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Review

Evaluation of Progress and Emerging Opportunities for Hybrid Rice in Bangladesh

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ABSTRACT

Since the initiation hybrid rice research in 1993 in collaboration with International Rice Research Institute (IRRI), Bangladesh Rice Research Institute (BRRI) has made significant progress in developing and releasing hybrid rice varieties adapted to local agro-ecologies. As of 2024, a total of 255 hybrid rice varieties have been officially registered, including 33 developed domestically. This study synthesizes BRRI's achievements in hybrid rice breeding, parental line development, and multilocation performance trials. As documented in 2024, BRRI has released eight hybrid rice varieties five for Boro season, two for T. Aman, and one for T. Aus with a 15–20% yield advantage over modern inbred varieties. Notably, BRRI hybrid dhan3 and BRRI hybrid dhan8 exhibit yield potentials exceeding 10.5 t/ha in the Boro season. BRRI has developed over 20 cytoplasmic male sterile (CMS) lines and 40 restorer lines using germplasm from IRRI, China, India, and indigenous sources. Multi-location trials during T. Aman 2022 season revealed that select hybrids outperformed checks by up to 29% in grain yield. These results underscore the suitability of IRRI-derived CMS lines for Bangladesh's rainfed conditions and highlight BRRI's capacity to generate heterotic hybrids for both irrigated and rainfed ecosystems. Continued investment in locally adapted parental lines and strategic field testing will be critical to scaling hybrid rice adoption and enhancing national food security. Seed production and distribution are driven primarily by private companies, which supply 90 percent of hybrid seed, while public research institutes focus on nucleus seed production and quality control. In 2022-23, BRRI developed hybrid rice variety produce 22.89 ton hybrid seed through contact grower which was distributed to different organizations.

Keywords: Yield potential, Seed production, Farmer adoption, Parental lines, Public-private partnership.

INTRODUCTION

Global food security faces mounting pressure as the world population continues to grow, demanding ever-higher agricultural productivity. Rice, as the staple food for more than half of the global population, plays a central role in this challenge. For every additional billion people, an estimated 100 million tons of paddy rice must be produced annually to meet consumption needs (Bin Rahman and Zhang, 2023). While some countries currently maintain a rice surplus, future projections suggest that climate change, land degradation, and population growth will strain production systems.

Bangladesh, one of the most densely populated countries in the world, exemplifies this urgency. With over 170 million people living within 147,570 km², the country must continually increase rice output to sustain its food supply. Although Bangladesh produced 41.3 million tons of rice in 2022–2023, ensuring a modest surplus, projections indicate that by 2050, the

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nation will need approximately 47 million tons to feed an estimated 210 million people (Biswas and Kabir, 2023; BRRI, 2023). At present, we have a surplus in rice (Kabir *et al.*, 2015). But, in the near future, there will probably be a shortage because of over population and climate change. Every year, 2.2 million people are added to the country's existing population (Streatfield and Karar, 2008). To satisfy these extra millions, we have to produce an additional 0.34 million tons of rice every year. This demand implies a required production increase of nearly 50%, despite shrinking arable land and growing environmental constraints (Ashikari *et al.*, 2005; Srividya *et al.*, 2010).

Hybrid rice technology offers a promising solution to this dilemma. With a yield advantage of 20–30% over conventional inbred varieties (Lin and Yuan, 1980; Siddiq, 1993), hybrid rice has the potential to break the current yield ceiling and support sustainable intensification. Since its introduction in Bangladesh in 1993 through collaboration with the International Rice Research Institute (IRRI), hybrid rice has undergone significant development. However, early adoption was hindered by technical, institutional, and perceptual barriers including limited local expertise, poor seed performance, and skepticism about economic viability.

Despite recent progress in breeding, seed systems, and policy support, hybrid rice still covers only about 12% of the total rice area (DAE, 2022). Moreover, comprehensive insights into its long-term performance, adoption dynamics, and strategic potential remain limited in the literature.

The objective of this paper is to critically review the development, adoption, and future prospects of hybrid rice in Bangladesh, with particular emphasis on its role in ensuring national food security under changing demographic and climatic conditions.

MATERIALS AND METHODS

This study adopts a qualitative review approach to assess the progress and prospects of hybrid rice in Bangladesh. The methodology involves a comprehensive synthesis of secondary data drawn from peer-reviewed journal articles, government publications, institutional reports, and relevant grey literature published recently.

Publications from the Bangladesh Rice Research Institute (BRRI) and the International Rice Research Institute (IRRI). Reports from the Ministry of Agriculture and the Department of Agricultural Extension (DAE). Data from national surveys and agricultural statistics (e.g., BBS, FAO). Studies by academic researchers and development organizations working on rice innovation and food security. To ensure analytical rigor, the literature was screened for relevance, credibility, and recency. Comparative insights from neighboring countries such as India, China, and Vietnam were also incorporated to contextualize Bangladesh's experience within the broader regional landscape.

This methodology enables a holistic understanding of hybrid rice development, highlighting both empirical findings and strategic implications for future interventions.

RESULTS AND DISCUSSION

Progress of hybrid rice in BRRI

The average yield of Boro-season BRRI-released hybrid varieties ranges from 8.0 to 10.5 t/ha (Biswas *et al.*, 2024). BRRI hybrid dhan3 is the most popular variety of the Boro season, followed by BRRI hybrid dhan5. It has tremendous yield potential and had average yield of 9.0 t/ha and the highest yield of more than 11.0 t/ha. The latest BRRI-released hybrid is BRRI hybrid dhan8 for the Boro season, having yield potential of more than 10.5 t/ha coupled with slender grain and growth duration of 145–148 days. It will soon undergo large-scale testing in farmers' fields. The first released BRRI hybrid, BRRI hybrid dhan1, was developed using IRRI CMS line IR58025A. Similarly, Hardinath Hybrid-1 (HH-1) first hybrid rice variety developed and released in Nepal (Subedi *et al.*, 2024). In 2010, BRRI was able to release the first-ever T. Aman hybrid rice variety in Bangladesh. It has yield potential of 6.0–6.5 t/ha with slender grain using the same IRRI CMS line, IR58025A. The most popular

BRRI-released T. Aman hybrid is BRRI hybrid dhan6. It has excellent cooking quality because of high amylose content and good physio-chemical properties and it yields 6.5–7.0 t/ha with 115–120 days' growth duration. It has gained popularity because of its slender grain, good cooking quality, as well as very good seed production ability. It is bred using IRRI CMS line IR79156A. So far, BRRI has been able to breed one T. Aus hybrid (BRRI hybrid dhan7) having yield potential of more than 7 t/ha coupled with very attractive long slender grain with 105–110 days' growth duration. It was released in 2020 and bred using IRRI CMS line IR75608A. So, it is clearly evident that IRRI CMS lines are suitable for the rainfed conditions of Bangladesh.

About 20 potential CMS lines for the dry and wet season with desirable grain type and duration have been developed along with 40 restorer lines (Hasan *et al.*, 2012; Hasan *et al.*, 2015). A specific and goal-oriented work plan has been prepared for developing heterotic rice hybrids for both the irrigated (Boro) and rainfed (T. Aman) ecosystems. Efforts are also being made to develop new sources of CMS lines adapted to Bangladeshi conditions. India has made impressive strides in hybrid rice development. So far, 117 three-line indica hybrids have been released, adapted to various growing conditions and durations (115–150 days), now covering 6.8% of the country's total rice area. Additionally, scientists have developed several indigenous CMS lines using diverse genetic and cytoplasmic sources, which are now key tools in breeding even better hybrid rice varieties (Rout *et al.*, 2020).

Sources of BRRI hybrid rice parental lines

Bangladesh Rice Research Institute (BRRI) is the leading public-sector organization in Bangladesh with a dedicated mandate for rice research. BRRI is responsible for developing rice varieties, improving cultivation technologies, and supporting national food security through rice research. Informal collaboration in hybrid rice research began between BRRI and IRRI in 1993. The initial work involved testing of F1 hybrids and evaluation of CMS lines and restorer lines from IRRI. Later, BRRI started hybrid rice breeding work to develop hybrid parental lines using germplasm from indigenous sources (BRRI gene bank, conventional breeding program) and international nurseries, mostly from IRRI. Several germplasm lines (A, B, and R) were also supplied by Chinese experts during their consultancy mission under the TCP project funded by FAO in 1997–1998. Those were found to be good CMS sources. Therefore, BRRI used those CMS sources and developed a good number of new CMS lines along with their maintainer lines. IRRI developed the CMS lines IR58025A and IR62829A and these were used to develop locally adapted CMS lines. Several selected local varieties/lines were identified as maintainers and were backcrossed to their respective CMS sources. A large number of high-yielding locally developed elite lines were tested along with some good restorers from IRRI. BRRI also received some Indian germplasm through IRRI. In this situation for promoting hybrid rice cultivation in the country, Bangladesh should develop its own parental lines. Keeping this view in mind, BRRI has developed several A, B, and R lines by using CMS sources from other countries (Table 1).

Table 1. A, B, R, and local lines used in hybrid rice development in Bangladesh (2002–2021).

Sl. no.	Designation	Cyto source	Country of origin	Restorer line	Source
1	Jin23A/B	WA	China	Gui99R	China
2	Gan 46A/B	Dissi	China	Ajay R	India
3	II 32A/B	ID	Indonesia	PMSRI-17-4-B-13	India
4	IR68886A/B	WA	Philippines	IR52713-2B-8-2B-1-2	IRRI
5	IR68888A/B	WA	Philippines	IR65209-3B-6-3-1	IRRI
6	IR68897A/B	WA	Philippines	IR65610-38-2-4-2-6-3	IRRI
7	IR70960A/B	Gambiaca	Philippines	IR44675R	IRRI
8	IR75595A/B	Dissi	Philippines	IR71137-328-2-3-3-2R	IRRI
9	IR75608A/B	Dissi	Philippines	IR69713-3-2-1-3-2R	IRRI
10	IR77801A/B	Dissi	Philippines	IR69702-91-2-3R	IRRI
11	IR77805A/B	Dissi	Philippines	IR73885-10-4-3-2-1-6R	IRRI
12	IR58025A/B	WA	Philippines	IR65482-7-216-1-2R	IRRI
13	IR79128 /B	WA	Philippines	IR69713-127-2-1-3-2R	IRRI
14	IR79156A/B	WA	Philippines	BR827R	BRRI
15	IR80151A/B	WA	Philippines	BR168 R	BRRI
16	IR80154 A/B	Gambiaca	Philippines	BR736R	BRRI
17	IR80156 A/B	Kalinga	Philippines	BR6839-41-5-1R	BRRI
18	BRRI1A/B	WA	Bangladesh	BR7013-62-1-1R	BRRI
19	BRRI2A/B	WA	Bangladesh	BR7011-37-1-2R	BRRI
20	BRRI3A/B	WA	Bangladesh	BR6723-1-1-2R	BRRI
21	BRRI4A/B	WA	Bangladesh	BRRI10R	BRRI
22	BRRI5A/B	WA	Bangladesh	BRRI11R	BRRI
23	BRRI6A/B	WA	Bangladesh	BRRI12R	BRRI
24	BRRI7A/B	WA	Bangladesh	BRRI13R	BRRI
25	BRRI10A/B	WA	Bangladesh	BRR114R	BRRI
26	BRRI11A/B	WA	Bangladesh	BRRI15R	BRRI
27	BRRI13A/B	WA	Bangladesh	BRRI16R	BRRI
28	BRRI21A/B	WA	Bangladesh	BRRI17R	BRRI
29	BRRI28A/B	Gambiaca	Bangladesh	BRRI20R	BRRI
30	BRRI30A/B	WA	Bangladesh	BRRI23R	BRRI
31	BRRI32A/B	Dissi	Bangladesh	BRRI27R	BRRI
32	BRRI35A/B	WA	Bangladesh	BRRI31R	BRRI
33	BRRI41A/B	WA	Bangladesh	BRRI32R	BRRI
34	BRRI48A/B	WA	Bangladesh	BRRI35R	BRRI
35	BRRI56A/B	WA	Bangladesh	BRRI37R	BRRI
Local germplasm					
1	Luhagara		Bangladesh		BRRI
2	Malail		Bangladesh		BRRI
3	Binnimuri		Bangladesh		BRRI
4	Sharisha Mota		Bangladesh		BRRI
5	Dongra		Bangladesh		BRRI
6	Dular		Bangladesh		BRRI
7	Kajalsail		Bangladesh		BRRI
8	Kacha Nonia		Bangladesh		BRRI
9	Khato Vajan		Bangladesh		BRRI
10	Sonaroti		Bangladesh		BRRI
11	Jupri		Bangladesh		BRRI
12	Sadamota		Bangladesh		BRRI

Multi-location trials of promising hybrids

Multilocation trials were conducted to assess the adaptability and yield potential of the identified hybrids. Twenty-one promising hybrids along with three checks were evaluated across five BRRI regional stations during the T. Aman season of 2022 under two sets. In this study, hybrids entries were compared against three checks - BRRI hybrid dhan6, used as the baseline for yield comparison, AZ 7006 and Dhanny Gold used as additional standards.

Results from Set-I showed that BRRI99A/BRRI42R was the top-performing hybrid, which resulted in 29% yield advantage over BRRI hybrid dhan6, 27% over AZ 7006 and 19% over Dhanny Gold. This hybrid also exhibited the highest spikelet fertility (SF), indicating excellent pollination and grain filling capacity. Its grain type was medium-slender (MS) and amylose content was 24%, suitable for non-sticky, fluffy cooked rice. Another strong performer, BRRI97A/BRRI42R, offering a 22% yield advantage over BRRI hybrid dhan6, 20% over AZ 7006, and 13% over Dhanny Gold. It showed good stability across locations and had a spikelet fertility of 80.3%. Similarly, BRRI99A/BRRI43R had a yield advantage of 21%, 19%, and 12% over the three checks, respectively. These three hybrids consistently outperformed the check varieties in grain yield across test locations. They also exhibited favorable agronomic traits, acceptable grain shape and desirable cooking quality (amylose content between 23.6% and 24.2%). Location-wise, Ishwardi and Barishal recorded the highest yields, suggesting that these sites possess favorable agro-ecological conditions for hybrid.

In Set-II, among the ten entries, several hybrids demonstrated significant yield advantages over the standard check varieties. Notably, IR102758A/BRRI43R gave the highest average grain yield, outperforming BRRI hybrid dhan6 by 21%, AZ 7006 by 21%, and Dhanny Gold by 13%. This hybrid also recorded the highest spikelet fertility, reflecting strong reproductive success. It featured a long slender grain type and an amylose content of 24.0%, which aligns well with market demand and consumer preferences. Another performer, IR102758A/BRRI42R showed a 18% yield advantage over both BRRI hybrid dhan6 and AZ 7006, and 10% advantage over Dhanny Gold. IR58025A/BRRI46R also showed promise with desirable spikelet fertility, grain type and amylose content. These findings are consistent with earlier findings by Sarkar (2016), as well as hybrid performance trends observed in multi-location trials conducted in the Philippines (Tabanao *et al.*, 2015) and India (Muralidharan *et al.*, 2020), where hybrid varieties consistently out yielded inbreds under diverse environments.

Overall, hybrids such as BRRI99A/BRRI42R, BRRI97A/BRRI42R, BRRI99A/BRRI43R, IR102758A/BRRI42R, and IR102758A/BRRI43R demonstrated significant yield advantages over the standard checks, along with good grain quality and agronomic traits. These entries hold strong potential for release and wider cultivation in Bangladesh's diverse rice-growing environments.

Table 2. Results of multilocation yield trials during T. Aman 2022 season (Set-I).

Sl. no.	Hybrids	PH (cm)	DTM	Yield (t/ha)						SF (%)	GSS	Amy. (%)	Ave. yield advantage over check (%)		
				Gaz	Ish	Bari	Ran	Son	Ave.				Ck-1	Ck-2	Ck-3
1	IR79156A/BRRI46R	108	111	7.4	7.6	5.8	7.4	5.8	6.8	76.3	LS	24.2	8.0	6.3	–
2	BRRI97A/BRRI53R	110	110	7.2	7.0	8.9	6.4	5.6	7.0	78.6	MS	23.4	11.4	9.7	3.2
3	IR79156A/BRRI53R	106	113	5.9	7.3	7.4	6.9	6.3	6.8	76.0	LS	23.2	8.0	6.3	–
4	IR105688A/BRRI53R	104	110	6.1	6.9	7.4	6.0	5.8	6.4	75.2	LS	23.5	1.6	–	–
5	BRRI97A/BRRI42R	107	114	6.8	8.7	8.4	7.7	6.7	7.7	80.3	MS	23.6	22.2	20.3	13.2
6	BRRI99A/BRRI42R	111	115	8.3	9.2	8.5	7.3	7.0	8.1	84.5	MS	24.2	28.6	26.6	19.1
7	BRRI99A/BRRI37R	110	110	6.0	7.9	6.9	7.2	6.3	6.9	77.8	MS	23.4	9.5	7.8	1.5
8	IR102758A/BRRI36R	109	114	6.5	7.1	6.1	6.3	5.8	6.4	75.0	MS	23.4	1.6	–	–
9	BRRI97A/BRRI43R	107	110	6.1	7.5	7.3	7.1	6.3	6.9	77.6	LS	24.0	9.5	7.8	1.5
10	BRRI99A/BRRI43R	111	118	7.4	8.8	7.8	7.1	7.0	7.6	79.8	LS	23.7	20.6	18.8	11.8
11	IR79156A/BRRI43R	113	119	6.7	8.4	7.2	7.4	6.8	7.3	78.7	MS	23.6	15.9	14.1	7.4
Ck-1	BRRI hybrid dhan6	112	116	5.8	7.3	5.8	6.4	6.2	6.3	75.0	LS	24.0			
Ck-2	AZ 7006	116	123	5.6	7.8	6.2	6.9	5.4	6.4	75.1	LS				
Ck-3	Dhanny Gold	118	127	6.3	7.0	7.8	7.4	5.6	6.8	75.8	LS				
Mean		110.1	115.0	6.6	7.8	7.3	7.0	6.2	7.0	77.6					
CV (%)		3.5	4.6	11.7	9.7	13.8	7.1	8.7	7.8	3.5					
LSD (0.05%)		2.6	3.6	0.5	0.5	0.7	0.3	0.4	0.4	1.9					

Note: PH = plant height, DTM = days to maturity, SF = spikelet fertility, GSS = grain size and shape, LS = long slender, MS = medium slender, Amy. = amylose content.
Gaz = Gazipur, Ish = Ishwardi, Bari = Barishal, Ran = Rangpur, Son = Sonagazi.

Table 3. Results of multilocation yield trials during T. Aman 2022 season (Set-II).

Sl. no.	Hybrids	PH (cm)	DTM	Yield (t/ha)						SF (%)	GSS	Amy. (%)	Ave. yield advantage over check (%)		
				Gaz	Ish	Bari	Ran	Son	Ave.				Ck-1	Ck-2	Ck-3
1	IR58025A/BRRI46R	111	120	7.4	7.8	8.1	6.4	5.8	7.1	78.0	LS	23.2	12.7	12.7	6.0
2	IR102758A/BRRI53R	110	116	7.2	7.7	7.9	5.8	5.6	6.8	77.5	MS	23.5	7.9	7.9	1.5
3	IR79125A/BRRI53R	114	119	6.8	6.4	7.4	6.4	5.8	6.6	76.0	LS	24.2	4.8	4.8	-
4	IR78369A/BRRI53R	116	123	6.1	7.5	7.4	6.2	5.8	6.6	75.6	MB	23.5	4.8	4.8	-
5	IR102758A/BRRI42R	107	114	6.8	8.7	7.4	6.6	6.7	7.4	75.8	MS	23.6	17.5	17.5	10.4
6	IR78369A/BRRI42R	111	115	6.3	7.0	7.5	6.2	5.8	6.6	79.1	M	24.2	4.8	4.8	-
7	IR58025A/BRRI36R	110	118	6.0	7.9	6.9	6.0	5.8	6.5	75.1	LS	22.4	3.2	3.2	-
8	IR105688A/BRRI43R	109	114	6.5	7.1	6.1	6.32	5.8	6.4	75.0	MS	23.4	1.6	1.6	-
9	IR102758A/BRRI43R	112	118	8.1	7.9	8.3	7.4	6.3	7.6	79.4	LS	24.0	20.6	20.6	13.4
10	IR58025A/BRRI43R	111	118	5.8	7.1	6.7	6.5	5.7	6.4	75.1	LS	22.7	1.6	1.6	-
Ck-1	BRRI hybrid dhan6	112	116	6.3	7.0	5.8	6.0	6.2	6.3	74.8	LS	24.0			
Ck-2	AZ 7006	116	124	5.6	7.5	6.2	6.7	5.6	6.3	77.3	LS				
Ck-3	Dhanny Gold	118	128	6.3	7.6	7.0	6.8	5.8	6.7	78.0	LS				
Mean		112.1	118.7	6.6	7.5	7.1	6.4	5.9	6.7	76.7					
CV (%)		2.8	3.5	10.6	7.6	10.8	6.5	5.3	6.1	2.1					
LSD (0.05%)		2.2	3.0	0.5	0.4	0.6	0.3	0.2	0.3	1.2					

Note: PH = Plant height, DTM = days to maturity, SF = spikelet fertility, GSS = grain size and shape, LS = long slender, MS = medium slender, MB = medium bold, Amy. (%) = amylose content, Gaz = Gazipur, Ish = Ishwardi, Bari = Barishal, Ran = Rangpur, Son = Sonagazi.

Evaluation of HRDC hybrids during Boro 2022–2023

Five hybrid rice varieties from the Hybrid Rice Development Consortium (HRDC) were evaluated with five check varieties at BRRI, Gazipur, during Boro 2022-23 season. Among the HRDC entries, IR138766H showed the most promising performance which represents an 8% yield advantage over SL8H and 2.03% over Heera. This hybrid also showed high spikelet fertility, favorable grain weight and growth duration. It demonstrated moderate blast disease resistance, rated 3 on a 1-9 scale (Table 8).

Table 8. Performance of HRDC hybrids during Boro 2022–2023.

Sl. no.	Variety	PH (cm)	SF (%)	TGW (g)	DTM	Yield (t/ha)	Blast Disease reaction on 1–9 scale	Remarks
1	IR138901H	98	77.7	22.5	144	9.40	3	
2	IR138766H	99	92.6	23.8	146	10.05	3	Good crop
3	IR139568H	106	80.4	23.2	153	8.80	3	
4	IR139526H	113	72.2	23.1	154	6.08	3	
5	IR139010H	113	60.6	24.0	154	7.65	3	
6	BRRI hybrid dhan5 (Ck-1)	108	81.4	30.8	148	11.07	3	
7	Tej Gold (Ck-2)	105	78.7	23.1	145	10.63	3	
8	SL8H (Ck-3)	96	85.0	26.2	147	9.35	3	
9	Heera (Ck-4)	98	84.3	27.0	153	9.85	3	
10	BRRI hybrid dhan8 (Ck-5)	105	74.9	24.2	153	10.65	3	
	CV (%)	5.9	10.9	10.3	2.7	16.3		
	LSD (0.5)	1.57	4.39	1.27	2.16	1.66		
	Heritability	0.96	0.93	0.97	0.96	0.81		

Note: PH = plant height, SF = spikelet fertility, TGW = 1,000-grain weight, DTM = days to maturity.

CMS seed multiplication

Seed production is a major constraint in hybrid rice cultivation. Four CMS lines (BRRI11A, IR79156A, BRRI74A and BRRI120A) along with their respective maintainers were evaluated during *T. Aman* 2022 season to assess the impact of key components on outcrossing rate (OCR) and seed yield. Seed yields of 470 kg/plot (0.94 t/ha), 315 kg/plot (0.93 t/ha), 10.3 kg/plot (1.03 t/ha), and 7.8 kg/plot (1.30 t/ha) were recorded for BRRI11A, IR79156A, BRRI74A and BRRI120A, respectively. Despite relatively high panicle exertion rates (PER) and OCR (30-33%), seed yield was notably low due to heavy rainfall during the supplementary pollination period. Pollen grain were washout through rainfall. Among these, BRRI120A is the promising candidates for profitable seed production.

Table 4. CMS seed multiplication of BRRI-released hybrids and promising lines during T. Aman 2022 season.

Combinations	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield		Remarks
							(kg/plot)	(t/ha)	
	A line	B line	A line	B line					
BRRI11A/B	90	94	82	80	78	30	470	0.94	Poor seed yield due
IR79156A/B	93	97	85	83	79	31	315	0.93	to rainfall during
BRRI74A/B	98	103	80	77	80	33	10.3	1.03	supplementary
BRRI120A/B	97	100	79	77	80	32	7.8	1.30	pollination

Note: PER = panicle exertion rate, OCR = outcrossing rate.

During the *Boro* 2022-23 season, efforts were made to produce sufficient quantities of pure CMS seeds for BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6, and BRRI hybrid dhan8. Seed yields from six CMS lines varied notably. IR79156A and BRRI99A produced the highest yields at 1.99 t/ha and 1.91 t/ha, respectively. Although pollen exertion rates (PER) and outcrossing rates (OCR) were relatively high, seed productivity remained below expectations. This was primarily attributed to elevated temperatures during the flowering period. Excessively hot conditions during pollination and seed set can affect both pollen viability and the receptivity of plant stigmas (Lordon and Zystro, 2024).

Table 5. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6, and BRRI hybrid dhan8 during Boro season, 2022–2023.

Designation	Plant		50% flowering		PER	OCR	Plot area (m^2)	Yield (kg/plot)	Seed yield (t/ha)
	A line	B line	A line	B line	A line	A line			
BRRI10A/B	86	88	125	122	78.0	38.0	1,300	58	0.45
BRRI11A/B	95	99	120	118	82.3	39.9	4,000	598	1.40
IR58025A/B	84	87	123	120	77.3	38.0	1,500	244	1.16
BRRI7A/B	94	97	120	117	78.0	38.3	3,400	419	1.23
IR79156A/B	88	91	123	121	83.0	43.5	6,800	1,352	1.99
BRRI99A/B	85	89	126	123	84.3	42.4	2,200	421	1.91

F_1 seed production of released hybrids

F_1 seed production for seven released BRRI hybrid rice varieties was carried out through contract growers at Ishwardi, Pabna during *Boro* season 2022-2023. Parental lines were sown using appropriate intervals between A and R lines in a two- or three-stagger system to ensure synchronization and effective pollination. The highest seed yield was recorded in BRRI hybrid dhan7, followed by BRRI hybrid dhan6. These results indicate that hybrid seed yields exceeding 2.0 t/ha are achievable on a commercial scale. Lower yields in BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan5 were attributed to high temperatures during flowering and hailstorm-induced shattering. Higher seed yield influences the farmers adoption rate in hybrid rice.

Table 6. F_1 seed production of BRRI-developed hybrids through contract growers, Ishwardi, Boro 2022–2023.

Sl. no.	Combination	Contract grower	Seed yield (kg)	Area (m^2)	Seed yield (t/ha)	Remarks
01	BRRI hybrid dhan2	AUS Bangla Agro	962	10,000	0.96	Less seed due to high temperature at flowering stage and shattering from hail storm
02	BRRI hybrid dhan3		3,510	28,000	1.25	
03	BRRI hybrid dhan4		1,500	10,000	1.50	Good
04	BRRI hybrid dhan5		2,728	28,000	0.97	Less seed due to high temperature at flowering stage and shattering from hail storm
05	BRRI hybrid dhan6		5,700	28,000	2.04	Good
06	BRRI hybrid dhan7		4,620	20,000	2.31	Good
07	BRRI hybrid dhan8		3,872	20,000	1.94	Good
	Total		22,892	144,000 (36 acres)		

Dissemination of hybrid rice technology

Several initiatives were undertaken to support domestic seed production to promote the adoption of BRRI-developed hybrid rice varieties. Hybrid Rice Division distributed a total of 21,606 kg of seed, including 16,750 kg of F_1 seed, 3,420 kg of A line, and 1,257 kg of R line seed during *Boro* 2022-23 season. These were provided free of cost to 24 seed companies, 130 farmers, BRRI scientists and staff, BRRI regional stations and extension personnel from DAE (Table 7). This effort aimed to strengthen collaboration with seed producers and accelerate the dissemination of hybrid rice technologies across Bangladesh.

Table 7. Amount of parental line and hybrid seed supplied to different organizations.

Sl. no.	Recipient	Nos.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
01	Seed companies	24	1,250	3,290	–	1,222
02	Farmers	130	1,500	130	–	35
03	BRRI scientists + staff	19	2,000	–	–	–
04	BRRI R/S (5) + DAE	6	12,000	–	–	–
Total		179	16,750	3,420	0.00	1,257
Grand total				21,606		

Released hybrid rice varieties in Bangladesh

A total of 254 hybrid rice varieties have been registered so far through the National Seed Board (NSB), including 211 for Boro, 37 for T. Aman, and 6 for T. Aus seasons (Table 9) (Halder, 2025). Of these, 33 hybrids (12.9%) were developed locally, demonstrating Bangladesh's growing capacity in hybrid rice breeding. The majority of registered hybrids originate from China (59.6%), followed by India (26.7%). Although a few domestic mega-varieties have been released, imported varieties from China and India still dominate the market in terms of both yield performance and farmer adoption (Khanh *et al.*, 2021). The country's ability to contribute only 13% of the total registered hybrids highlights its potential for further innovation in this sector.

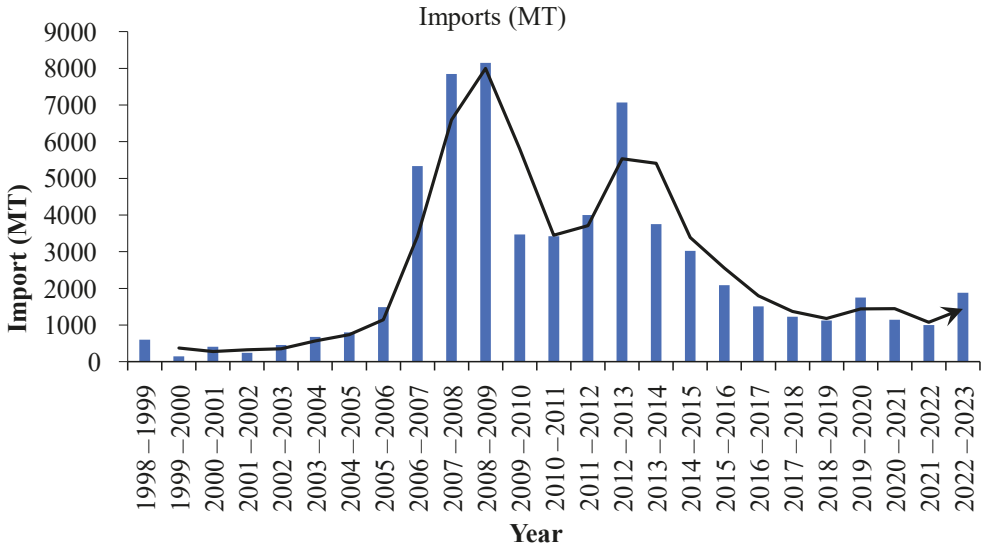
Table 9. Released hybrid rice varieties in Bangladesh, with their origin.

Origin	Number of Varieties	Season			Country of origin and % share
		Aus	Aman	Boro	
Bangladesh	35	1	12	22	13.78
China	153	3	9	141	60.24
India	65	2	16	47	25.59
Philippines	1	0	0	1	0.39
Total	254	06	37	211	100

(MoA, 2025)

Imports and local production of hybrid rice seed

During the early years (1998–2004), hybrid rice seed production in Bangladesh was negligible, and the entire demand was met through imports. Local hybrid rice seed production has increased steadily since 2005, reflecting growing domestic capacity. Conversely, import volumes declined gradually after reaching their peak between 2008 and 2010. In recent years, domestic seed production has surpassed 10,000 metric tons, whereas imports have stabilized at relatively low levels. Currently, more than 85% of the total hybrid rice seed demand is met through local production, although the majority of parental lines sourced from abroad (Fig. 1).



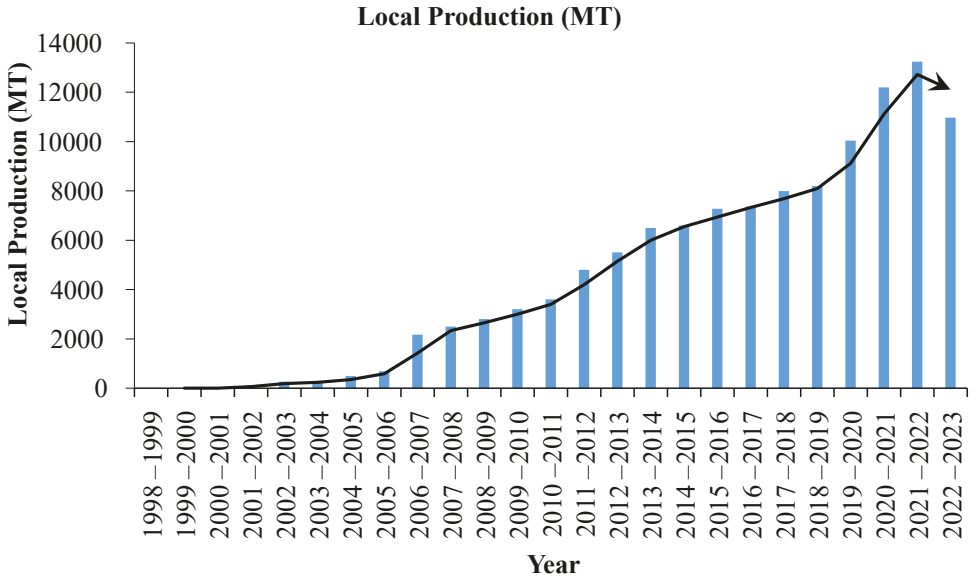


Fig. 1. Year-wise imports and local production of hybrid rice seed from 1998–1999 to 2022–2023 showing in percentage. (MoA, 2024).

Prospects of hybrid rice in Bangladesh

Hybrid rice is now a proven technology for Bangladesh and it covers more than 12% of the cultivated area. Most of the hybrids perform well in the dry season (Boro) and monocrop area. Hybrids cover about 25% of the area in the Boro season but about 5% in T. Aus and T. Aman season. It is obviously required for its 15–20% yield advantage and short duration. The government of Bangladesh has taken pragmatic steps to develop and use hybrid rice technology on a large scale by involving public, private, and nongovernment organizations. Research, seed production, and technology transfer agencies in the public, private, and NGO sectors are also interested in exploring the prospects of this technology. The government has allowed some NGOs and private seed companies to introduce and commercialize exotic hybrids for large-scale cultivation by farmers with a view to obtaining immediate benefit from this technology. Special attention has been given to developing hybrid rice varieties within the country and, in this regard, the Ministry of Agriculture (MoA) approved a new hybrid rice project for BRRI titled High-Yielding Hybrid Rice Variety Development through Modernization of Research. The foremost constraint to overcome by researchers is to identify heterotic hybrid combinations that are adaptable under Bangladeshi conditions as well as being able to out yield the most popular commercial varieties by at least 20%. Another hurdle to be overcome is to develop a cheaper seed production package, which is necessary to make this technology commercially viable, along with creating job opportunities for rural dwellers. Zoning of hybrid rice seed production is urgently needed, such as a seed village where only one variety will be produced without any barrier. Cytoplasmic diversity searching is necessary for avoiding sudden disease infestation. Cooking quality needs to be improved coupled with high amylose content and slender grain. As the parental lines of BRRI-developed hybrid rice varieties are readily available, these lines are being provided free of cost to interested persons/companies for small and medium enterprise development, resulting in increasing demand and number of new ventures. Some constraints were identified for prospect of hybrid rice in India (Spielman *et al.*, 2013). Yet,

the adoption rate of hybrid rice in Bangladesh still lags behind regional counterparts. Concerns regarding high seed cost, grain acceptability, and yield stability persist, especially among smallholder farmers. Moreover, the lack of comprehensive data on long-term performance, socio-economic impact, and environmental sustainability limits informed decision-making.

The way forward

To accelerate the adoption and impact of hybrid rice in Bangladesh, a comprehensive and prioritized strategy is needed:

i) Breeding and Seed Technology
   - Develop stress-tolerant hybrids resilient to drought, flood, and salinity-prone areas.
   - Diversify and stabilize CMS lines with improved grain and cooking quality.
   - Introduce breeder-usable molecular tools to enhance breeding efficiency.
   - Initiate systematic screening for super hybrid rice varieties under Bangladeshi conditions.

ii) Seed Industry and Policy Support
   - Strengthen institutional mechanisms for breeder, foundation, and certified seed production of public hybrids.
   - Establish land-use planning and zoning for hybrid seed villages to ensure genetic purity.
   - Recognize the hybrid rice seed industry as a priority sector in national financial and industrial policy.
   - Provide targeted subsidies and incentives to reduce the high cost of hybrid seed production.
   - The hybrid seed productivity should be enhanced at least up to 2.5-3.0 t/ha to make the availability of hybrid seed at a cheaper rate.

iii) Capacity Building and Knowledge Exchange
   - Enhance scientists' capacity in hybrid rice breeding, seed production, and agronomic management through advanced training.
   - Facilitate exchange of parental lines for both three-line and two-line hybrids.
   - Promote collaborative research, study tours, and higher education (MS, PhD) on hybrid rice within and outside the country.

iv) International and Institutional Collaboration
   - Expand technological cooperation with China, including joint ventures with the China National Hybrid Rice Research and Development Center (CNHRRDC). Foster stronger linkages among public institutes, private companies, and NGOs for seed production and dissemination.

CONCLUSION

Since the collaboration between BRRI and IRRI in hybrid rice research in 1993, Bangladesh has made significant strides in developing and releasing high-yielding varieties for different agro-ecological conditions of the Bangladesh. BRRI has demonstrated strong national research capacity by developing over 20 CMS, 40 restorer lines and releasing eight hybrid rice varieties that have a yield advantage of 15-20% over traditional inbreeds. However, hybrid rice adoption is still relatively low compared with neighboring countries. Constraints such as high seed cost, grain quality concerns, yield variability, and dependence on imported parental lines hinder the expansion. Strengthening domestic breeding programs, ensuring genetic diversity, and improving hybrid seed production technologies are critical to enhancing local competitiveness.

In order to reduce seed costs and guarantee quality assurance, future success will require consistent investment, efficient public-private cooperation, and enabling policy support. With strategic interventions and wider dissemination, hybrid rice has the potential to significantly improve farmers' livelihoods, increase productivity, and ensure food security of Bangladesh.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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