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BIOPHYSICAL FACTORS DEFINING RICE YIELD GAPS IN BANGLADESH

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Abstract

An investigation was carried out with a view to determine the causes for low productivity as well as profitability at farmer's field level. The study was carried out at three upazila of Tangail district of Bangladesh in both T. Aman (rainfed lowland) and Boro season (irrigated lowland) considering two popular Bangladesh Rice Research Institute (BRRI) released varieties: BRRI dhan49 and BRRI dhan28, respectively. Standard BRRI recommended practices were applied in one part of the plot called as BRRI managed plot while usual farmer's practices were applied in other part called farmer's managed plot. The yield contributing characters such as number of total and productive tillers, grains per square meter, grain and straw yield showed significant response irrespective of management, location and year. BRRI dhan49 of BRRI managed plot produced significantly higher yield (5.25 t/ha) than farmer's treated plot (4.72 t/ha) in T. Aman season. Again, among the three locations, plots of Basail and Shakipur upazila produced statistically similar yield (5.21 and 5.20 t/ha, respectively) but significantly higher than Kalihati upazila (5.0 t/ha). Again, significant yield variation was observed between the years of cultivation due to the weather factors response. In case of Boro season, BRRI managed BRRI dhan28 produced significantly higher yield (5.29 t/ha). Location and year were also affected on yield and yield contributing characters. A total of 10.1% yield advantage was gained through BRRI management in T. Aman season while 14.95% yield advantage was obtained in Boro season. Again, Boro rice cultivation was more profitable than aman due to higher yield advantages, though irrigation cost is comparatively higher in Boro season. In case of farmer's income, 30.06% income was increased in Boro season compared to farmers practice and it became 24.21% in aman season. Finally, this study concluded that biophysical factors such as proper input application with quality management practices may reduce yield gap between researchers and farmers managed plot in Bangladesh.

Key word: Rice (*Oryza sativa*), yield gap, biophysical factors.

Introduction

Rice is a staple food and accounts more than 40% of the calorie supply of most Asians (IRRI, 2008). About 90% of the world's rice is grown and produced (142 million ha area with production of 622 million tons) in Asia (FAO, 2010). Like in many other Asian countries, rice is also the staple food in Bangladesh and it contributes one-half of the agricultural GDP and 55% of the total labor employment (Bangladesh Economic Review, 2009). However, because of the continuous increase in population growth, rice demand in 2050 is projected to be 56% higher than in 2001 (Mukherjee et al., 2011). The productivity and sustainability of rice-based cropping systems are threatened because of (i) the inefficient use of agricultural inputs (fertilizer, water and labor); (ii) increasing scarcity of water and labor; (iii) changing climatic factors; (iv) emerging energy crisis and rising fuel prices; (v) emerging socioeconomic changes such as urbanization, migration of labor, and preference for nonagricultural work (Ladha et al., 2009). In addition, recent increases in the prices of farm inputs in relation to outputs, fewer off-farm work opportunities for supplementing farm income, reduced remittances from relatives working outside villages, and declining income and purchasing owner of poor consumers have threatened the existence of rice producers and consumers (Ladha et al., 2003).

Bangladesh produced about 50.1 million tons of rough rice from 11.7 m ha of land in 2010 with a productivity of 4.3 t ha^{-1} (FAO, 2012). The present productivity is far below the attainable yield of 8–10 t ha^{-1} in the dry season (Boro) and 5–6 t ha^{-1} in the wet season (Transplanted Aman) in farmers' field experiments (BRRI 2007, 2008, 2009, 2010). This difference in yield in farmers' fields between farmer-managed and researcher-managed trials is mainly due to the differences in management practices adapted by researchers and farmers. The causes of such a yield gap are classified into two broad categories: (i) biotic factors such as poor-quality seeds and seedlings, insects, diseases, weeds, and rodents; (ii) abiotic factors such as soil, nutrients, and water. However, a large portion of this yield gap remains unexplained. Bangladesh is under tremendous pressure to increase rice production due to its increasing population along with scarcity of land, water, labor, and energy. An adequate understanding and the development of appropriate practical technologies to minimize the causes of the yield gap are critical for meeting the challenges of continued gains in rice production, with-out degrading the natural resource base. Minimizing the yield gap and increasing profit and product quality are becoming increasingly difficult to achieve by using a single-technology-centric approach. Depending on the demand and profitability of new technologies, farmers generally integrate new technology with the cultural practices being practiced by them on their farms. This study therefore evaluated a set of selected best management practices along with the farmers' management techniques in rice production for determining causes of low productivity and profitability at farmers' fields. As well as, to determine the factors affecting behind yield gap between researchers and farmers managed plot in Bangladesh.

Materials and Methods

The study was carried out in three upazilla of Tangail district namely Basail, Shakipur and Kalihati to evaluate a set of selected best management practices along with the farmers' management techniques to find out the reasons of low yield of rice at farmer's level. Trials were conducted at both T. Aman (rainfed lowland) and Boro (irrigated lowland) season in the two successive years (2012 and 2013). In each season, a total of three trails were carried out with the financial assistance of "Minimizing Rice Yield Gap" project fully funded by Government of Republic of Bangladesh. A total of 12 trails carried out with in this stipulated period. Popular BRRI released variety BRRI dhan49 was selected as test variety in T. Aman season and BRRI dhan28, one of the most popular mega variety for Boro season was selected as test variety for the experiment. In each season foundation seed was used for ensuring good seed source as well as prevention of varietals' admixture for all the trails. In each trail, three bighas of land (4014 decimal) was selected at farmer's level.

The whole experimental area was divided into two parts: standard BRRI recommended practices were applied in one part of the plot called as BRRI managed plot while usual farmer's practices were applied in other part called farmer's managed plot. In case of BRRI management, 30 and 45 day old seedlings were transplanted in T. Aman and Boro season, respectively. In each of the cases, standard spacing of 20×20 cm was practiced during transplanting. Standard BRRI recommendation for fertilizer application was carried out along with other agronomic practices (done as and when necessary) in BRRI managed plot while farmers followed their own cultivation protocol. In Both cases foundation seed (produced by BADC, Bangladesh) of respective variety was used in every season. Fertilizer management (Urea: TSP: MoP: Gypsum: $ZnSO_4$) for both T. Aman and Boro season were 149: 52.3: 82.2: 60: 7.5 and 260: 97.11: 119.52: 112.05: 11.21 kg/ha, respectively (BRRI 2013). However, in case of farmer's management farmer's usually used Urea: TSP: MoP: Gypsum: $ZnSO_4$ for both T. Aman and Boro season @ 175: 30: 28: 4: 0 and 280: 60: 55: 70: 07 kg/ha, respectively. Proper care was taken regarding disease and pest infestation. Data of yield components along with some other characteristics were taken when the crop achieved 80% maturity. Then the data were transferred to worksheet of MS Excel (Microsoft Office 2007) and necessary statistical analysis was done using Crop Stat software.

Results and discussion

Number of tillers per m^2

In case of T. aman season, BRRI dhan49 OF BRRI managed plot produced higher number of tillers per m^2 (381) than farmer's managed plot (377) (Table 1). Again, among the three locations, trials of Basail upazila produced significantly highest number of tillers per m^2 (386) than Shakipur (374) and Kalihati (366) upazila, respectively. Tiller number was significantly increased in the second year (396) than first year of trials. While BRRI dhan28 of BRRI managed plot produced significantly higher number of tillers per m^2 irrespective of year and locations in Boro season. BRRI managed plot produced highest number of tillers (418) than farmer's managed plot (395). Out of three locations; Basail upazila of Tangail district produced significantly highest number of tillers per m^2 (423) than other two upazilas of the same district (Table 2). This may be happened due to genetic potentiality of the variety and micro environmental variation among the locations. The similar observations were found by Hossain (2007), Mannan (2005) and Roy et al. (2004) who explained that significant variation was observed due to tillering ability of a particular variety which is dependent on both genetic potentialities as well as microenvironment.

Number of productive tillers per m^2

A positive trend was observed in the number of productive tillers for both BRRI dhan49 and BRRI dhan28 irrespective of both treatment and year. In case of T. aman season, BRRI managed plot produced significantly higher number of productive tillers per m^2 (377) than farmer's managed plot (348) and significantly higher number of productive tillers (344) was produced in the second year (Table 1). No significant variation was observed in productive tiller number in between locations. Again in Boro season, BRRI dhan28 of BRRI managed plot produced significantly higher number of productive tillers per m^2 irrespective of management, locations and year (Table 2). Highest numbers of productive tillers (374) were observed in BRRI managed plot while farmer's managed plot produced only 344 productive tillers. Among the three locations, Basail upazila produced significantly highest number of productive tillers (383) per m^2 than other two upazilla. These results had an agreement with Mannan (2005) and Roy et al. (2004) who reported that the panicle production depends on the genetic potentiality of the variety and the origin of land productivity.

Number of grains per m^2

In case of T. aman season, BRRI dhan49 of BRRI managed plot produced significantly higher number of grains per m^2 (224767) than farmer's treated plot (22659) (Table 1). Again, among the three locations, Basail upazila of Tangail district produced significantly highest number of grains per m^2 (24100) than Shakipur (24020) and Kalihati (23018) upazila, respectively. Significant numbers of higher grains (24213) were produced in the second year than the starting period. In case of Boro season, BRRI dhan28 of BRRI managed plot produced significantly higher number of grains per m^2 (20349) than farmer's managed plot (Table 2). Among the three locations, Basail upazila of Tangail district produced significantly highest number of grains per m^2 (21851) than other two upazilla. Again, significant numbers of higher grains (20906) were observed in the second year. Varietal variation in grains per m^2 was also reported by Hossain and Islam (1986), Hussain *et al.* (2003) and Ali *et al.* (1992) also reported that grains per m^2 was varied due to fertilizer as well as cultural management practices.

Grain yield

BRRI managed plot of BRRI dhan49 produced significantly higher yield of 5.25 t/ha than farmer's treated plot (4.72 t/ha) in T. Aman season (Table 1). Again, among the three locations, Basail and Shakipur upazila of Tangail district produced statistically similar yield (5.21 and 5.20 t/ha) but significantly higher than Kalihati (5.00 t/ha) upazila. Again, significant yield variation was observed in the second year (5.41 t/ha) than the initial year due to seasonal variation. Irrespective of management, location, and season, BRRI dhan49 produced highest yield of 5.87 t/ha while lowest yield was recorded as 4.16 t/ha. In case of Boro season, BRRI managed plot of BRRI dhan28 produced significantly higher yield of 5.82 t/ha than farmer's managed plot (4.95 t/ha) (Table 2). Among the locations, significantly highest yield (5.42 t/ha) was obtained at Basail upazila while Shakipur and Kalihati upazila produced statistically similar yields (5.04 and 4.89 t/ha, respectively). Again significantly higher yield (5.44) was obtained in the second year than starting period. Irrespective of management, location and season, highest yield of 6.12 t/ha was obtained for BRRI dhan28. Other studies in India and Bangladesh rice fields also reported comparatively higher yields in the range 0.8–2.0 Mg ha^{-1} with the use of improved methods of more than one crop production factor in an integrated way (Regmi et al., 2009; Alam and Mondal (2003).

Straw Yield

In case of T. aman season, BRRI managed BRRI dhan49 produced significantly higher straw yield of 6.48 t/ha than farmer's treated plot (6.04 t/ha) (Table 1). Again, among the three locations, Kalihati upazila of Tangail district produced significantly higher straw yield (6.53 t/ha) than Basail and Shakipur upazila. Year had no significant effect on the straw yield. Irrespective of location, year and management, highest straw yield was obtained as 6.57 t/ha while lowest yield was obtained as 5.77 t/ha. In case of Boro season, farmer's managed plot of BRRI dhan28 produced straw yield of 6.27 t/ha which was at par with BRRI managed plot (Table 2). Among the locations, Basail and Shakipur upazila produced statistically similar straw yield (6.38 and 6.29 t/ha, respectively) but significantly higher from Kalihati upazila (6.13 t/ha). Irrespective of location, year and management, highest straw yield was obtained as 6.47 t/ha while lowest was obtained as 6.01 t/ha. This result was supported by Hossain (2007), Mannan (2005) and BRRI 2010). They reported that the genetical character is its inherent productivity capacity and the straw yield varied significantly due to variety differences.

Harvest index (%)

BRRI managed BRRI dhan49 gave significantly higher harvest index (46.13) than farmer's treated plot (43.84) in T. Aman season (Table 1). Among the three locations, Basail and Shakipur produced statistically similar harvest index (45.97 & 45.76 t/ha, respectively) while Kalihati gave comparatively lower harvest index (43.23). Significant variation in harvest index was observed in different year also while highest harvest index was observed (46.31) in second year. Irrespective of management, location and year, highest harvest index was obtained as 47.86 while lowest was obtained as 38.79. In case of Boro season, BRRI managed BRRI dhan28 gave significantly higher harvest index (45.63) than farmer's treated plot (43.99) in Boro season (Table 2). Among the three locations, Basail upazila produced significantly higher harvest index (45.78) than other two upazilla. Again, highest harvest index of 46.58 was observed in the second year due to seasonal variation. Irrespective of management, location and year, highest harvest index was obtained as 47.20 while lowest was obtained as 43.06.

Table 1. Effect of different treatments on yield and yield contributing characters of BRRI dhan49

Treatments	Tiller No.	Productive tillers	grains m-^{2}	Grain yield(t/ha)	Straw yield (t/ha)	Harvest index (%)
Management effect						
BRRI Rec. (M1)	381	377	24767	5.25	6.48	46.13
FP (M2)	377	348	22659	4.72	6.04	43.84
SE	2.82	2.82	62.6	0.05	0.05	0.32
LSD 0.05	8.69	8.7	192.9	0.16	0.18	1.00
Location effect						
Basail (L1)	386	327	24100	5.21	6.10	45.97
Sakipur (L2)	374	327	24020	5.20	6.14	45.76
Kalihati (L3)	366	326	23018	5.00	6.54	45.23
SE	3.46	3.22	76.68	0.06	0.07	0.40
LSD 0.05	10.65	9.93	236.27	0.19	0.22	1.24
Seasonal variation						
Year 1 (Y1)	362	309	23212	4.86	6.25	43.66
Year 2 (Y2)	396	344	24213	5.41	6.28	46.32
SE	2.82	2.63	62.61	0.05	0.06	0.33
LSD 0.05	8.69	8.11	192.91	0.16	0.18	1.01
Interaction effect						
Y1L1M1	389	343	24378	5.49	6.36	46.28
Y1L1M2	363	286	22882	4.62	5.82	44.19
Y1L2M1	350	326	24629	5.26	6.46	44.87
Y1L2M2	352	281	22085	4.38	5.77	43.07
Y1L3 M1	360	332	23897	5.25	6.49	44.72
Y1L3M2	355	289	21402	4.16	6.57	38.79
Y2L1M1	393	353	25643	5.76	6.46	47.86
Y2L1M2	402	327	23499	5.87	5.78	46.22
Y2L2M1	399	373	25166	4.83	6.55	47.23
Y2L2M2	394	327	24199	5.29	5.77	47.15
Y2L3M1	394	359	24887	5.69	6.54	46.50
Y2L3M2	395	325	21887	4.91	6.54	42.90
SE	6.91	6.44	153.35	0.12	0.14	0.80
LSD 0.05	21.30	19.85	472.54	0.39	0.14	2.47

SE= Standard error, LSD= Least significance difference at 5% level

Economic productivity

A partial budgeting was done for both T. Aman and Boro season. An average gross margin of 16795.92 taka (per ha.) achieved in BRRI managed plot while farmer's managed plot gave 12730.00 taka in T. Aman season which leads to 24.21% income increased over farmer's practice. Again, a total of 16255 taka gross margin gained at BRRI managed plot in Boro season while famer's practice gained 11368 taka gross margin. Here, a substantial amount i.e. 30.06% income increased in BRRI managed plot than farmer's management (Table 3).

Minimized yield gap

A clear picture of increased yield under BRRI recommendation plot was observed throughout investigation period. A total of 10.10% yield advantage was gained through BRRI management in T. Aman season while 14.95% yield advantage was obtained in Boro season (Fig. 1 & Fig. 2). Again, Boro rice cultivation was more profitable than aman crop though irrigation cost is comparatively higher in Boro season because 30.06% income increased in Boro season compared to farmers practice and it become 24.21% in aman season (Table 3). This yield advantage was obtained due to judicious application of different fertilizers in right time, transplanting of proper aged seedling, timely operation of other intercultural activities, extra care against different biotic and abiotic stress especially supplement irrigation in T. Aman season. Possibly, these are the reasons behind the yield gaps between researchers and farmers managed plot.

Table 2. Effect of different treatments on yield and yield contributing characters of BRRI dhan28

Treatments	Tiller No.	Productive Tillers	grains m-2	Grain yield(t/ha)	Straw yield (t/ha)	Harvest index (%)
Management effect						
BRRI Rec. (M1)	418	374	20349	5.82	6.26	45.62
FP (M2)	396	344	19795	4.95	6.27	43.99
SE	1.59	0.58	144.3	0.01	0.01	0.19
LSD 0.05	4.91	1.78	444.65	0.13	0.02	0.61
Location effect						
Basail (L1)	423	383	21851	5.42	6.38	45.78
Shakipur (L2)	404	354	20124	5.04	6.29	44.36
Kalihati (L3)	393	340	18239	4.89	6.13	44.26
SE	1.95	0.70	176.73	0.05	0.08	0.24
LSD 0.05	6.02	2.17	544.59	0.15	0.26	0.74
Seasonal variation						
Year 1 (Y1)	391	346	19237	4.79	6.22	46.58
Year 2 (Y2)	423	373	20906	5.44	6.31	43.03
SE	1.59	0.57	144.306	0.041	0.01	0.20
LSD 0.05	4.92	1.78	444.66	0.129	0.02	0.61
Interaction effect						
Y1L1M1	424	386	20762	6.12	6.23	46.52
Y1L1M2	385	350	21019	5.26	6.47	44.78
Y1L2M1	459	425	23884	5.3	6.43	45.06
Y1L2M2	424	370	21740	4.97	6.37	43.06
Y1L3 M1	391	351	19516	5.67	6.17	44.86
Y1L3M2	384	327	19401	5.06	6.27	46.67
Y2L1M1	433	383	20141	4.38	6.23	47.20
Y2L1M2	407	354	21439	5.05	6.47	43.73
Y2L2M1	389	339	16978	5.45	6.13	47.05
Y2L2M2	373	317	17744	5.06	6.04	45.61
Y2L3M1	411	355	17487	4.79	6.33	44.30
Y2L3M2	399	346	20749	4.26	6.01	44.39
SE	3.91	1.41	353.47	0.10	0.01	0.48
LSD 0.05	12.05	4.35	1089.18	0.31	0.05	1.49

SE= Standard error, LSD= Least significance difference at 5% level

Table 03. Economic profitability of different treatments irrespective of different location and year

Treatment	Total income (TK/ha)			Total expense (TK/ha)	Gross margin (TK/ha)	% Income increased over FP
	Rice Yield (t/ha)	Straw Yield (t/ha)	Income (tk/ha)			
			Aman			
BRRI Rec.	5.25	6.48	90480	73684	16795.92	24.21
FP	4.72	6.04	81560	68830	12730.00	
			Boro			
BRRI Rec.	5.82	6.26	113020	96765	16255	30.06
FP	4.95	6.27	101725	90357	11368	

In case of aman season, rice price=16 tk/kg while in boro season rice price=18 tk/kg and straw price is always 01 tk/kg. All the expenses of variable cost combined as total expense and express in tk value.

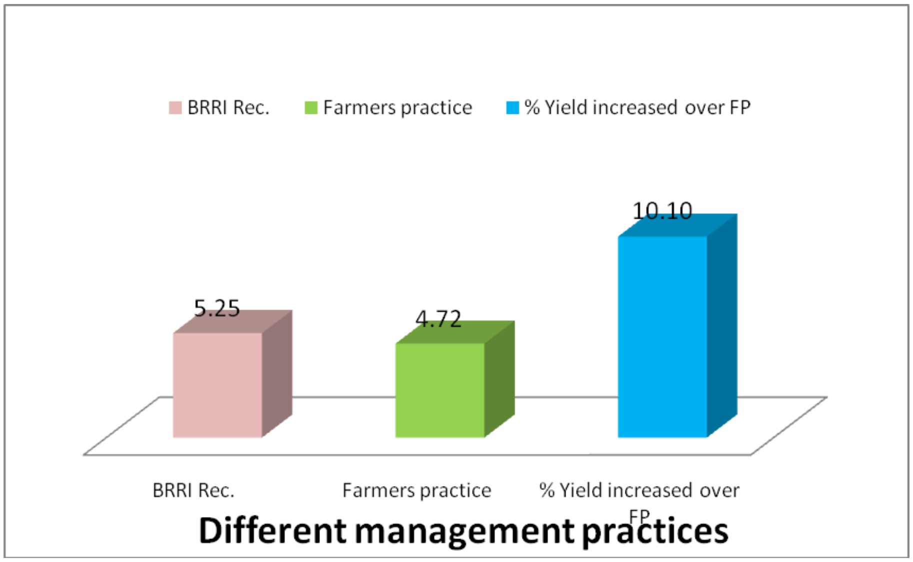

Fig.1. Yield performance of BRRI dhan49 under different management practices

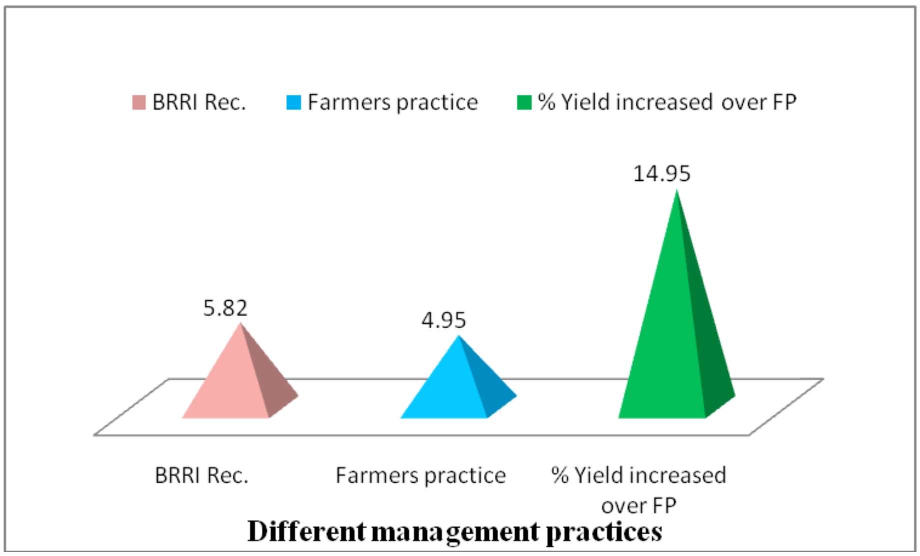

Fig.2. Yield performance of BRRI dhan28 under different management practices

Conclusion

The yield and yield contributing characters of the studied varieties varied significant with the variation of management, location and year. Both of the varieties (BRRI dhan49 and BRRI dhan28) in BRRI managed plot produced significantly higher yield. Again, among the three locations, plots of Basail and Shakipur upazila produced statistically similar yield (5.21 and 5.20 t/ha, respectively) but significantly higher than Kalihati upazila (5.0 t/ha). Again, significant yield variation was observed between the years of cultivation due to the weather factors response. A total of 10.1% yield advantage was gained through BRRI management in T. Aman season while 14.95% yield advantage was obtained in Boro season. Again, Boro rice cultivation was more profitable than aman due to higher yield advantages, though irrigation cost is comparatively higher in Boro season. In case of farmer's income, 30.06% income was increased in Boro season compared to farmers practice and it became 24.21% in aman season. Finally, this study concluded that biophysical factors such as proper input application with quality management practices may reduce yield gap between researchers and farmers managed plot in Bangladesh.

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