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Adaptation of some cold tolerant Rice genotypes in *Haor* areas of Bangladesh

Md. Romel Biswash*[1], Md. Humayun Kabir[2], Md. Niaz Morshed[1], Mahmuda Khatun[1], Khandokar Khalid Ahmed[1], Md. Mir Mehedi Hasan[1], Afruz Zahan[2], Shamsunnaher[2], Md. Rafiqul Islam[3], Md. Atiqul Islam[4], Md. Humayun Kabir[4]

[1]*Adaptive Research Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh*
[*]*Institute of Soil Science, University of Chinese Academy of Sciences, Nanjing, China*
[2]*Senior Scientific Officer, Adaptive Research Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh*
[3]*Principal Scientific Officer, Adaptive Research Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh*
[4]*Chief Scientific Officer, Adaptive Research Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh*

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Abstract

Rice is the most important staple crops of Bangladesh. In the haor (low lying) areas of Bangladesh, early planted dry season (November–May) rice has to face cold stress at the early seedling to reproductive stages. The growers of the haor areas consider their dry season rice as a chance crop as it might encounter the flash flood at the maturity stage. Three cold tolerant advanced lines IR100722-B-B-B-B-11, IR100723-B-B-B-B-61, TP16199 along with BRRI dhan28 and BRRI dhan67 as checks were evaluated in ten locations especially haor areas in Bangladesh during the dry season 2021-22. Across the environments and genotypes, the advanced line IR100722-B-B-B-B-11 gave a slightly higher mean grains yield (4.96t/ha) than the other IR100723-B-B-B-B-61, TP16199 tested entries (4.75t/ha, 4.77t/ha) and significantly higher yield than check variety BRRI dhan67 (4.68t/ha) and BRRI dhan28 (4.09t/ha). The growth duration of the highest grains yielder IR100722-B-B-B-B-11 was 151 days. On the other hand, the mean growth duration of the other two advance lines (IR100723-B-B-B-B-61 and TP16199) was 150 and 155 days respectively which was 7-10 days higher than the two check varieties BRRI dhan28 and BRRI dhan67 (145 and 147 days). The highest number of mean grains per panicle (86) was produced by BRRI dhan67. Therefore, the three advanced lines IR100722-B-B-B-B-11, IR100723-B-B-B-B-61, and TP16199 was not suitable for the haor areas for its longer growth duration for the chance of damage by early flash flood, although it has cold tolerance ability. Among the genotypes, none of the advanced tested lines was recommended for advance stage like Proposed Variety Trial.

* **Corresponding Author:** Md. Romel Biswash ✉ romel.brri@gmail.com

Introduction

Rice (*Oryza sativa* L.), the four- letter word, isn't just the staple food; it's at the center of the overall life of Bengalis, whether it's culture, politics, or the frugality. Internationally, rice is the staple food of 3.5 billion people, which is about half the world's population. (Deepa, 2022) and for 2.11 percent of the total population in Bangladesh (World Population Prospects, 2019). Bangladesh produced 36.5 million tons of paddy in 2019 and rank third in the world for the first time that year. Bangladesh was in third place maintaining the durability of product with a product of 37.4 million tons in 2020 and 37.8 million tons in 2021 (FAO- Food Outlook- June 2022). For that reason, rice plays a significant role in the socio-economic of the country. Enhancing rice product is the key to ensuring food security. Rice security is synonymous with food security in numerous rice-growing countries like Bangladesh (Brolley, 2015), which is an important issue for determining social and political stability (Nath, 2015). In order to feed its enormous population in the coming days, Bangladesh will need to produce more food grain with its limited resources. Numerous abiotic stresses significantly lower rice output (Vij and Tyagi, 2007), posing a threat to future food security as well as to agriculture (Kumari *et al.,* 2009).

In Bangladesh 15 million hectares of rice throughout the world suffer from cold damage at one or other stages of growth (Das, 2015). Rice is a cold-sensitive plant that has its origin in tropical or subtropical areas, and cold damage can beget serious yield losses, especially when low temperatures come about during the reproductive stages (Kuroki *et al.,* 2007). Optimum temperature for rice growing is 25 to 35°C for *Indica* and 20 to 33°C for *Japonica* (Yoshida, l98l). In early vegetative stage due to cold injury of rice plants causes stunted plant growth and increased seedling mortality that eventually lead to uneven seedling stand establishment (Biswas *et al.,* 2017). Eventually low temperature could affect the experimental processes of rice plant, prejudice photosynthesis, and therefore reduce growth and affect in circular yield loss due to lower carbohydrate vacuity for grain production (Das, 2015).

Numerous other phenotypic defects are also brought on by cold stress, including delayed heading, insufficient panicle exertion, and spikelet degeneration (Shimono *et al.,* 2007; Ye *et al.,* 2009). However, spikelet sterility is the most prevalent sign of harm when rice plants are in the reproductive stage and are exposed to low temperatures (Jacobs and Pearson, 1994; Cruz *et al.,* 2006). When pollen grains are forming at the booting stage of microsporogenesis, spikelet sterility comes from pollen abortion brought on by cold injury (Mackill *et al.,* 1996). Since only the management practices cannot minimize the problem, selection of new inheritable sources of cold forbearance is veritably important to enable rice breeders to develop and grow cold-tolerant rice. Several studies have been conducted that revealed the forbearance for low-temperature stress during germination and posterior growth is controlled by a complex commerce of multiple traits (Hrudayanath *et al.,* 2013).

In the haor areas of Bangladesh, early planted dry season (November -May) rice has to face cold stress at the reproductive stages (Panicle initiation to flowering). Spikelet sterility is observed in this early planted dry season rice if the mean temperature in mid-February to mid-March prevails below 20 °C for further than 5- 6 days at the reproductive stage of the Plant (Biswas *et al.,* 2011). The growers of the haor areas consider their Boro crop as a chance crop as they might have to encounter the flash flood every many time at the maturity stage (Rashid *et al.,* 2017). Recent loss due to early flash flood in dry season 2017 at the haor area is irrecoverable. Since its commencement in 1971, the scientists in Bangladesh Rice Research Institute are giving their sweats to develop cold tolerant rice varieties.

With this view, the Plant Breeding division of Bangladesh Rice Research Institute (BRRI) has developed some Cold Tolerant Rice (CTR) genotypes. Multi-location trials are to be done for finding out the performance of the advanced lines in terms of yield, growth duration, plant height, panicle per m^2, filled grains, 1000 grains weight, sterility (%), disease and insect incidence etc.

The results of multi-location trials of promising rice lines frequently reflect differences in grain yield and other characters of rice shows is inconsistent in other locations. The main objective of this study is to find out short-duration, cold-tolerant, and high-yielding genotypes that is cold tolerant and can be harvested before a flash flood.

Materials and method

Three cold tolerant advanced lines IR100722-B-B-B-B-11, IR100723-B-B-B-B-61, TP16199 along with BRRI dhan28 and BRRI dhan67 as checks were evaluated in ten locations i.e., the BRRI Gazipur research farm (West byde) which is not belong to haor areas; Kishoreganj (Karimganj, Mithamoin, Itna, Nikli); Netrokona (Mohonganj, Modon); Habiganj (Baniachang, Ajmeriganj) and Sunamganj (Taherpur) during the dry season 2021-2022. In all the locations, trails were setups with the same RCBD design with three replications. The unit plot size for each entry was 20 m^2 (5m x 4m).

Seeding time was the 3rd week of November 2021 to the 1st week of December 2021 in different locations and seedling ages for different locations also varied from 35-40 days. Seedlings were transplanted at 20cm x 20cm spacing. Fertilizers were applied at 124: 22: 75: 20: 4 kg NPKSZn /ha. All fertilizers except urea were applied as basal and urea was applied in 3 equal splits at 15, 30, and 45 DAT. Other standard management practices were followed as and when necessary. Appropriate measures were taken to control the insect infestation and disease incidence was not controlled. Date of seeding, transplanting, flowering and maturity, plant height and yield components, lodging tolerance, insect infestation, disease incidence, and phenotypic acceptance at vegetative and ripening stages were recorded. Feedback information from farmers and DAE personnel was also recorded. For yield estimation, 10 m^2 sample area from each plot was harvested at maturity and grain yields were adjusted to 14% moisture content. Data were statistically analyzed by using statistical software Statistic 10 and R.

Results

Among the three advanced lines, IR100722-B-B-B-B-11 advanced line gave slightly higher mean grains yield (4.96t/ha) than the other two (IR100723-B-B-B-B-61, TP16199) advanced lines (4.75 and 4.77t/ha), but there was no significant differences in grain yield within the three advanced line. The advanced line IR100722-B-B-B-B-11 gave significantly higher gain yield than both the check varieties BRRI dhan67 (4.68t/ha) and BRRI dhan28 (4.09t/ha) (Table 1).

The mean grains yield of the other two advanced lines (IR100723-B-B-B-B-61, TP16199) not statistically higher than the checks variety BRRI dhan67 (4.68t/ha) but significantly higher than the other checks variety BRRI dhan28 (4.09t/ha) (Table 1). The heat map shows the significant variation in the grain yield (t/ha) with different environments among the tested genotype and the check varieties (Fig. S1). The mean growth duration of the highest means yielder advanced line IR100722-B-B-B-B-11 was 151 days.

On the other hand, the mean growth duration of the other two advanced lines (IR100723-B-B-B-B-61 and TP16199) was 150 and 155 days respectively which was 5-10 days higher than the two check varieties BRRI dhan28 and BRRI dhan67 (145 and 147 days) (Table 1). The heat map demonstrates the considerable differences in growth duration (days) between the tested genotype and the checks varieties under various environmental conditions. (Fig. S1). Plant height was significantly varied due to both the entries and environmental effects (Table 1).

Among the tested entries TP16199 advanced line was tallest (118cm) followed by the other two advanced lines IR100722-B-B-B-B-11 and IR100723-B-B-B-B-61 at 115 and 113cm. The mean plant height of the checks varieties BRRI dhan28 and BRRI dhan67 was found at 107 and 117cm. On the other hand, the mean shortest plant height was found at 88cm of BRRI dhan28 at Ajmeriganj in Habijang district (Table 1).

Number of panicles/m^2 significantly varied in all the advanced lines across the locations (Table 2). Among the advanced lines, the IR100723-B-B-B-B-61 tested line gave the highest number of panicles/m^2 (332) followed by the other two advanced lines IR100722-B-B-B-B-11 (328) and TP16199 (325).

The check variety, BRRI dhan67 gave the second highest number of panicles/m² (329) but the lowest panicles/m² was 315 which were found in the check variety BRRI dhan28.

The heat map displays the considerable difference in the number of panicles per square meter under various environmental conditions for the tested genotype and the checks varieties (Fig S2). Filled grains/panicle was varied significantly by genotype and location (Table 2). On an average, the highest number of mean grains/panicle was produced (86) by one of the check varieties BRRI dhan67.

All the three tested lines produced similar filled grains/panicle which ranged from 79-81. The lowest number of grains/panicle was obtained in BRRI dhan28 (75) size. Among all the entries, the lowest mean 1000-grain weight was found in IR100723-B-B-B-B-61 (21.3 g) followed by the other two entries (IR100722-B-B-B-B-11 and TP16199) was 21.9 and 21.7gm. The mean 1000 grain weight of the check varieties BRRI dhan28 and BRRI dhan67 was 21.8 and 21.6gm respectively (Table 2).

The lowest sterility (%) was found in check variety BRRI dhan67 (31), whereas it was 35-39 for other tested entries and check variety BRRI dhan28 (Table 2). Therefore, Pearson's correlation test shows that, there was strongly correlation between grain yield in panicle/m², filled grains/panicle & plant height but negative correlation about growth duration and sterility (%) (Fig. 1).

Disease infection (10 locations)

The tested genotype including check varieties was infected by some disease (Table 1). Neck blast incidence was found sporadically in almost all tested genotypes in Karimganj, Mithamoin, Itna, Nikli, Madan, and Mohanganj. The genotypes (IR100722-B-B-B-B-11 and IR100723-B-B-B-B-61) were more susceptible to blast disease compared to another genotype (TP16199). Brown spots (1-60%) were found in all the genotypes at Ajmeriganj and Baniachang Upazila in the Habijang district (Table 1). Grain spot (2%) was also found in the IR100723-B-B-B-B-61 genotype at Mithamoin Upazila in the Kishoreganj district. Sheath blight was also found in BRRI dhan67 (5%) at Madan Upazila in Netrokona district (Table 1).

Insect infestation

Yellow Stem borer (1-7%) was found in 07 locations (Karimganj, Mithamoin, Itna, Nikli, Madan, Mohanganj, and Taherpur) out of 10 locations (Table 2) and Rice bug (1-2%) was also found in all the genotypes at Ajmeriganj Upazila in Habijang district (Table 2).

Lodging incidence

All the tested genotypes including checks were highly susceptible to lodging. All the tested genotypes and checks were lodged (10-100%) in 7 to 9 locations except BRRI Gazipur (WB) at the milking to ripening stage (Table 2). That's why the number of unfilled grains and sterility percentage were higher in this experiment.

Phenotypic acceptance

The best phenotypic acceptance was found in Check variety BRRI dhan67. Attractive plant growth, uniform flowering, and maturity, well wrapped with culm, erect flag leaf, and medium slender grain was found in BRRI dhan67. Phenotypic acceptance of all the tested genotypes ranged from 3-5 in vegetative and 5-7 in reproductive stage (Table 2).

On the other hand, phenotypic acceptance of the tested genotype was not attractive to the farmers due to uneven plant growth and irregular flowering, lodging tendency, and also higher growth duration. The phenotypic acceptance of the other two check varieties BRRI dhan28 and BRRI dhan67 was good and attractive (Table 2).

Preference of Farmer

Farmers didn't prefer any of the advanced lines compared to the check varieties BRRI dhan28 and BRRI dhan67.

Table 1. The grain yield (t/ha), growth duration (days) and plant height (cm) of the three advanced lines with two checks varieties under ALART (CTR) in dry season 2021-2022.

Genotypes	Locations										
	Ajmeriganj	Baniachang	Itna	Nikli	Mithamoin	Mohonganj	Modon	Karimganj	Taherpur	Gazipur (WB)	Mean
Grain yield (t ha^{-1})											
IR100722-B-B-B-B-11	5.26	4.70	3.97	4.15	5.43	4.84	5.84	5.59	3.24	6.60	4.96
IR100723-B-B-B-B-61	4.18	4.95	3.70	3.72	6.24	4.24	5.21	5.67	3.76	5.82	4.75
TP16199	4.43	5.50	3.83	3.71	5.21	5.10	5.93	5.72	2.13	6.11	4.77
BRRI dhan28(Ck)	3.69	4.74	2.84	2.75	4.09	3.46	5.01	5.44	2.93	5.94	4.09
BRRI dhan67(Ck)	5.08	5.02	3.69	4.04	4.90	3.53	5.96	5.49	3.09	6.05	4.68
$LSD_{0.05}$						0.67					0.21
CV						8.80					
Growth duration (days)											
IR100722-B-B-B-B-11	155	151	147	147	147	151	146	147	164	151	151
IR100723-B-B-B-B-61	153	150	150	149	145	148	144	145	163	151	150
TP16199	158	158	155	152	149	156	151	149	164	159	155
BRRI dhan28(Ck)	150	146	143	141	145	146	140	141	156	146	145
BRRI dhan67(Ck)	149	150	145	143	143	147	145	143	158	148	147
$LSD_{0.05}$						NS					NS
CV											
Plant height (cm)											
IR100722-B-B-B-B-11	108	114	117	120	122	111	112	120	106	117	115
IR100723-B-B-B-B-61	100	108	113	116	122	112	116	124	108	114	113
TP16199	109	110	121	119	121	125	121	124	117	116	118
BRRI dhan28(Ck)	88	104	118	115	107	108	109	105	100	117	107
BRRI dhan67(Ck)	108	121	115	115	123	113	119	122	115	122	117
$LSD_{0.05}$						5.28					1.67
CV						2.86					

Table 2. Different yield contributing parameters of the three advanced lines with two checks varieties under ALART (CTR) in dry season 2021-2022.

Genotypes	Locations										
	Ajmeriganj	Baniachang	Itna	Nikli	Mithamoin	Mohonganj	Modon	Karimganj	Taherpur	Gazipur (WB)	Mean
Panicles m^{-2} (no.)											
IR100722-B-B-B-B-11	323	324	303	296	339	342	417	318	311	311	328
IR100723-B-B-B-B-61	327	329	306	290	384	311	369	352	329	321	332
TP16199	307	315	295	270	314	392	471	345	296	347	325
BRRI dhan28(Ck)	328	353	248	259	338.3	316	408	271	270	357	315
BRRI dhan67(Ck)	341	327	276	358	290	325	434	273	325	344	329
$LSD_{0.05}$	38.88										12.3
CV	7.33										
Filled grains panicle^{-1} (no.)											
IR100722-B-B-B-B-11	69	87	88	85	72	75	94	90	44	87	79
IR100723-B-B-B-B-61	61	88	85	77	92	64	87	99	53	93	80
TP16199	62	103	79	76	62	95	98	109	41	83	81
BRRI dhan28(Ck)	54	89	74	59	76	61	85	91	56	104	75
BRRI dhan67(Ck)	91	105	84	81	77	75	98	87	77	87	86
$LSD_{0.05}$	17.40										5.60
CV	13.60										
1000-grain weight (gm)											
IR100722-B-B-B-B-11	23.2	22.6	23.6	23.9	18.9	19.1	19.4	21.7	23.7	23.2	21.9
IR100723-B-B-B-B-61	22.1	23.3	20.9	22.0	22.0	19.8	18.6	20.6	21.9	21.6	21.3

Genotypes	Locations										
	Ajmeriganj	Baniachang	Itna	Nikli	Mithamoin	Mohonganj	Modon	Karimganj	Taherpur	Gazipur (WB)	Mean
TP16199	20.9	23.6	24.1	23.5	20.6	19.7	20.7	20.4	19.9	23.7	21.7
BRRI dhan28(Ck)	22.3	21.7	22.9	21.6	21.8	21.2	20.9	22.5	21.3	21.6	21.8
BRRI dhan67(Ck)	21.0	24.8	21.3	23.0	19.0	21.4	21.0	20.9	20.2	23.9	21.6
$LSD_{0.05}$	2.46										0.77
CV	6.91										
Sterility (%)											
IR100722-B-B-B-B-11	34	24	36	40	32	42	30	27	55	32	35
IR100723-B-B-B-B-61	38	35	37	47	21	47	33	23	60	33	38
TP16199	45	30	41	40	39	31	26	24	70	49	39
BRRI dhan28(Ck)	44	20	40	43	34	51	38	22	60	30	38
BRRI dhan67(Ck)	26	31	31	36	26	41	25	27	42	28	31
$LSD_{0.05}$						8.94					2.82
CV						15.19					

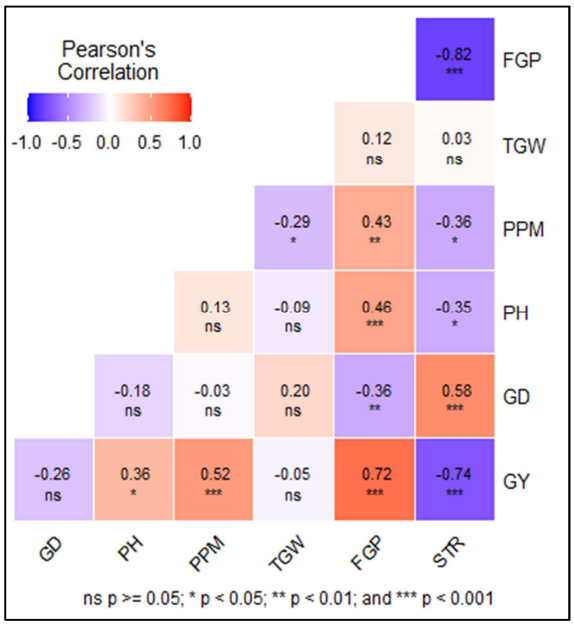

Fig. 1. Pearson's correlation test shows the correlation between the different yield contributing components with grains yield (t/ha). In there, grains yield (t/ha) was a strong correlation with the number of panicle/m², filled grains/panicle, and plant height. Grains yield (t/ha) also shows a negative correlation with growth duration and sterility (%).

Discussion

The interaction effect of genotypes and environments (location) was highly significant between grain yield in panicle/m², filled grains/panicle & plant height but negative correlation about growth duration and sterility (%). Across the locations, advanced line IR100722-B-B-B-B-11 gave significantly higher gain yield (4.96t/ha) than both the check varieties BRRI dhan67 (4.68t/ha) and BRRI dhan28 (4.09t/ha). The other two advanced lines (IR100723-B-B-B-B-61, TP16199) did not produced significantly higher grains yield than check variety BRRI dhan67 (4.68t/ha) but produced statistically higher grain yield than other check variety BRRI dhan28 (4.09t/ha). The highest grain yield (6.60t ha^{-1}) was found in IR100722-B-B-B-B-11 advanced line at BRRI Gazipur (WB)which is not belong to haor areas followed by another advanced line TP16199 (6.11t ha-1) at BRRI Gazipur (WB) (Table 1). BRRI dhan28 and BRRI dhan67 gave (5.94t ha-1) and (6.05t ha-1) at BRRI Gazipur (WB) respectively. The lowest grain yield was found in TP16199 (2.13t ha-1) advanced line at Sunamganj (Taherpur). Out of tens locations, the grain yield of a few locations such as Itna, Nikli in Kishoreganj district, and Taherpur in Sunamganj districts was comparatively lower than other locations.

Because the ALART experiment was severely inundated by the flash flood in several times. Growth durations were not significantly varied among the entries due to environmental effects (Table 1 and Fig. 1). Out of three advanced lines, IR100723-B-B-B-B-61 was found to be the lowest growth duration (144 days) at Modon in Netrokona district (Table 1). The highest growth duration was found in all the advanced lines and checks variety in Taherpur upazila at Sunamganj districts (Table 1). The ALART (CTR) experiment across the different locations in the

country was flooded several times after the milking to ripening stage. That's why, the experimental plot in many places was completely lodged, and as a result, a higher rate of infertility happened. The main purpose of this ALART (CTR) is to recommend a cold tolerant rice advanced line that would be more suitable for hoar areas. In this trial, the advanced line (IR100722-B-B-B-B-11) produced a slightly higher grain yield than the other advanced lines (IR100723-B-B-B-B-61, TP16199) and check the varieties BRRI dhan28 and BRRI dhan67.

The yield contributing components of the IR100722-B-B-B-B-11 advanced line such as panicle per/m^2 and 1000 grains weight were almost similar to the checks varieties. That reason IR100722-B-B-B-B-11 advanced line gave slightly higher grains yield but the growth duration was 4-6 days higher than the checks varieties and also the number of filled grains per panicle was lower than the checks variety BRRI dhan67. Not only that, the sterility percentage of the tested lines IR100722-B-B-B-B-11 was higher than the checks variety BRRI dhan67 but lower than other checks variety BRRI dhan28.Recently, BRRI invent the BRRI dhan69, it was a dry season variety in Bangladesh, and this variety had a moderate level of cold tolerance both at the seedling and reproductive stages (Rashid and Yasmeen, 2017).

In contrast to BRRI dhan28, it grows for a week longer. However, there will still be a danger of an early flash flood due to its longer growth duration (Rashid and Yasmeen, 2017). The mean growth duration of the three advance lines was 5-10 days higher than the check varieties which may not be suitable for haor areas. That has a chance of an early flash flood due to its longer growth duration.

Although the tested genotypes were not attractive to the farmers due to their poor phenotypic acceptance, higher pest, and disease infestation, highly lodging susceptibility, and some physiological changes which were found on the leaves due to the cold effect on the vegetative stage. Based on the results, and farmer's perspective, none of the entries was recommended for PVT.

Conclusion

Out of the three advanced lines, the IR100722-B-B-B-B-11 gave slightly higher grains yield (4.96t/ha) than the other two advanced lines IR100723-B-B-B-B-61 (4.75t/ha), TP16199 (4.77t/ha) and but there is no significant differences among the three advanced line. Although IR100722-B-B-B-B-11 tested line gave the highest yield but growth duration was 4-6 days higher than the checks varieties (Table 1). The yield contributing parameters of the IR100722-B-B-B-B-11 tested line such as panicle per/m^2 and 1000 grains weight were almost similar to the checks varieties but the number of filled grains per panicle was lower than the checks variety BRRI dhan67. Not only that, the sterility percentage of the tested lines IR100722-B-B-B-B-11 was higher than the checks variety BRRI dhan67 but lower than other checks variety BRRI dhan28 (Table 2). That seems the tested line IR100722-B-B-B-B-11 was affected by the cold. Dry season rice in the haor regions of Bangladesh usually matures from the last week of April to the 3rd week of May. During the experimental time in haor reason, flash-floods were initiated before rice harvesting. That's the reason all the genotypes including checks varieties were almost (10-100%) lodged except BRRI Gazipur (WB). Although, the tested genotypes were not attractive to the farmers due to their poor phenotypic acceptance, higher pest, and disease infestation, sterility (%), and some physiological changes which were found on the leaves due to the cold effect on the vegetative stage. Based on results and the farmer's perspective, none of the advanced lines could be recommended as Cold tolerant (CTR) high-yielding rice variety through a national variety release system like the proposed variety trial (PVT).

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Conflicts of Interest

The authors declare no conflict of interest.

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