Material

Performance of Hybrid Rice in Bangladesh: A Comparative Study

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バングラディッシュにおけるハイブリッドライスの評価

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Abstract A comparative study was carried out to evaluate four imported (one from China and three from India) hybrid rice cultivars with a check high yielding variety (BRRI Dhan-29) (as control) at the farmer field-level in 33 locations of Bangladesh. Yield and yield contributing characters, physicochemical properties and cost-return benefits of hybrid rice were analyzed. The Chinese cultivar - Sonarbangla-1 performed best in terms of all the parameters considered. The other three Indian cultivars (Amarsiri-1, Aalok and Loknath) had lower performance than the check variety (control). Sonarbangla-1 produced a 20% higher rice yield (7.55 t ha^{-1}) than the check variety (6.26 t ha^{-1}). Yield advantage for the hybrid rice was mainly due to heavier grain weight (35%) and to increased values in the proportion of filled grains/panicle over the check variety (28%). Shorter field duration was observed in Sonarbangla-1 than the check variety. About a 16% and 32% higher cost was incurred in Sonarbangla-1 than the check variety when calculated on a full-cost and cash-cost basis, respectively. However, gross return was 21% higher in Sonarbangla-1 than the check variety thus contributing to a 5% higher benefit-cost ratio. These results suggest that Sonarbangla-1 is a promising hybrid rice under Bangladesh context.
Key Words: Bangladesh, BRRI Dhan-29, Hybrid rice

バングラディッシュにおけるハイブリッドライスの評価 Mohammad Masud PARVEZ[1,2,*], Md. Harun-Ar-RASHID[3], Syeda Shahnaz PARVEZ[1,4] and Md. Tariful ISLAM[3]. [1]*Chemical Ecology Unit, National Institute for Agro-Environmental Sciences, 3-1-3 Kannondai, Tsukuba, Ibaraki 305-8604, Japan* [2]*Bangladesh Agricultural Institute, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh* [3]*Agricultural Advisory Society, 6/5 Sir Syed Road, Dhaka-1207, Bangladesh* [4]*Laboratory of Pomology, Institute of Agriculture and Forestry, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan*

要　約　バングラディッシュで主に栽培されている多収量品種ダーン（BRRI：バングラディッシュイネ研究所の Dhan-29）(control) と中国から1品種およびインドから3品種，計4品種の輸入したハイブリッドライスをバングラディッシュ内の33箇所の水田で比較栽培した．そして収量および物理化学特性と費用対効果が高いかどうかを比較し，ハイブリッドライスの評価を行った．ハイブリッドライスの収量，特に中国から輸入されたハイブリッドライス：ショナルバングラー1（Sonarbangla-1）は，すべての試験で用いたパラメーターにおいて最も優れていた．一方，他の3つのインドから輸入されたアマールシリー1（Amarsiri-1），アーロック（Aalok）およびロックナッス（Loknath）はバングラディッシュ品種ダーンに比べて劣っていた．収量から見るとショナルバングラー1は7.55 t ha^{-1}であり，バングラディッシュ品種ダーンは6.26 t ha^{-1}であったことから約20%収量が高かった．ハイブリッドライスの収量増加の要因は35%籾重が増大し，また穂に対する籾の割合が28%増加していたことにあると考えられる．また，ショナルバングラー1は他の品種より栽培期間が短かった．栽培に関しての総費用および支払い費用を算出すると，ショナルバングラー1は他の品種に比べてそれぞれ約16%と32%程度高いことが明らかとなった．しかしながら，ショナルバングラー1はバングラディッシュ品種ダーンに比べ5%コストが高くなるものの，純利益は21%高かった．以上の結果からショナルバングラー1は，バングラディッシュの稲作に貢献できるハイブリッドライスと考えられる．
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Introduction

Asia occupies the home of 60% of the world's population which solely dependent on rice as a source of staple food. More than 10% of the earth's arable land is under rice cultivation producing 530 million tons of rough rice in 110 countries. This, represents one-third of the world's cereal production and is almost equal to the world's wheat production (FAO, 1994). Developing nations located in Asia are the main producers of more than 95% of the world's total rice (IRRI, 1995).

During the late 1980s and early 1990s, visualizing the continued decreasing trend in the yield of irrigated rice systems, scientists involved in rice research and farming, and policy makers started searching for viable means for the potential enhancement of rice

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yield under the existing environment. Focus in this area increased more than before when IRRI (International Rice Research Institute) reported a 1.5% estimated increase per annum of the world's population by the year 2025 (IRRI, 1995), while the global rice-consuming population is increasing by 2% per year. Under such an alarming global situation and with very little possibilities for expanding the area for irrigated rice, both scientists and policy makers must work hard to attain an increased rice production using the land presently occupied by rice cultivation.

The green revolution in the late 1960s contributed significantly through the introduction of HYVs (high yielding varieties) of rice and adoption of associated improved management practices particularly in many Asian countries (BARKER and HERDT, 1985; HAZELL and RAMASAMY, 1991; JANAIAH *et al.* 2002; PINGALI *et al.* 1997; PINGALI and HOSSAIN, 1999). Although a high rise in the rice yield was observed during 1966 to 1980s, growth in Asian rice production sharply decreased in the 1990s (JANAIAH *et al.* 2002). Such a fall in production was mainly due to a deceleration in the most intensively irrigated rice-fields where farm-level yield had reached nearly 6.0 t ha^{-1}. Both farmers and policy makers require another breakthrough in technology at this threshold yield of rice to obtain a sustainable, productive and profitable agricultural economy in Asia. In fact, scientists urgently need to meet the challenges of a rapid increase in global population growth.

It has been reported that hybrid rice greatly contributed more than 15-20% extra yield advantage over the existing HYVs (HE *et al.* 1987; RAJARATHINAM and BALASUBRAMANIYAN, 1999; SUREKHA *et al.* 1999). In order to meet current and future global demand for rice, the Chinese success in commercialization of hybrid rice technology motivated farmers, policy makers and scientists of many Asian countries like India, Sri Lanka and Vietnam to exploit this opportunity under an irrigated rice cultivation environment (JANAIAH *et al.* 2002; JANAIAH and HOSSAIN, 2000; LIN, 1991; LIN, 1994; VIRMANI *et al.* 1998).

India, the nearest neighboring country to Bangladesh, started systematic research on hybrid rice in 1989 and released 12 rice hybrid varieties for cultivation at the farm-level (ANONYMOUS, 1998; JANAIAH *et al.* 2002). However, until 1997 no government permission was directed for the commercial cultivation of hybrid rice in Bangladesh. During 1998-99, the government of Bangladesh permitted the import of hybrid rice seeds from China and India for commercial cultivation and accordingly 4 hybrid rice cultivars (1 from China and 3 from India) were imported. This study was therefore undertaken to assess the performance of imported hybrid rice seeds developed by commercial companies at the farmer field-level in various locations of Bangladesh. This study also provided the opportunity to establish a linkage between public and private sectors involved in hybrid rice seed development. The results presented here are the first report of a comparative study covering yield and yield contributing characters, physicochemical properties and cost-return benefits of hybrid rice under Bangladesh context.

Materials and methods

1. Plant material

Seeds of four cultivars of hybrid rice (*Oryza sativa* L.) - one from China - Sonarbangla-1 (CNSGC-6), three from India namely Aalok (HR 6201), Amarsiri-1, Loknath 503, and a check HYV (control) - BRRI Dhan-29 (from Bangladesh) were collected from several authorized local seed companies and their performance assessed during the Boro season in 1998-99.

2. Experimental design and statistical analysis

Independent plot size was 9 m x 9 m with the spacing between rows and within hills kept at 20 cm. Thirty-five to forty-five day old seedlings of each cultivar were used in this experiment. Two seedlings per hill were transplanted between 11 January and 15 February 1999.

The experiment was established at the 33 farmer rice fields in 10 districts of Bangladesh as a randomized complete block design (RCBD) with three replicates and analyzed by the analysis of variance (ANOVA). The treatment means were tested by the least significant difference (LSD) both at the 0.05 and 0.01 level probability levels.

3. Fertilization and management practices

Each plot was fertilized with urea, triple super phosphate, muirate of potash, gypsum and zinc sulphate according to the recommended doses, 250, 130, 125, 80 and 10 kg ha^{-1}, respectively. Urea was used as a top-dressing. Appropriate amounts of cow-dung and compost as a source of organic manure were applied based on availability and soil fertility level.

Management practices such as weed control, irrigation, insect-pest management were carried out as and when required.

4. Data collection

Grain yield, yield contributing characters and other ancillary parameters were recorded for each experimental site. Furthermore, data on the cost of production and net return were recorded. All the data were analyzed and are presented as the means of three replicates.

5. Analysis of physicochemical properties

Physicochemical properties of the rice grain such as milling outturn, head rice, chalkiness, appearance, length (L), breadth (B), L/B ratio, size and shape, alkali spreading value, amylose and protein content, cooking time, elongation ratio, imbibition ratio, cooking quality/taste of each cultivar were analyzed. In brief, milling outturn was determined by dehulling 200 g rough rice in a Satake rice mill followed by 45 sec polishing in a Satake grain testing mill (TM-05). Head rice outturn was expressed for both rough and milled rice. Grain length and breadth were measured using a slide caliper. For determining the size and shape, milled rice was first classified into three classes based on length - long (>6 mm in length), medium (5-6 mm in length) and short (<5 mm in length). The grains were also classified into three classes according to the ratio of length and breadth - slender (ratio > 3), bold (ratio 2-3) and round (ratio <3). Amylose content (JULIANO, 1971), gelatinization temperature (LITTLE *et al.* 1958) and protein content (by the Kjeldahl method) were determined. Volume of cooked and milled rice was measured by the water displacement method. Five grams of milled rice was placed in a cylinder containing 50 ml water and changes in the volume of water were recorded. For cooked rice volume 5 g of milled rice was measured. Cooking time was measured as when 90% of cooked rice was totally gelatinized. Data are presented as the mean of three replicates.

6. Production of paddy, cost of production and monetary return

The average paddy and straw yield of the varieties tested were recorded in terms of unit area (kg ha^{-1}). The cost of production and benefit-cost ratio was calculated on a full-cost and cash-cost basis. Full-cost included human labor, bullock power, seeds, fertilizers, insecticides, irrigation, and interest on working capital. On the other hand, cash-cost included cost of seeds, fertilizers, insecticides, irrigation and interest of the outflow cash. Price of the paddy and straw were determined as based on the local market value.

Results

1. Yield and yield contributing parameters

Table 1 shows the average grain yield (unhusked paddy), yield contributing characters, field duration and other important ancillary characters of the four cultivars of hybrid rice and the check variety (BRRI Dhan-29) (control) at 33 locations in 10 districts of Bangladesh. The Chinese hybrid rice Sonarbangla-1 ranked top in terms of paddy yield (7.55 t ha^{-1}) followed by the check variety BRRI Dhan-29 (6.26 t ha^{-1}), Aalok (6.06 t ha^{-1}), Loknath (5.11 t ha^{-1}) and Amarsiri-1 (4.86 t ha^{-1}). Yield of Sonarbangla-1 was 20.6% higher than the check variety (control). As compared to the check variety, the performance of the other hybrid cultivars was lower by 3.19% for Aalok, 18.36% for Loknath and 22.36% for Amarsiri-1.

Average grain per unit area (number m^{-2}) was the highest (30619) in the check variety (control) and the lowest (25234) in Loknath (Table 1). The other hybrid cultivars had average grain ranging from 26132 to 29561. The highest weight of 1000-grain was found in Sonarbangla-1 (28.44 g) followed by Loknath (23.18 g). Weight of 1000-grain ranged between 21.00 and 21.48 g among the check variety (control), Amarsiri-1 and Aalok (Table 1). By contrast, the grain size of Sonarbangla-1 was bolder, that of Loknath medium bolder, and BRRI Dhan-29, Aalok and Amarsiri-1 more or less similar medium size grain. The proportion of filled grain was the highest in Sonarbangla-1 (ca 79%) followed by Loknath (ca 76%). However, in the other three cultivars including the check variety (control), the proportion of filled grain fluctuated between 52 and 62% (Table 1).

The proportion of effective tiller $hill^{-1}$ was more or less similar in BRRI Dhan-29 and Sonarbangla-1 (ca 66-67%), and in Amarsiri-1, Aalok and Loknath (ca 58-63%) (Table 1). The average field duration of the crop was the highest in the check variety (control) (BRRI Dhan-29) (109 days) and the lowest in Loknath (93 days). Aalok, Amarsiri-1 and Sonarbangla-1 required field duration ranging from 98 to 102 days (Table 1).

The highest average plant height was found in the check variety (control) (97.0 cm) and the lowest in Loknath (87.9 cm) (Table 1). The remaining cultivars ranged between 93.3 and 95.3 cm. Panicle production (number m^{-2}) was the highest in the check variety (control) (339) and the lowest in Sonarbangla-1 (292) (Table 1). The other three hybrid rice cultivars had panicle production ranging from 314-336. Total number of leaves at tillering stage was the highest in Amarsiri-1 (109) and the lowest in Aalok (84). Length of the flag leaf was the highest in Aalok (29.72 cm) and the lowest in Amarsiri-1 (27.64 cm). On the other hand, breadth of the flag leaf was the highest in Sonarbangla-1 (1.70 cm) and the lowest in Amarsiri-1 (1.42 cm). Percentage of seedling recovery was the highest in Aalok (68.3%) and the lowest in Loknath (53.6%). All these ancillary characters are directly involved in the photosynthetic activity, accumulation and transformation of photosynthates to grain filling and consequently in yield, but the cultivars tested did not show any significantly differences with regard to these parameters.

2. Physicochemical properties

Table 2 shows the physicochemical properties of rice grain of the tested cultivars. The milling outturn ranged between 65 and 70%. Milling outturn in the check variety (control) was the lowest (65%) and the highest in Loknath (70%). Sonarbangla-1 that produced the highest yield had a 68% milling outturn. The values for the percentage of head rice was found to be significantly different among the cultivars tested and ranged from 67 to 90% (Table 2). The highest proportion of head rice was found in Loknath (90%) followed by Aalok and BRRI Dhan-29 (75%), Amarsiri-1 (74%) and Sonarbangla-1 (67%).

The characteristics for chalkiness of the rice grain were termed as translucent (Tr), white belly (Wb) and white center (Wc). The check variety BRRI Dhan-29 (control) had a translucent (Tr) rice grain and all the other hybrid rice cultivars had translucent with either white belly or white center (Tr/Wb or Tr/Wc) (Table 2). The physical appearance of all the cultivars was rated good (Table 2). The length and breadth of the grain ranged from 5.3 to 6.0 mm and 1.9 to 2.4 mm, respectively (Table 2).

The highest and the lowest grain lengths were found in Amarsiri-1 (6.0 mm) and Loknath (5.3 mm), respectively. The highest and the lowest breadths were observed in Sonarbangla-1 (2.4 mm) and Amarsiri-1 (1.9 mm), respectively (Table 2). Check variety BRRI Dhan-29 (control) had grain with a moderate length and breadth. The length and breadth ratio was the highest in Amarsiri-1 (3.2) followed by Aalok (2.9), BRRI Dhan-29 (2.8), and Loaknath and Sonarbangla-1 (2.4). The size and shape of the grain of the cultivars was graded as long (L), slender (S), medium (M) and bold (B). Except for Amarsiri-1, all the cultivars including the check variety BRRI Dhan-29 (control) had a medium-bold (MB) grain (Table 2).

The alkali spreading value ranged between 3.1 and 5.4 (Table 2). The check variety (control) had the lowest value, while the highest value was observed in Loknath. Sonarbangla-1 had a moderate alkali spreading value (4.0). Amylose content was the highest (26.7%) in the check variety (BRRI Dhan-29) (control) followed by Loknath (25.3%), Aalok (23.4%), Sonarbangla-1 (22.1%) and Amarsiri-1 (21.9%). On the other hand, protein content was highest in Loknath (7.7%). The other cultivars including the check variety (control) had similar protein content and ranged between 6.7 and 6.8%.

Cooking time in all the cultivars was almost identical ranging from 19.0 to 20.5 minutes (Table 2). Both elongation ratio and imbibition ratio were parallel in all cultivars and ranged from 1.3 to 1.5 and 4.3 to 4.7, respectively. As for the cooking quality, Sonarbangla-1 was rated as hard non-sticky, Amarsiri-1 as soft sticky, Aalok as tasteless, Loknath as granular, and the check variety BRRI Dhan-29 as soft granular.

3. Production, cost and return

Production of paddy, cost of production and return of the main product and by-product are presented in Table 3. The highest (7545 kg ha^{-1}) and the lowest (4860 kg ha^{-1}) paddy production were observed in Sonarbangla-1 and Amarsiri-1, respectively. The check variety (BRRI Dhan-29) (control) had a production of 6257 kg ha^{-1}. Price of paddy (US$ kg^{-1}) was almost the same in all the hybrid rice cultivars tested and the check variety (control) and ranged from 0.1346 to 0.1356 (Table 3). Yield and price of straw for all the cultivars tested were identical (Table 3).

The gross return (US$ ha^{-1}) for Sonarbangla-1, Amarsiri-1, Aalok, Loknath and the check variety (BRRI Dhan-29) (control) were 1083.92, 693.30, 869.86, 732.64 and 896.37, respectively

Table 1. Comparison of means of different characters of four hybrid rice cultivars and a check variety (control) in Bangladesh.

Parameters/Characteristics	Sonarbangla-1 (F_1)	Amarsiri-1 (F_1)	Aalok (F_1)	Loknath (F_1)	BRRI Dhan-29 (Check variety)	CV%	LSD value	
							0.05 level	0.01level
A. Unhusked paddy yield (t ha^{-1})	7.55**	4.86**	6.06^{ns}	5.11**	6.26	18.12	0.75	1.08
B. Yield contributing characters								
1. Grains (number m^{-2})	29561^{ns}	26669^{ns}	26132*	252.34*	30619	13.74	4154.34	5992
2. 1000-grain weight (g)	28.44**	21.48^{ns}	21.08^{ns}	23.18**	21.00	5.76	0.92	1.32
3. % filled grain $panicle^{-1}$	79.10**	51.67*	58.17^{ns}	76.24**	61.66	12.36	12.38	17.85
4. % cffective tillers $hill^{-1}$	66.28^{ns}	58.49**	63.02^{ns}	60.92*	67.00	15.82	6.83	9.85
C. Field duration (days)	102**	99**	98**	93**	109	5.76	2.83	4.08
D. Other ancillary characters								
1. Plant height (cm)	95.30**	94.20**	93.30**	87.90**	97.00	1.84	1.17	1.68
2. Panicle production (number m^{-2})	292**	314^{ns}	318^{ns}	36^{ns}	339	13.74	30.00	43.28
3. Total leaves at tillering stage	86.00^{ns}	109.00^{ns}	84.00^{ns}	104.00^{ns}	93.00	14.38	16.16	23.3
4. Length of flag leaf (cm)	28.60^{ns}	27.64^{ns}	29.72*	28.58^{ns}	28.32	9.94	1.36	1.96
5. Breadth of flag leaf (cm)	1.70^{ns}	1.42^{ns}	1.47^{ns}	1.44^{ns}	1.58	14.71	0.17	0.24
6. % seedling recovery	60.50*	54.27^{ns}	68.38**	53.62^{ns}	45.53	19.73	12.74	18.38

Means of each characteristics were compared with the check variety (BRRI Dhan-29) (control) by LSD at 0.05 and 0.01 probability levels.
* and ** indicate significant differences, respectively from the check mean either positively or negatively, and ns indicates statistically non-significant.

Table 2. Comparison of physicochemical properties of four hybrid rice cultivars and a check variety (control) in Bangladesh.

Cultivar/ Variety	Milling outturn (%)	Head rice (%)	Chalkiness	Appearance	Length (L) (mm)	Breadth (B) (mm)	L/B ratio	Size and shape	Alkali spreading value	Amylose (%)	Protein (%)	Cooking time (min)	ER	IR	Cooking quality/taste
Sonarbangla-1	68	67	Tr/wb	Good	5.8	2.4	2.4	MB	4.0	22.1	6.8	20.0	1.5	4.3	Hard, non-sticky
Amarsiri-1	67	74	Tr/wc	Good	6.0	1.9	3.2	LS	4.1	21.9	6.7	19.0	1.4	4.3	Soft, sticky
Aalok	68	75	Tr/wb	Good	5.8	2.0	2.9	MB	5.3	23.4	6.7	20.0	1.4	4.4	Tasteless
Loknath	70	90	Tr/wc	Good	5.3	2.2	2.4	MB	5.4	25.3	7.7	19.5	1.4	4.4	Granular
BRRI Dhan-29 (Check variety)	65	75	Tr	Good	5.6	2.0	2.8	MB	3.1	26.7	6.8	20.5	1.3	4.7	Soft, granular

L = Long S = Slender Tr = Translucent ER = Elongation Raito
M = Medium B = Bold Wb = White belly IR = Imbibition Ratio
R = Round R = Round Wc = White centre

(Table 3). Calculation of total cost of production on the basis of full-cost and cash-cost ranged from US$ 600.13 to 617.23 and US$ 293.2 to 310.06, respectively (Table 3). The highest and the lowest cost were incurred in Sonarbangla-1 and check variety BRRI Dhan-29 (control), respectively in both calculation bases (Table 3). The other three cultivars did not vary significantly.

The benefit-cost ratio of the cultivars at full-cost ranked the highest in Sonarbangla-1 (1.76) and the lowest in Amarsiri-1 (1.14) while based on cash-cost it was the highest in the check variety (BRRI Dhan-29) (control) (3.82) and the lowest in Amarsiri-1 (2.31). Sonarbangla-1 had a 3.50 benefit-cost ratio on the cash-cost basis calculation (Table 3).

Discussion

In this paper we report a comparative study of four imported hybrid rice cultivars with a local HYV (check variety) in an actual field environment in Bangladesh. The main objective of this study was to evaluate the hybrid rice cultivars in order to facilitate generation of information to determine the feasibility of commercial exploitation of hybrid rice in a cropping system in Bangladesh.

In our study we found that the hybrid rice Sonarbangla-1 produced a more than 20% higher yield than the check variety BRRI Dhan-29 (control) (Table 1). As compared to the check variety (control), the average grains (number m^{-2}) were identical in Sonarbangla-1. Yield advantage in this hybrid rice was associated mainly with a 35% heavier grain weight and 28% increase in the proportion of filled grains per panicle over the check variety (Table 1). Furthermore, short field duration in Sonarbangla-1 was observed when compared to the check variety (control) (Table 1). Taken together, the present study revealed that Sonarbangla-1 performed best among the cultivars tested. The characteristics of Sonarbangla-1 contributing to a higher yield are identical to other recent findings (SUREKHA *et al.* 1999).

The milling outturn in Sonarbangla-1 was 68%, a 5% higher value than that of the check variety (control) (Table 2). As compared to the control, 17% lower amylose content was observed in the grain of Sonarbangla-1 hybrid rice suggesting it is a non-sticky rice (Table 2). Other physicochemical properties did not vary significantly between the hybrid rice cultivars and the check variety.

The production of the main product (paddy) and by-product (straw), cost of production, gross return and benefit-cost ratio are presented in Table 3. Higher cost of production than the control variety was observed in all the hybrid rice cultivars and Sonarbangla-1 ranked top. About 16% and 32% higher cost was associated with Sonarbangla-1 when calculated on full-cost and cash-cost basis, respectively, coinciding with a recent findings by JANAIAH *et al.* (2002). For gross return, except for Sonarbangla-1, all

Table 3. Comparison of production, cost and return of four hybrid rice cultivars and a check variety (control) in Bangladesh.

Items	Sonarbangla-1 (F_1)	Amarsiri-1 (F_1)	Aalok (F_1)	Loknath (F_1)	BRRI Dhan-29 (Check variety)
Paddy yield (kg ha^{-1})	7545	4860	6055	5107	5257
Price of paddy (US$ kg^{-1})	0.1356	0.1346	0.1356	0.1354	0.1352
Straw yield (kg ha-1)	7545	4860	6055	5107	6257
Price of straw (US$ kg^{-1})	0.008	0.008	0.008	0.008	0.008
Gross return (US$ ha^{-1})	108.92	693.3	869.86	732.64	896.37
Total cost (US$ ha^{-1})					
(i) Full-cost basis[a]	617.23	608.51	608.03	600.13	534.19
(ii) Cash-cost basis[b]	310.06	300.77	300.38	293.2	234.48
Benefit-cost ratio					
(i) Full-cost basis[a]	1.76	1.14	1.43	1.22	1.68
(ii) Cash-cost basis[b]	3.50	2.31	2.90	2.50	3.82

[a] Full-cost includes human labor, bullock power, seeds, fertilizers, insecticides, irrigation and interest on working capital.
[b] Cash-cost includes cost of seeds, fertilizers, insecticides, irrigation and interest on working capital.

other hybrid rice cultivars did not perform as well as the control variety. The gross return was the highest in Sonarbangla-1 and represented a 21% higher return than the check variety (control). Similarly, the benefit-cost ratio was the highest in Sonarbangla-1 and was ca 5% higher than the check variety (control) (Table 3). Our results are quite similar with recent findings in which the authors showed that in Bangladesh, hybrid rice production was ca 9% more profitable than that of rice HYV (JANAIAH *et al.* 2002).

Hybrid rice as an innovative technology first greatly contributed to increased rice production in China, then spread across tropical Asia in the late 1980s (JANAIAH *et al.* 2002; LIN, 1991; LIN, 1994; VIRMANI *et al.* 1998). Increasing rice yields in an irrigated environment, hybrid rice has already been shown to be a potential source. However, farmers in Bangladesh (JANAIAH *et al.* 2002) and India (JANAIAH *et al.* 2002; JANAIAH and HOSSAIN, 2000) are not willing to grow hybrid rice for more than one crop season. Although hybrid rice produces a higher yield than the existing HYVs, still it is not popular among the growers and consumers due to its poor grain quality, lower price and higher cost for hybrid seed (JANAIAH *et al.* 2002). The cost of hybrid rice seed is ca 10-15 times higher than that of HYVs. Therefore, in spite of a ca 15-20% yield advantage, rice growers are not motivated to include hybrid rice in their cropping systems.

In conclusion, our study showed that Sonarbangla-1 performed best among the hybrid rice cultivars and the local check HYV (BRRI Dhan-29) tested. We found that such performance of Sonarbangla-1 was associated with a 20% yield advantage and 21% extra monetary return over the existing HYV BRRI Dhan-29. However, success for adoption and commercialization of hybrid rice on a large-scale in Bangladesh depends on efficient and economical production and distribution of hybrid seed by the state-owned seed multiplication industry. Chinese success is a crystal clear picture in this regard.

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