Breeding History of Three Mega Rice (*Oryza sativa L.*) Varieties (BR11, BRRI dhan28, BRRI dhan29) of Bangladesh – A Review

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Abstract

Rice is a staple food consumed by billions of people worldwide, particularly in Asia. However, outdated rice cultivars and poor cultivar replacement have led to a decline in rice productivity in Bangladesh. To address this, the Bangladesh Rice Research Institute (BRRI) developed three mega rice varieties: BR11, BRRI dhan28, and BRRI dhan29. BR11 is a popular Transplanted Aman (T. Aman) rice variety known for its high yield potential, excellent cooking quality, and moderate resistance to diseases. BRRI dhan28 is characterized by clean, medium-slender grains, high amylose content, and moderate resistance to blast disease. BRRI dhan29 has a longer growth duration, high amylose content and yield potential. These three mega varieties have demonstrated high adaptation rates across different rice ecosystems in Bangladesh. The breeding history and pedigree of BR11, BRRI dhan28, and BRRI dhan29 reveal their origins from IRRI varieties, such as IR20 and IR5. These varieties have been extensively utilized as parent lines in the development of other rice cultivars with desired agronomic traits. The genetic analysis of these mega varieties has identified favorable alleles and genes associated with traits like anaerobic germination tolerance, drought tolerance, blast resistance, bacterial blight resistance, low chalkiness, and high amylose content. Mega rice varieties such as BR11, BRRI dhan28, and BRRI dhan29 have made substantial contributions to rice production in Bangladesh. Continued research and breeding efforts based on the pedigree and genetic information of these varieties can further improve rice yields, grain quality, and stress tolerance, ensuring food security for the growing population.

Introduction

Rice (*Oryza sativa L.)* is a staple food that plays a crucial role in the diets of billions of people around the world. It is a versatile grain that provides essential nutrients and sustenance to individuals across various cultures and regions. Rice cultivation has a long history, dating back thousands of years, and it remains a vital crop in many countries. Asia consumes the most of the world's rice, making up 90% of the total (Futakuchi et al., 2021).

The great nutritional content of rice is one of the main factors in its status as a staple food. It contains plenty of carbohydrates, which are the body's main source of energy. Additionally, rice has trace levels of protein, B vitamins, iron, and other vitamins and minerals. Its minimal fat and cholesterol content make it a popular healthy choice. More than 60% of the usual person's daily calorie intake comes from eating rice (Naher et al., 2014).

The cultivation of rice has a long history in Bangladesh. Except for the high regions in the southeast, rice is farmed everywhere over the nation. The country's agroclimatic conditions are ideal for cultivating rice all year round. However, compared to other rice-growing nations, the average national production of rice is substantially lower (2.94 t/ha). About 76% of the people live in rural areas, and 47.5% of the total manpower is involved in agriculture. In Bangladesh, agriculture contributes 19.3% of the gross domestic product (GDP) of the country (Bangladesh Finance Bureau, 2014).

Nearly all 13 million agricultural households in the nation grow rice. Over the previous three decades, the area used to cultivate rice has been essentially unchanged at 10.5 million hectares. Rice is grown on over 75% of the total cropped land and over 80% of the total irrigated land. Thus, rice plays a vital role in the livelihood of the people of Bangladesh (BRKB, 2023).

However, the prolonged use of outdated cultivars vulnerable to diseases, insects, and pests has resulted in a decline in rice productivity in Bangladesh. Lack of exposure to new cultivars is one of the main reasons for poor cultivar replacement; as a consequence, older cultivars are still farmed more extensively (Hossain et al., 2022).

Before the "Green Revolution" in the 1960s, most farming was done using local landraces, which had extremely low yield potentiality and several unexpected agronomic features as lodging tendency, poor nitrogen fertilizer response, low harvest index, and greater disease infestation (Rahman et al., 2016). The introduction of the first semi-dwarf rice variety, IR8, in 1960 at the International Rice Research Institute (IRRI), Philippines, marked the beginning of the "Green Revolution" in South Asia's main rice-producing nations.

In comparison to local landraces of rice, this semi-dwarf variety had a better production potential, a higher harvest index, and was more sensitive to nitrogenous fertilizer. Since then, improved breeding lines and rice varieties produced by IRRI have significantly increased rice output globally. At that time, lower plant height, improved agronomic characteristics, and particular adaptability were the main breeding goals for rice (Mackill and Khush, 2018; Siddiq and Vemireddy, 2021).

The creation of Bangladesh Rice Research Institute (BRRI) in 1970 marked the beginning of rice breeding operations in Bangladesh, including cultivar introduction, development, and dissemination. IRRI created rice variety IR20 debuted as the first released variety of Bangladesh during the green revolution. It was approved for BR1 cultivation in Bangladesh in 1970 for the Boro and Aus seasons. In the Boro and Aus seasons, BR1 had a yield potentiality of 5.5 t/ha and 4.0 t/ha, respectively. 106 contemporary inbred rice varieties have been created by BRRI so far for cultivation in various rice ecosystems (BRKB, 2023).

Figure 1. High yielding rice plant

What is mega variety?

Variety is defined as mega if variety covers a minimum of 5% of total crop-specific area in a given country (Gatto et al., 2021).

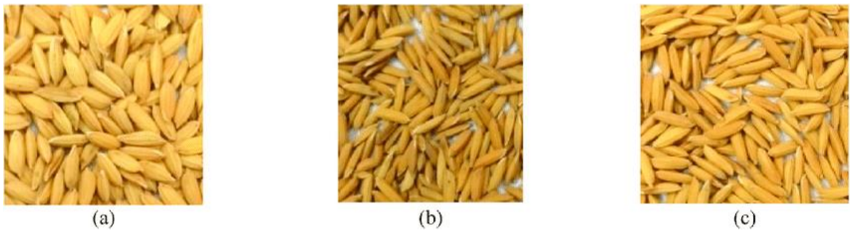
High-yielding rice varieties are typically characterized by traits such as shorter growth duration, disease resistance, tolerance to adverse environmental conditions, and improved agronomic practices. These varieties have been instrumental in increasing rice production in many parts of the world and have contributed significantly to meeting the growing demand for food. It's important to note that the specific high-yielding rice varieties can vary depending on the region and country. For example, in the Philippines, the International Rice Research Institute (IRRI) has developed and promoted several high-yielding rice varieties such as IR8, IR64, and NSIC Rc222, which have played a significant role in the Green Revolution and boosting rice production.

Several so-called mega types of important crops have started to rule the world's agricultural landscapes. Mega varieties often display wanted quality traits, are extensively adaptable, and are distributed via well-established marketing channels (Pandey, 2012). There is a lack of structural data on how much mega variants of important food crops predominate national agricultural landscapes, particularly in developing nations. According to a research, just four kinds are grown on 65% of the world's rice land and six types are grown on 71% of the world's maize land (Ceccarelli et al., 2013).

Mega rice varieties in Bangladesh

In Bangladesh, BR11, BRRI dhan28 and BRRI dhan29 are the most promising line of mega varieties of rice. For over the past three decades– BRRI dhan28 and BRRI dhan29 – were the mainstay of Bangladesh’s pursuit of rice self-sufficiency. Among over a hundred modern rice varieties that Bangladesh rice breeders developed over the last 50 years, these two highly productive varieties stole the show by outperforming most of the others. After gaining popularity among millions of rice growers in Bangladesh, these two varieties expanded to the extent that in recent years 70% of the country’s Boro rice fields came under the coverage of just these two varieties – BRRI dhan28 and BRRI dhan29 (Ahmad, 2022).

The cultivar BR11 is said to be the most popular cultivar among them and is grown during the Transplanted Aman (T. Aman) season in lowland areas that get rain. In 1980, the well-known rice cultivar BR11 was made introduced. Due to its high production (6.0 t/ha), excellent cooking quality (amylose 26%), and appealing phenotype (plant height 115 cm, 145 days of development), it is generally liked by farmers. Its natural photosensitivity is also poor (Biswas et al., 2020). On the other hand, the most common cultivars for an irrigated environment during the Boro season are the rice varieties BRRI dhan28 and BRRI dhan29 (Iftekharuddaula et al., 2011; Kretzschmar et al., 2018). In 1994, the BRRI dhan28 cultivar was introduced. Due to its excellent grain quality, which includes a high amylose content (28%), medium thin grain, high yield (6.0 t/ha), and relatively quick growth (140 days), it gained popularity among farmers over time. In the same way, BRRI dhan29 was also published in 1994. It has a high yield (7.5 t/ha) and a relatively lengthy growing period (160 days), which contributes to its widespread acceptance in single Boro regions. In the dry season, BRRI dhan28 occupies 23% of the rice producing lands whereas BRRI dhan29 occupies 28% of the areas (BRRI, 2019).



(a) BR 11 (b) BRRI dhan28 (c) BRRI dhan29

Figure 2. Grains of three mega variety of rice in Bangladesh (Ansari et al., 2021).

Importance of mega varieties

When it comes to addressing the nation's existing and expanding food security demands, researchers, policymakers, and practitioners who work in Bangladesh often advocate for the use of hybrid and HYV rice. This is important because rice is the primary food source for more than 150 million people in Bangladesh, and rice consumption accounts for about 70% of caloric intake and 58% of protein intake (Mottaleb and Mishra, 2016). 40 million people in Bangladesh were unable to satisfy their daily food needs in 2014, according to the World Food Program (Osmani et al., 2016), and 11 million individuals in Bangladesh experienced severe hunger. Furthermore, Bangladesh continues to face issues with food security and the environment due to complex socio-environmental variables including population increase, diminishing arable land, and a lack of resources (Shew et al., 2019).

In 1971, when Bangladesh's population was just roughly 70.88 million, the nation produced a total of roughly 10.59 million tons of rice. To feed its 135 million citizens, the nation is presently generating roughly 25.0 million tons. This suggests that rice output increased considerably more quickly than the population. The adoption of modern rice varieties on around 66% of the country's rice acreage, which contributes to approximately 73% of its total rice output, has been a major factor in this increasing rice production. However, Bangladesh's population is expected to expand by another 30 million people over the next 20 years and continues to grow by two million people annually. Bangladesh would thus need roughly 27.26 million tons of rice in 2020. The overall area of rice will likewise decrease during this period, reaching 10.28 million hectares. Therefore, the current rice yield of 2.74 t/ha has to be improved to 3.74 t/ha (BRKB, 2023).

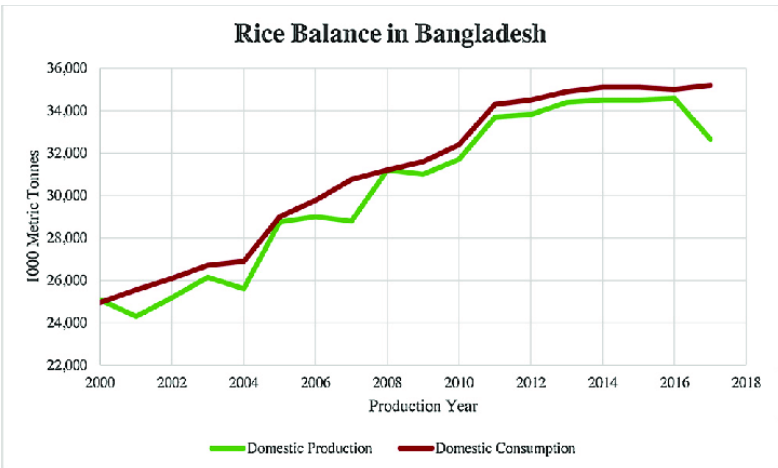


Figure 3. Rice Consumption and Production in Bangladesh.2000–2017.

[Data acquired from FAOSTAT (http://www.fao.org/faostat/en/#data/ BC)]

According to FAOSTAT, both the rice production and consumption has increased significantly in last few years. It is observed almost doubled amount of production and consumption in the year of 2018 than 2000.

For over 156 million people in the nation, rice is the staple food. If the population grows at the current pace of 2 million people year, there would be 238 million people in the world in 2050. To feed this ever-growing population, more rice must be produced overall. Due to the building of businesses, factories, homes, roads, and highways, the overall amount of cultivable land is also declining at a pace of more than 1% year. On the other hand, urbanization tends to modify people's eating choices, necessitating the growing of new crops on rice-growing land alongside existing ones (Shelly et al., 2016). As a result, efforts should be undertaken to boost rice production per unit area. In addition, agriculture is experiencing a variety of unfavorable circumstances as a result of climate change, including drought, flood, salt, high temperature stress, and poor soil fertility. In these conditions, strategies should be put into place to boost rice production in a sustainable way for the country's food and nutritional security.

Mega rice varieties have higher yield advantage than that of conventionally bred rice. Thus, it is suggested that by cultivation of mega rice varieties (BR11, BRRI dhan28, BRRI dhan29) may be a solution to this high demand of food for this fast-growing population in our country.

Breeding history of BR11

Characteristics of BR11

- T. aman rice variety
- Released in 1980
- Bold grain with high amaylose content of 26%
- Longer (145 days) maturity
- Moderately resistant to tungro disease and tolerant to yellow stem borer
- High yield (6.0t/ha)
- Created world record in Mexico by giving 14.5t/ha yield in 1976

Figure 4. BR11 Rice (Source: www.knowledgebank-brri.org)

Development of BR11

BR11 was produced by the cross combination between two IRRI varieties IR20 (female) and IR5 (male). The pedigree of BR11 is BR52-87-1-HR88. The variety BR4 which was released in 1975, has high amylose content and BR10 which was released in 1980, has higher yield comparatively. Both BR4 and BR10 have been originated from the same parental combination like popular cultivar BR11. Although BR4 and BR10 share a common parentage, BR10 has a higher yield potential. The parent varieties, IR20 and IR5, are known for their cooking quality, moderate resistance to diseases such as bacterial leaf blight and blast, and IR20 also exhibits some tolerance to salinity (Khush, 2005). Actually, the cross combination of IR20 and IR5 led to develop three rice varieties BR4, BR10 and BR11. BR11 gained popularity due to its stable yield of 6.5 tons per hectare during the T. Aman season. It exhibited moderate resistance to tungro disease and tolerance to yellow stem borer. The widespread adoption of BR11 led to its use as a parent and standard check in research studies. The Aman season in Bangladesh encompasses diverse rice-growing environments, prompting the development of area-specific rice varieties. Rice breeders have aimed to retain the favorable agronomic traits of BR11 in newly developed breeding lines.

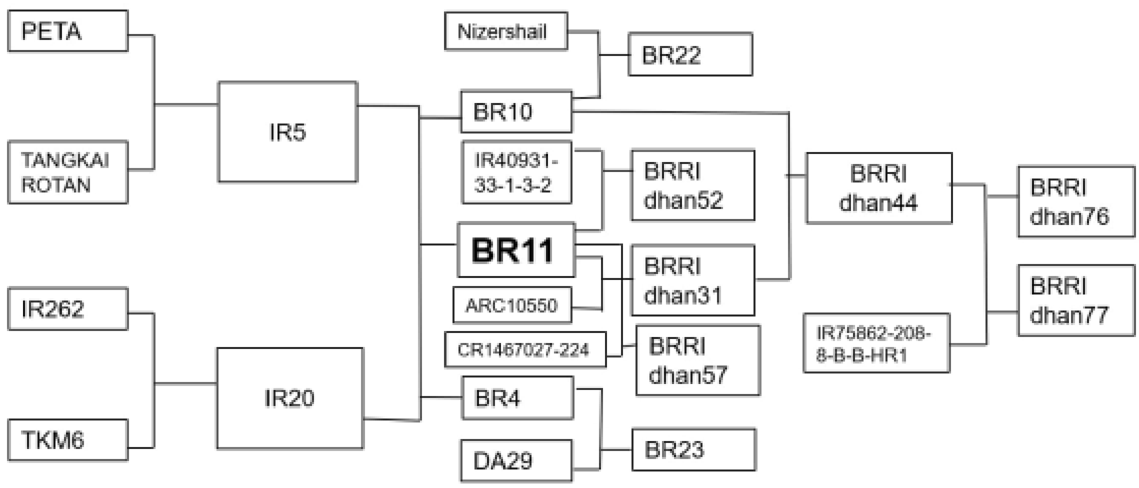


Figure 5. Breeding history and pedigree tree of BR11 (Ahmed et al., 2022)

Important progenies of BR11

The IR20-derived rice varieties BR11, BR4, and BR10 have been important parent lines in Bangladesh's breeding effort for the grain. They have created a large number of rice cultivars with unique agronomic traits including photosensitivity, earliness, and tidal flooding resistance. By mating BR10 with the regional Nizershail photosensitive rice variety, the well-known photosensitive variety BR22 developed. On the other hand, BR4 was the source of BR23. In order to reduce grain output losses, both BR22 and BR23 have gained popularity as options for delayed planting in flood-prone locations (Biswas et al., 2019).

Additionally, utilizing BR11 as a foundation, two significant T. Aman rice varieties—BRRI dhan31 and BRRI dhan52—were created. Marker-assisted backcrossing, a method for transferring essential features into well-liked varieties like BR11, was made possible by the availability of genome-wide molecular markers (Collard and Mackill, 2008). In addition to other desirable features, the submergence tolerance gene SUB1 was inserted into the key rice varieties of various growing regions, including BR11 (Septiningsih et al., 2009; Iftekharuddaula et al., 2011).

As a consequence of the cross between BR11 and CR146-7027-224, BRRI dhan57 was created, which is renowned for its long, thin grain and drought resistance traits. A straight cross between BR10 and BRRI dhan31 led to the development of BRRI dhan44, a variety that can withstand tidal floods. Additional BRRI dhan44 and IRRI line crossings produced the BRRI dhan76 and BRRI dhan77 varieties, which had better tidal flood resistance and agronomic features (Ahmed et al., 2022).

Overall, the pedigree history shows how important IR20-derived varieties were in the creation of the majority of T. Aman rice varieties in Bangladesh, especially BR4, BR10, and BR11. The parent varieties IR20 and IR5, created by IRRI, have been instrumental in Bangladesh's production of improved rice varieties and their offspring. Therefore, the pedigree information shows that IR20 and IR5, together with BR4, BR10, and BR11, lay the foundation for the establishment of current T. Aman rice varieties in Bangladesh.

Breeding history of BRRI dhan28

Characteristics of BRRI dhan28

- Boro rice variety
- Released in 1994
- Clean rice medium slender grain
- High amylose content (28.0%)
- Height 90cm
- Shorter maturity (140 days)
- Moderately resistance to blast
- High yield (6.0t/ha)

Figure 6. BRRI dhan28 (Source: www.knowledgebank-brri.org)

Development of BRRI dhan28

A cross between IR28 and Purbachi resulted in the rice variety BRRI dhan28. The breeding of rice was greatly aided in the 1980s by the pedigree number IR2061, which was created by combining three breeding lines (IR833, IR1561, IR24) and wild rice (*Oryza nivara*). IR28, IR29, and IR34 were developed from this cross and were widely adaptable across major rice-growing countries (Khush, 2005). IR28 was released as a variety in various Asian and African countries, including Bangladesh. Similarly, IR29 and IR34 were released in China, the Philippines, India, Indonesia, and other countries.

An advanced line known as IR2061-465-4-5-5, derived from the same pedigree lineage as IR28, IR29, and IR34, contributed to the creation of the widely used and highly adaptable rice variety IR64 (Mackill and Khush, 2018). The indica rice variety IR64 is semi-dwarf, has a short growth duration, and is resistant to blast disease (Grand et al., 2012), green leaf hoppers, and brown plant hoppers (Cohen et al., 1997). Due to its vulnerability to the Tungro disease, IR64 was not immediately marketed as a variety in Bangladesh, but it was utilized as a parent in the development of contemporary rice varieties for the Boro season.

In conclusion, the pedigree history shows that BRRI dhan28 and IR64 have a common ancestor with IR28, IR29, and IR34.

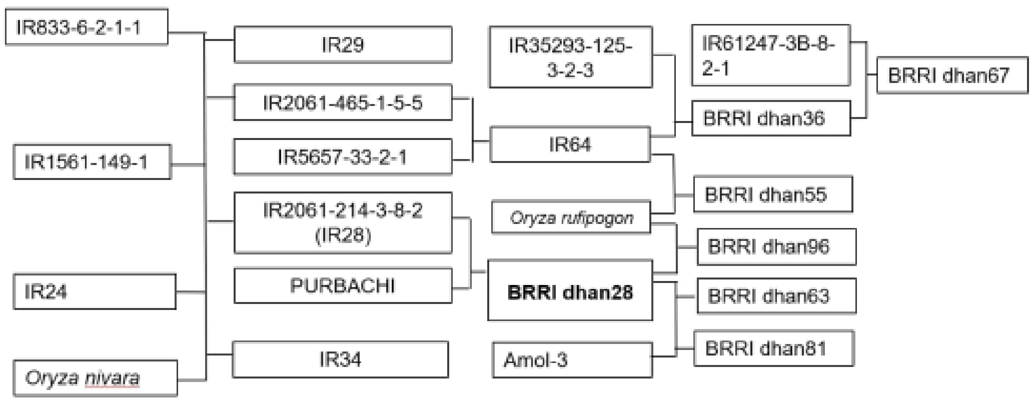


Figure 7. Breeding history and pedigree tree of BRRI dhan28 (Ahmed et al., 2022)

Important progenies of BRRI dhan28

In Bangladesh's irrigated rice ecosystem, the BRRI dhan28 variety is a popular rice variety during the Boro season and is renowned for its earliness, cooking quality, and high yield. It is now considered to represent the typical Boro season production potential for short-duration rice types. BRRI dhan28 regularly produces good yields at the farm level despite having a tendency to lodge during maturity, making it frequently utilized as a standard check by rice researchers (Ahmed et al., 2022).

BRRI dhan63 and BRRI dhan81 were developed from crosses with BRRI dhan28 as the male parent, specifically with the variety Amol-3. Additionally, BRRI dhan96 was developed through backcross breeding between BRRI dhan28 and Oryza rufipogon, a wild rice variety. This cross was conducted to introduce better agronomic and grain quality traits while retaining the background of BRRI dhan28. The successful creation of these new kinds raises the possibility that wild rice might improve the qualities of modern rice types in Bangladesh (BRRI, 2019).

In addition, the pedigree history demonstrates that BRRI dhan28 and IR64 come from the same parents. This shows that the development of rice cultivars in Bangladesh might greatly benefit from IR64. For instance, IR64's ancestors included BRRI dhan36 and dhan55. At the seedling stage, BRRI dhan36 demonstrated fair cold tolerance (Khatun et al., 2016), but BRRI dhan55, was advised for cultivation throughout both the Aus and Boro seasons. However, Bangladeshi rice consumers did not like it because of its low amylose level. The most salt-tolerant rice variety in the Boro season, BRRI dhan67, was created using BRRI dhan36 as a background parent, and its yield potential varies with salinity. The BRRI dhan67 plant demonstrates considerable cold resistance at both the seedling and reproductive stages, according to recent field tests.

The pedigree information demonstrates that the evolution of well-known rice varieties including BRRI dhan28, dhan36, dhan55, dhan63, dhan67, dhan81, and dhan96 was fundamentally influenced by the same ancestral lines as IR64.

Breeding history of BRRI dhan29

Characteristics of BRRI dhan29

- Boro rice variety
- Release in 1994
- Longer growth duration (160 days)
- High amylose content (29.4%)
- High fertilizer uptake capacity
- Moderate resistance to blight and blast
- High yield (7.5 t/ha)

Figure 8. BRRI dhan29 (Source: www.knowledgebank-brri.org)

Development of BRRI dhan29

The breeding history of Boro rice varieties can be traced back to the cross combination of IR5 and IR20, which served as the foundation for the development of BR4 and BR10 varieties. In the 1980s, BG90-2 became a widely used and productive rice variety in the main rice-producing nations. It was formally introduced as a rice variety in Sri Lanka, China, and India. Another rice variety known as BRRI dhan29 was produced by crossing BG90-2 and BR10, with BR10 from the T. Aman variety serving as the male parent (Ahmed et al., 2022).

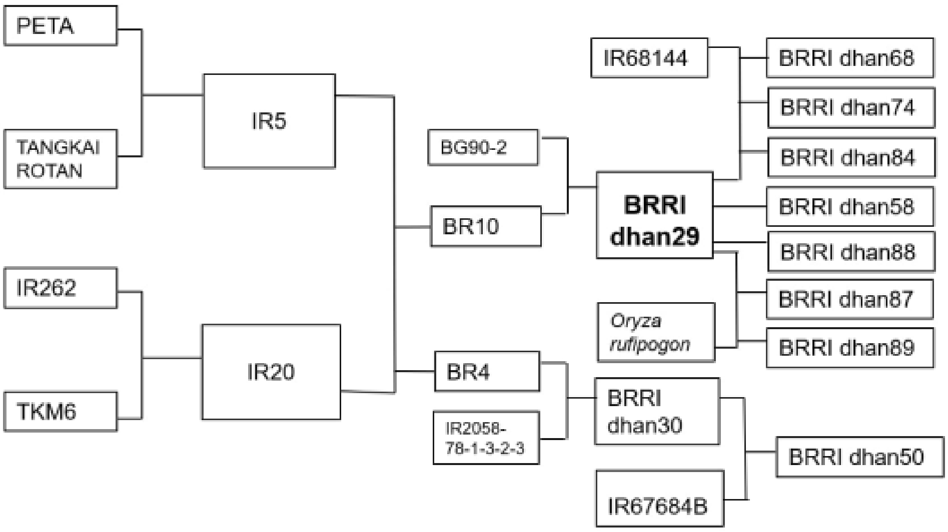


Figure 9. Breeding history and pedigree tree of BRRI dhan29 (Ahmed et al., 2022)

Important progenies of BRRI dhan29

Boro rice, which is cultivated in the irrigated rice ecosystem of low-lying haor areas during the dry season, is one of the three rice-growing seasons in Bangladesh. Due to its strong yield (above 7.5 t/ha) and extended growing length throughout the Boro season, BRRI dhan29 has become more popular in these regions. It has become the standard for long-duration rice cultivars due to its constant output throughout all irrigated rice regions. Because of this, BRRI dhan29 has been often used as a standard check variety in several rice research investigations. A number of other rice cultivars have been created using BRRI dhan29 as a parent, including BRRI dhan58, BRRI dhan68, BRRI dhan74, BRRI dhan84, BRRI dhan87, BRRI dhan88, and BRRI dhan89. A hybrid between BRRI dhan29 and IRRI line IR68144 generated BRRI dhan68, BRRI dhan74, and BRRI dhan84, whereas BRRI dhan58 and BRRI dhan88 were developed via somaclonal research (Aditya and Baker, 2006). BRRI dhan74 and BRRI dhan84 are zinc-enriched Boro varieties released in 2015 and 2017, respectively. The emergence of BRRI dhan87 and BRRI dhan89 via backcross breeding was made possible by BRRI dhan29's compatibility with wild rice, *Oryza rufipogon*. BRRI dhan30, derived from the cross combination of IR20 and IR5, served as the parent for BRRI dhan50, a popular Boro variety known as Banglamoti. The long, thin grains and mild fragrance of BRRI dhan50 are widely recognized as Banglamoti, making it a popular option in the country of Bangladesh's rice market. Overall, the pedigree information as a whole emphasizes the contributions of IRRI varieties IR20 and IR5 in the evolution of contemporary Boro rice, particularly BR4 and BR10, and their major progenies.

Favorable alleles of BR11, BRRI dhan28 and BRRI dhan29

In order to find characteristics associated with grain quality and stress tolerance in rice breeding populations, trait-based SNP genotyping has shown to be a valuable tool. Over 100 verified SNP markers connected to 25 distinct QTLs/genes are used by the International Rice Research Institute (IRRI) to provide genotyping services. Numerous significant genes for anaerobic germination tolerance, drought tolerance, blast resistance, bacterial blight resistance, as well as grain quality traits like low chalk and high amylose content, have been identified through the genome-wide analysis of the rice varieties BR11, BRRI dhan28, and BRRI dhan29. According to the genetic data, these rice varieties have valuable alleles or genes that are linked to these desirable characteristics.

Table 1. Genetic information related to presence of different favorable alleles in the background of three rice varieties BR11, BRRI dhan28 and BRRI dhan29 (Ahmed et al., 2022)

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

'+' refers to present and '–' refers to absent in the rice variety

Present status of BR11, BRRI dhan28 and BRRI dhan29

It has been noted that BR11, BRRI dhan28, and BRRI dhan29 demonstrate very high adaption rates across multiple rice ecosystems in Bangladesh based on current data on the adaptation of BRRI-developed rice varieties (BRRI, 2019). Upto the year 2023, a total of 47 T. Aman rice varieties have been created by the Bangladesh Rice Research Institute (BRRI), with over 70% of them adapting to the Aman season. Depending on the habitat (e.g., flood-prone, saline, or submerged), growth period, yield potential, and other variables, these T. Aman cultivars are best suited to certain regions. During the T. Aman or wet season, the cultivar BR11 makes up around 11% of the rice-growing area in Bangladesh. Furthermore, during the Boro or dry season, BRRI has created 51 Boro rice varieties, which are grown in the irrigated rice habitat. Boro rice types exhibit approximately 70% adaptability in the Boro season, much as T. Aman varieties. The lands used for rice production are split between the BRRI dhan28 and BRRI dhan29 cultivars, accounting for 23% and 28%, respectively. According to BRRI, these two cultivars together make up more than 50% of the Boro rice-growing area in Bangladesh, significantly boosting the nation's output of the grain.

Conclusion

As an overpopulated and agro-based country, mega varieties are a great blessing to us. BR11, BRRI dhan28 and BRRI dhan29, all three mega rice varieties, have come from IRRI varieties, with the help of Bangladesh's rice breeding program. But recently, these varieties have been replaced by new hybrids and modern varieties. However, BRRI dhan28 and BRRI dhan29 are still popular in low-lying haor areas. Mega varieties have the ability not only to give a higher yield and better grain quality but also the opportunity to get a better price at the farm level and are farmer-friendly. Many new modern progenies are being developed based on these three mega rice varieties. The pedigree and genetic basis studies of these varieties will help the researchers in the further development of new varieties that may be able to give higher yields and grain quality as well as be more tolerant to biotic or abiotic stress.

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