRI dhan28	
BRRI dhan81	Boro	100	143	6.5	2017	BRRI dhan28	
BRRI dhan96	Boro	87	145	7.0	2020	BRRI dhan28	

NOTE: PH: plant height, GD: growth duration or maturity days

4. Breeding history of popular cultivar BRRI dhan29

4.1 Characteristics of BRRI dhan29

The rice variety BRRI dhan29 is one of the most popular Boro rice varieties. It was released in 1994 for cultivation in favorable Boro ecosystem of Bangladesh. According to Digital Herbarium of Crop Plants by BSMRSTU (retrieve from: http://dhcrop.bsmrau.net/rice-variety-brri-dhan-28/) and Ahmed et al. 2023, the main features of this cultivar include:

- medium slender and white grain,
- longer growth duration (160 days),
- high amylose content (29.4%),

- Moderately resistance to leaf blight, sheath blight,
- high yield (7.5 t/ha).

Fig. 5. Phenotype of BRRI dhan29 (Source: knowledgebank-brri.org)

4.2 Development of mega variety BRRI dhan29

According to the pedigree-based breeding history, the cross combination of IR5 and IR20 formed the foundation of Boro rice varieties in terms of developing BR4 and BR10 (Fig. 6). BG90-2 was a well-known high-yielding variety in major rice-producing countries in the 1980s. In India, China, and Sri Lanka, it was introduced as a rice variety. The rice variety BRRI dhan29 was developed by crossing BG90-2 and BR10, with T. Aman variety BR10 functioning as the male parent.

4.3 Important Progenies of BRRI dhan29

So far, seven rice varieties have been created using BRRI dhan29 as a background parent: BRRI dhan58, BRRI dhan68, BRRI dhan74, BRRI dhan84, BRRI dhan87, BRRI dhan88, and BRRI dhan89. In this regard, BRRI dhan58 and BRRI dhan88 developed from somacolonal research lines (Aditya and Baker 2006). The cross between BRRI dhan29 and one IRRI line, IR68144, resulted in three varieties: BRRI dhan68, BRRI dhan74, and BRRI dhan84 (Fig. 6). Recently, BRRI dhan29 was found to be more compatible with wild rice *Oryza rufipogon*. Backcross breeding led to the development of two rice varieties, BRRI dhan87 and BRRI dhan89, from the cross combination of BRRI dhan29 and *Oryza rufipogon* (Acc no. IRGC103404). The rice variety BRRI dhan29 was backcrossed twice to recover its essential agronomic features. Furthermore, the yield advantage of these two rice varieties indicated that wild rice has a higher potential for transferring yield-related features into current Bangladeshi rice varieties (BRRI 2018). Aside from that, BRRI dhan29 is utilizing as a model rice variety for agronomic and grain quality trait introgression. For example, BRRI dhan29 was utilized to generate near isogenic lines of Golden rice, GR2-E BRRI dhan29 Golden Rice, where transgenic lines performed similarly to golden rice (Biswas et al. 2021).

4.4 key features key features of BRRI dhan29 and their progenies

In 1994, the popular cultivar BRRI dhan29 was produced. Since then, seven rice varieties have been developed from the BRRI dhan29 pedigree group: BRRI dhan30, BRRI dhan50, BRRI dhan58, BRRI dhan68, BRRI dhan74, BRRI dhan84, BRRI dhan87, BRRI dhan88, and BRRI dhan89 (Table 3). The majority of the rice varieties in this category are from the Boro and Aman seasons and were introduced between 1994 and 2018. Plant height, maturity days, and yield were the most variable agronomic parameters. It varied from 82 to 122 for plant height, 127 to 145 days for growth duration in Aman, 141 to 156 days for growth duration in Boro, 5.0 to 6.5 tonnes per acre for yield in Aman, and 6.5 to 8.0 tonnes per acre for yield in Boro. Among the BRRI dhan29 rice varieties, two rice cultivars, BRRI dhan87 and BRRI dhan89, have out yielded other existing rice varieties generated from this group.

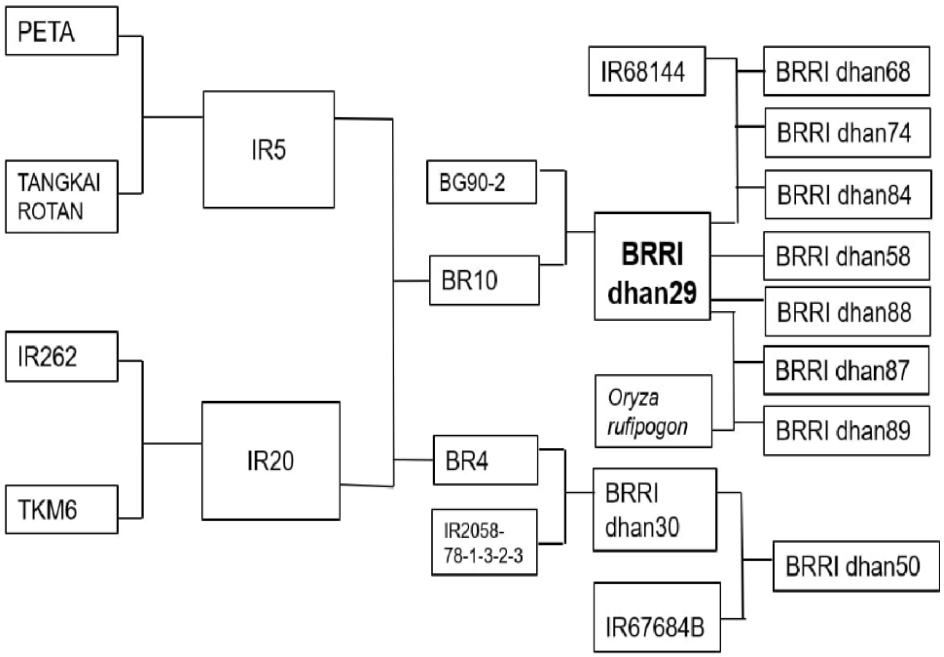


Fig. 6. Breeding history and pedigree tree of BRRI dhan29 and its relatives (Ahmed et al 2023).

Table 3. Agronomic characters and release year of improved rice varieties developed from BRRI dhan29 group (Adapted from: Ahmed et al 2023).

Variety	Season	PH (cm)	GD (days)	Yield (t/ha)	Release year	Group	Reference
BRRI dhan29	Boro	95	160	7.5	1994		
BRRI dhan30	T. Aman	120	145	5.0	1994	BRRI dhan29	
BRRI dhan50	Boro	82	155	6.0	2008	BRRI dhan29	
BRRI dhan58	Boro	100	150	7.2	2012	BRRI dhan29	
BRRI dhan68	Boro	97	149	7.3	2014	BRRI dhan29	(BRRI, 2020)
BRRI dhan74	Boro	95	147	7.1	2015	BRRI dhan29	
BRRI dhan84	Boro	96	141	6.5	2017	BRRI dhan29	
BRRI dhan87	T. Aman	122	127	6.5	2018	BRRI dhan29	
BRRI dhan88	Boro	96	142	7.0	2018	BRRI dhan29	
BRRI dhan89	Boro	106	156	8.0	2018	BRRI dhan29	

NOTE: PH: plant height, GD: growth duration or maturity days

5. Genetic information and favorable alleles of BR11, BRRI dhan28 and BRRI dhan29

Trait-based SNP genotyping has just paved the way for finding critical stress tolerance and grain quality features in breeding populations. IRRI-based genotyping service laboratories provide over 100 verified SNP markers for 25 identified QTLs/genes (IRRI: https://isl.irri.org/services/genotyping/trait-based-genotyping). The genotyping of three rice types, BR11, BRRI dhan28, and BRRI dhan29, indicated the presence of multiple significant genes (Table 4). These rice varieties have essential alleles or genes for anaerobic germination tolerance, drought tolerance, blast resistance, bacterial blight resistance, and grain quality features including low chalk and high amylose content, according to the genetic information.

Table 4. Genetic information related to presence of different favorable alleles in the background of three rice varieties BR11, BRRI dhan28, and BRRI dhan29 (Adapted from Ahmed et al 2023).

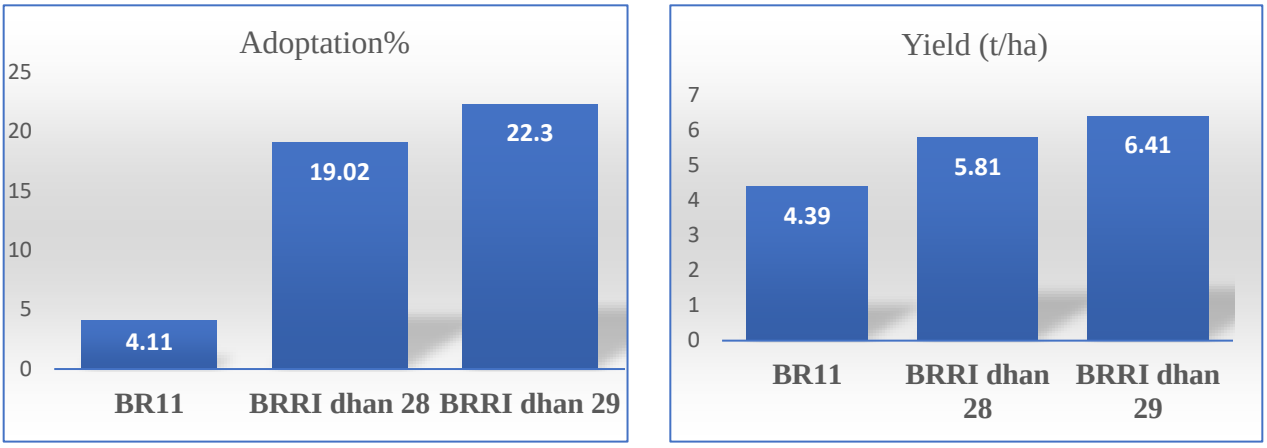
Favorable allele/genes	Variety name			Major function
	BR11	BRRI dhan28	BRRI dhan29	
AG1	+	–	–	Anaerobic germination tolerance
AG3	+	+	–	Anaerobic germination tolerance
DTY3.2	+	–	–	Drought tolerance
DTY12.1	+	+	+	Drought tolerance
Pi54	+	–	–	Blast resistance
Pi-ta	–	+	–	Blast resistance
Pi25 (*Pid3*)	+	+	+	Blast resistance
Pid2	+	+	+	Blast resistance
Xa4	–	+	–	Bacterial blight resistance
Xa26	–	+	–	Bacterial blight resistance
Sweet13	+	+	–	Bacterial blight resistance
Chalk5	+	+	+	Low chalkiness in grain
Waxy	Wx(a)	Wx(a)	Wx(a)	High amylose content

6. Present status of BR11, BRRI dhan28, and BRRI dhan29

On the basis of Annual Research Review Workshop- 2021-2022 by BRRI the present status of BR11 BRRI dhan28, and BRRI dhan29 throughout rice ecosystems in Bangladesh are discussing below:

Adaptation percentage (%):

In T.aman season, the coverage of BR11 was about 4.11% of the total areas. Adoption of this variety is decreasing but still popular in Rangamati (15.58%), Rangpur (9.42%), and Sylhet (8.07%) regions. In Boro, Adoption of BRRI dhan28 was about 19.02% and for BRRI dhan29 it was about 22.3% of the total growing areas. The area coverage of the two varieties was about 41.25% in 2021-22, whereas those two varieties together adoption was about 62% in the year 2016-17. The adoption of those two varieties has been decreasing gradually due to disease (Blast) susceptibility (BRRI, 2022) (Fig. 7a).



a b

Fig. 7. Present status of BR11, BRRI dhan28, and BRRI dhan29 in 2011-12 response to their adaptation rate (a) and yield percentage (tons/ha) (b) (Adapted from: BRRI, 2022).

Yield (t/ ha):

In T. Aman among BRRI varieties, BRRI dhan87 was the top yielder (4.72 ton/ha) whereas the average yield of BR 11 was about 4.39 tons/ha (Fig. 7b).

In the Boro season, the average yield of BRRI varieties in 2021-22 was about 6.00 ton/ha. Among BRRI varieties, BRRI dhan92 was the top yielder (6.69 ton/ha), followed by BRRIdhan89 (6.59 ton/ha), BRRI dhan29 (6.41 ton/ha). And the average yield of BRRI dhan28 was about 5.81 tons/ha (BRRI, 2022).

7. CONCLUSIONS

Rice breeding is an ongoing process and all varieties are expected to be replaced by improved varieties over time. In this study it has been shown that, how three popular rice cultivars (BR11, BRRI dhan28, and BRRI dhan29) were developed from IRRI cultivars (IR20 and IR64) through rice breeding programs of Bangladesh. Then, gradually these popular rice varieties are also being replaced in most of the rice production areas by new rice varieties with higher yield potentiality and acceptable grain quality traits. In case Ofri dhan28 and BRRI dhan29, they are still popular among rice farmers, particularly in low lying haor areas. The development of high-quality popular varieties like BR11, BRRI dhan28, and BRRI dhan29 is still remain a challenge to rice breeders. In general, new rice varieties that aim to replace those old varieties must offer a clear advantage in terms of yield and grain quality to secure better price at farm level. Besides, In Bangladesh, population growth is continuing at more than 2% annually in many developing rice-growing countries. To feed this growing population, the growth rate of rice production needs to accelerate further. For this we need varieties with higher yield potential, greater yield stability, shorter growth duration, and superior grain quality. In that case it will be more vital than ever to improve our

understanding of the genetic foundation of old popular rice varieties, as well as their significant progenies, major agronomic properties, and grain qualities.

REFERENCES

Ahmed, M. E., Biswas, A., & Afrin, S. (2022). Contribution of IR20 and IR64 in developing three Bangladeshi popular rice cultivars. *Plant Breeding and Biotechnology*, *10*, 81-93.

AIS (Agricultural Information Service). 2016. Krishi Diary (Bangla). Khamarbari, Farmgate, Dhaka, 1215, 15.

BBS (Bangladesh Bureau of Statistics), 2020. Monthly Statistical Bulletin, Statistics division Ministry of Planning Government of the Peoples Republic of Bangladesh, 21-22.

BBS (Bangladesh Bureau of Statistics), 2011. Monthly Statistical Bulletin, Statistics division Ministry of Planning Government of the Peoples Republic of Bangladesh, 32-37.

BER (Bangladesh Economic Review). 2015. Bangladesh Economic Review 2015. Ministry of Finance, Government of the People's Republic of Bangladesh, Bangladesh Secretariat, Bangladesh, 46.

BRKB. 2021.Bangladesh Rice Knowledge Bank. Bangladesh Rice Research Institute, Gazipur. 4.

Bastiaans, L. (1993). Understanding yield reduction in rice due to leaf blast. Wageningen University and Research. Thesis, 86-89.

Biswas, P. S., Swamy, B. M., Kader, M. A., Hossain, M. A., Boncodin, R., Samia, M., ... and Reinke, R. (2021). Development and field evaluation of near-isogenic lines of GR2-EBRRI dhan29 golden rice. *Frontiers in Plant Science*, *12*, 619739.

BRRI. 2016. Annual Report of Bangladesh Rice Research Institute 2014-15, BRRI Gazipur 1701, Bangladesh, 12-36.

BRRI. 2018. Annual Report of Bangladesh Rice Research Institute 2017-18, BRRI Gazipur 1701, Bangladesh,15-43.

BRRI. 2019. Annual Report of Bangladesh Rice Research Institute 2018-19, BRRI Gazipur 1701, Bangladesh, 10-36.

BRRI. 2020. Modern Rice Cultivation. 23rd Edition. 103.

BRRI. 2023. Annual Report of Bangladesh Rice Research Institute 2021-22, BRRI Gazipur 1701, Bangladesh, 4-8.

Collard, B. C., and Mackill, D. J. (2008). Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*, 557-572.

Grand, X., Espinoza, R., Michel, C., Cros, S., Chalvon, V., Jacobs, J., and Morel, J. B. (2012). Identification of positive and negative regulators of disease resistance to rice blast fungus using constitutive gene expression patterns. *Plant Biotechnology Journal*, *10*, 840-850.

Iftekharuddaula, K. M., Newaz, M. A., Salam, M. A., Ahmed, H. U., Mahbub, M. A. A., Septiningsih, E. M., and Mackill, D. J. (2011). Rapid and high-precision marker assisted backcrossing to introgress the SUB1 QTL into BR11, the rainfed lowland rice mega variety of Bangladesh. *Euphytica*, *178*, 83-97.

Kabir, M. S., Salam, M. U., Chowdhury, A., Rahman, N. M. F., Iftekharuddaula, K. M., Rahman, M. S., ... and Biswas, J. K. (2015). Rice vision for Bangladesh: 205 beyond. *Bangladesh Rice Journal*, *19*, 1-18.

Khatun, M., Ahmed, M. M. E., Syed, M. A., Akter, F., Das, S., Haq, M. E., and Dipti, S. S. Identification of Ideal Trial Sites and Wide Adaptable T. Aus Rice Genotypes Suitable for Bangladesh. *Bangladesh Rice Journal*, 77.

Khush GS. 2005. IR varieties and their impact. International Rice Research Institute, 88-89.

Mackill, D. J., and Khush, G. S. (2018). IR64: a high-quality and high-yielding mega variety. *Rice*, *11*, 1-11.

Roumen, E. C. (1992). Small differential interactions for partial resistance in rice cultivars to virulent isolates of the blast pathogen. *Euphytica*, *64*, 143-148.

Sarkar, M. M. A., Rahman, M. H., Haque, M. R., Islam, S., and Sultana, R. (2021). Economic Study of Aman Rice Variety Binadhan-17 Production in Some Selected Areas of Bangladesh. *Saudi Journal of Economics and Finance*, *5*, 456-462.

Septiningsih, E. M., Pamplona, A. M., Sanchez, D. L., Neeraja, C. N., Vergara, G. V., Heuer, S., and Mackill, D. J. (2009). Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond. *Annals of Botany*, *103*, 151-160.

Siddiq, E. A., and Vemireddy, L. R. (2021). Advances in genetics and breeding of rice: an overview. *Rice improvement: physiological, molecular breeding and genetic perspectives*, 1-29.

Vanavichit, A., Kamolsukyeunyong, W., Siangliw, M., Siangliw, J. L., Traprab, S., Ruengphayak, S., ...and Tragoonrung, S. (2018). Thai Hom Mali Rice: Origin and breeding for subsistence rainfed lowland rice system. *Rice*, *11*, 1-12.