Bangladesh Rice J. 19(2): 37-46, 2015

Increasing Crop Diversity and Productivity of Rice (*Oryza sativa* L.)-Wheat (*Triticum aestivum* L.) Cropping System through Bed Planting

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ABSTRACT

Adoptions of new crop establishment methods, changing management practices and inclusion of new crops in the rice-wheat cropping system are very important for maintaining and increasing system productivity. Experiments were conducted at the Bangladesh Rice Research Institute, Gazipur and farmers' fields in Chuadanga during 2002-03 to evaluate the performances of rice, wheat and mungbean in bed planting and to evaluate the system productivity of Rice-Wheat-Mungbean cropping pattern. Wheat-Mungbean-Direct seeded rice (DSR), Wheat-Mungbean-Transplant rice (TPR), Wheat-Fallow-DSR and Wheat-Fallow-TPR cropping system under bed planting and conventional methods were evaluated. Grain yields of wheat, mungbean, rice and rice equivalent yield (REY) under bed planting were significantly higher (25.41, 40.91, 13.00 and 21.12%, respectively) than the conventional method. The Wheat-Mungbean-Rice cropping pattern produced significantly greater REY (38.25%) than Wheat-Fallow-Rice cropping pattern. Total variable cost was lower (17.33%) in bed planting than conventional method. Gross return, gross margin and benefit-cost ratio of Wheat-Mungbean-Rice cropping system in bed planting were higher (14.43, 40.99 and 38.52%, respectively) than the conventional method.

Key words: Bed planting, rice-wheat cropping system

INTRODUCTION

Rice and wheat are grown in sequence on the same land in the same year over 26 million ha of South and East Asia to meet the food demand of rapidly expanding human population (Timsina and Connor, 2001). South Asian countries, Bangladesh, India, Nepal and Pakistan with a geographical area of 401.72 million ha, hold nearly half of the world population of 3.1 billion (Timsina and Connor, 2001). Nearly 60% of the farming households live on less than 30% of global agricultural lands (Gupta *et al.*, 2003a) and approximately 240 million people in South Asia consume rice and/or wheat produced in rice-wheat system (Benites, 2001). Moreover, the annual productivity of the rice-wheat system in the Indo-Gangetic Plain is lower (5-7 t ha^{-1}) compared with currently attainable (8-10 t ha^{-1}) and site potential (12-19 t ha^{-1}) yields (Aggarwal *et al.*, 2000).

The continuous cultivation of two crops or more per year including rice and wheat has provided food and livelihoods for millions of rural and urban poor in South Asia. Now a crisis looms as the population is growing at more than 2% (nearly 24 millions additional mouth to feed) each year and agricultural land area dwindles and yield increase are leveling off (Hobbs, 2003). Increasing food production of this area in the next 20 years to match population growth is challenging. It is made even more difficult because, land area devoted to agriculture will be stagnated or declined and better quality land and water resources is expected to be diverted to other sector of the national economy. In order to grow more food from marginal and good quality lands, the quality of natural resource base must be improved and sustained. Efficiency of natural resources like, seed, water, fuel and labour require to be improved. Development of resource conservation technologies is essential since they provide one of the few ways to achieve the above goals.

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To meet up the increasing food demand, the productivity of the rice-wheat cropping system must be increased and continued. There should be several options for increasing productivity and reducing cost of production and to conserve natural resources. Development or adoption of new crop establishment methods, changing management practices and inclusion of new crops in the system may be some ways of increasing productivity and resource conservation. Bed planting in rice-wheat cropping systems may be a technique for improving resource use efficiency and increasing the yield (Connor *et al*., 2003). In this system, the land is prepared conventionally (full tillage) and raised bed and furrows are prepared manually or using a raised bed planter. Crops are planted in rows on top of the raised beds and irrigation water is applied in the furrows between the beds. Water flows horizontally from the furrows into the beds. This system is often considered for growing high value crops that are more sensitive to temporary waterlogging stress. Growing wheat on raised beds though introduced in the Indo-Gangetic Plain, the practice of rice, the major water-using crop in the rice-wheat cropping system, on raised bed introduced very recently (Connor *et al*., 2003). An additional advantage of bed planting becomes apparent when beds are permanent, that is, when they are maintained over the medium term and not broken down and reformed for every crop (Hobbs and Gupta, 2003a). All the crops of the system, except the first crop, grown in zero tillage, which cut down the costs of land preparation and bed making, and only repairing cost for bed is needed.

Crop diversification may also be an important contributor to environmental sustainability and economic viability of rice-wheat areas. Bed planting system greatly facilitates and provides the opportunity for increasing crop diversification and higher productivity for crops traditionally grown on flat surfaces, especially in the wet season, because of less water logging. Crop diversification of the rice-wheat system ameliorates the family incomes, minimizes peak labour demands, facilitates easier weed and nitrogen management, and often results in better yield (Gupta *et al*., 2003b).

Inclusion of grain legumes in the dry-wet transition period of rice-wheat cropping system as a third crop may be another option of increasing cropping intensity, crop diversity and productivity of the system. Although the non-rice season across the rice-wheat area is low rainfall, heavy pre-monsoonal rain can have disastrous effects on the third crop, such as maize or mungbean grown after wheat or before rice, both during establishment and grain filling because of water logging (Timsina and Connor, 2001; Quayyam *et al*., 2002). Due to lack of proper crop establishment techniques and temporary water logging at reproductive stage, inclusion of a grain legume like mungbean in rice-wheat cropping system very often faces problems. Bed planting may be a solution of this problem because raised beds not only facilitate irrigation but also drainage, and there in lies their potential to increase the yield of crops other than rice in the system. Therefore, the study was undertaken to evaluate the performances of rice, wheat and mungbean in bed planting for increasing crop diversity through inclusion of mungbean in rice-wheat cropping systems and to evaluate the total system productivity of rice-wheat-mungbean cropping systems under bed planting.

MATERIALS AND METHODS

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) experimental farm, Gazipur and at farmers' fields in Chuadanga in Rabi season 2002-03 (November to March, wheat), *Kharif-I* season 2003 (March to June, mungbean) and *Kharif-II* season 2003 (June to November, rice). In both the locations, the experiment was repeated simultaneously in two separate fields. The soil of the experimental plots in BRRI farm was clay loam whereas in farmers' fields it was silty loam. Four cropping patterns namely Wheat-Mungbean-Direct seeded rice (DSR), Wheat-

Mungbean-Transplant rice (TPR), Wheat-Fallow-DSR and Wheat-Fallow-TPR under two planting methods, bed (raised bed) and conventional (flat) planting were evaluated. The experiment was laid out in a randomized complete block (RCB) design with three replications.

For wheat, 70 cm wide raised beds (40 cm top and 30 cm furrow) were made manually following the conventional land preparation and height of beds was 15 cm. Beds prepared for wheat were used for mungbean and rice. The beds prepared for wheat kept intact and mungbean, DSR and TPR on bed were grown as zero tillage condition. Normal tillage practices were followed in conventional method for all the crops. Weed population and dry biomass of weed were recorded at the time of weeding from a sample area of 0.25 m^2 for all the crops. Grain yields and yield components of all the crops were collected at maturity. The productivities of different cropping systems were compared in terms of rice equivalent yield (REY). Cost of land preparation, bed preparation, labour wage, inputs and irrigation and price of the products and byproducts were recorded. Simple economic analysis such as total variable cost (TVC), gross return, gross margin and benefit-cost ratio (BCR) were done for different planting methods.

Crop management practices

The wheat variety Kanchan was used in both the locations. The seed rates were 120 kg ha^{-1} and 90 kg ha^{-1} for conventional and bed planting, respectively. Seeds were treated with Viatvax-200 at the rate of three gram kg^{-1} seed. For beds, seeds were sown on 26 and 17 November in Gazipur and Chuadanga, respectively, in two rows bed^{-1} and for conventional method, row-to-row distance was 20 cm. In the row, seeds were sown continuously and covered properly with soil. Phosphorus (P), potassium (K), sulphur (S) and zinc (Zn) were applied at the rates of 36, 25, 20 and 4 kg ha^{-1}, respectively. The N rates were 100 kg ha^{-1} and 80 kg ha^{-1} for conventional and bed planting, respectively. Twenty-five percent seed and 20% N were reduced in bed planting based on previous results (Gupta *et al*., 2000; Hossain *et al*., 2001). Two-thirds N and whole P, K, S and Zn fertilizers were applied at the time of final land preparation. The remaining one-third N was top dressed at 19 days after sowing at crown root initiation stage (three leaf stage) followed by irrigation. For the treatments with bed planting, N was top dressed on the top of beds only. Seeds were sown in rows in both bed and conventional methods. Other crop management practices were followed as per recommendation (Sufian, 2001). Wheat was harvested on 22 and 15 March in Gazipur and Chuadanga, respectively.

Mungbean variety BARI Mung-5 was used in both the locations. Seed rate was 50 kg ha^{-1} for both the conventional and bed planting. Seeds were sown in two rows at 20 cm apart, on the top of beds keeping 10 cm at each edge in bed and for conventional method, row-to-row distance was 35 cm. Seeding dates of mungbean were 23 March and 16 March in Gazipur and Chuadanga, respectively. Nitrogen, P and K were applied at the rate of 18, 16 and 15 kg ha^{-1}, respectively. For the treatments with conventional tillage, all the fertilizers were applied at the time of final land preparation and for bed planting it was applied on bed top before sowing. Other recommended crop management practices were followed. Irregular maturity was observed in both the locations. Mature pods were picked up manually thrice from each plot during 26 May-15 June and 18 May-10 June at Gazipur and Chuadanga, respectively.

Aman rice varieties BRRI dhan30 and BRRI dhan39 were used in Gazipur while BR11 and BRRI dhan30 were used in Chuadanga. In the *Kharif-II* season a pre-sowing herbicide, Glycel (41% Glyphosate) was applied at the rate of 3.7 liter per hectare on fallow plots only as huge number of weeds grew on fallow lands. It was applied 15 days before sowing and transplanting of direct seeded and transplanted rice, respectively, in all the fields. For DSR, seed rates were 60 and 45 kg ha^{-1} for conventional and bed planting, respectively. Pre-germinated seeds were sown in rows in both the methods with same spacing as in wheat. In Gazipur, seeds were sown on 1 July and that of on 28 June in Chuadanga. For TPR, 27- and 28-day-old seedlings were transplanted on 20 and 18 July in Gazipur and Chuadanga, respectively. Two to three seedlings hill^{-1} were used maintaining the spacing of 20 cm × 20 cm. For the beds, seedlings were transplanted in two rows at 20 cm apart on the top of beds keeping 10 cm at each edge. Irrigation water was applied between the furrows of bed one day before transplanting to make the soil soft.

Phosphorus, K, S and Zn were applied at the rates of 20, 35, 10 and 4 kg ha^{-1}, respectively. The N rates were 100 and 80 kg ha^{-1} for conventional and bed planting, respectively. In the conventional treatment, the whole of P, K, S and Zn were applied at final land preparation while in bed planting, fertilizers were applied on the top of the beds before sowing and transplanting. For DSR, N was applied in four equal splits. One-forth of N fertilizer was applied as basal and the remaining splits were top dressed at 20, 40 and 60 days after sowing (DAS) for BRRI dhan39 and at 20, 45 and 70 DAS for other three varieties (BRRI, 2000). For TPR, urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting (DAT) for BRRI dhan39 and at 15, 35 and 55 DAT for other varieties. For the treatments with bed planting, N fertilizer was top dressed on the top of beds (BRRI, 2000). Other recommended crop management practices were followed. In Gazipur, rice was harvested on 1-13 November and in Chuadanga it was harvested on 7-8 November.

RESULTS AND DISCUSSION

Agronomic productivity

Grain yields of wheat, mungbean and rice were significantly affected by planting method both at on-farm and on-station. The grain yields of all the crops in the system under raised bed planting were significantly higher than that of conventional (flat) planting (Table 1).

Table 1. Grain yield of wheat, mungbean and rice and total rice equivalent yield (REY) under bed planting and conventional planting methods.

Planting method	Grain yield			
	Rabi	Kharif-I	Kharif-II	REY* (t ha^{-1})
	Wheat (t ha^{-1})	Mungbean (kg ha^{-1})	Rice (t ha^{-1})	
Experimental farm, BRRI, Gazipur (1)				
Raised bed	3.15 a	678.17 a	5.28 a	10.42 a
Flat	2.80 b	481.83 b	4.79 b	9.11 b
CV (%)	5.59	9.18	5.09	2.97
Experimental farm, BRRI, Gazipur (2)				
Raised bed	2.88 a	780.00 a	4.38 a	9.39 a
Flat	2.27 b	550.83 b	4.16 b	7.98 b
CV (%)	8.26	1.89	4.03	3.18
On-farm, Chuadanga (1)				
Raised bed	3.79 a	850.83 a	5.18 a	11.42 a
Flat	3.13 b	628.17 b	4.71 b	9.72 b
CV (%)	5.36	3.62	4.39	2.89
On-farm, Chuadanga (2)				
Raised bed	3.43 a	805.83 a	5.15 a	10.88 a
Flat	2.74 b	626.67 b	4.57 b	9.12 b
CV (%)	8.10	3.72	4.58	3.73

Figures in a column followed by different letters differ significantly at the 5% level by DMRT. *REY was calculated based on the local market price of rice, wheat and mungbean @ Tk 7.50, 9 and 30, respectively.

These higher yields in raised beds might be attributed to the higher number of grains panicle^{-1} and more 1000-grain weight of wheat, higher number of pods plant $^{-1}$ of mungbean and higher number of grains panicle^{-1} of rice since the differences of other components were insignificant (Table 3).The total REY was also higher in bed planting than the conventional method. The higher grain yield of each crop of the system in raised bed resulted significantly higher REY than flat in every locations. Yield increase in wheat, mungbean and rice by bed planting was also reported by Hobbs and Gupta (2003b), Sayre (2003), Hossain *et al.* (2004), Talukder *et al.* (2004), Meisner *et al.* (2005) and Mollah *et al.* (2008).

Table 2. Grain yield of wheat, mungbean and rice, and total REY of different rice-wheat cropping systems.

Cropping Pattern			Grain yield*			
Rabi	Kharif-I	Kharif-II	Wheat (t ha^{-1})	Mungbean (kg ha^{-1})	Rice (t ha^{-1})	REY (t ha^{-1})
Experimental farm, BRRI, Gazipur (1)						
Wheat	Mungbean	TPR	2.89	589.17	5.11 a	10.94 a
Wheat	Mungbean	DSR	2.99	570.83	5.27 a	11.14 a
Wheat	Fallow	TPR	3.03	-	5.17 a	8.80 b
Wheat	Fallow	DSR	3.00	-	4.59 b	8.19 c
CV (%)			5.59	9.18	5.09	2.97
Experimental farm, BRRI, Gazipur (2)						
Wheat	Mungbean	TPR	2.55	671.67	4.37	10.11 a
Wheat	Mungbean	DSR	2.63	659.17	4.36	10.16 a
Wheat	Fallow	TPR	2.51	-	4.17	7.17 b
Wheat	Fallow	DSR	2.61	-	4.18	7.31 b
CV (%)			8.26	1.89	4.03	3.18
On-farm, Chuadanga (1)						
Wheat	Mungbean	TPR	3.39	730.33	5.35 a	12.33 a
Wheat	Mungbean	DSR	3.54	748.67	4.88 b	12.12 a
Wheat	Fallow	TPR	3.42	-	5.31 a	9.41 b
Wheat	Fallow	DSR	3.50	-	4.23 c	8.43 c
CV (%)			5.36	3.62	4.39	2.89
On-farm, Chuadanga (2)						
Wheat	Mungbean	TPR	3.06	717.50	5.32 a	11.85 a
Wheat	Mungbean	DSR	3.15	715.00	4.82 b	11.46 a
Wheat	Fallow	TPR	3.10	-	5.17 a	8.90 b
Wheat	Fallow	DSR	3.04	-	4.14 c	7.79 c
CV (%)			8.10	3.72	4.58	3.73

Figures in a column followed by different letters differ significantly at the 5% level by DMRT. *BRRI dhan30 in experimental farm, BRRI, Gazipur (1) and on-farm, Chuadanga (2), BRRI dhan39 in experimental farm, BRRI, Gazipur (2) and B11 in on-farm, Chuadanga (2)

Yield of wheat and mungbean did not differ under different rice-wheat based cropping patterns (Table 2). There were also no significant differences in yield components of both wheat and mungbean while the rice grain yield was affected by different cropping patterns in both the locations. In Gazipur, both TPR and DSR of BRRI dhan30 in Wheat-Mungbean-Rice cropping pattern and TPR in Wheat-Fallow-Rice cropping pattern produced statistically similar grain yields, which were significantly higher than DSR in Wheat-Fallow-Rice cropping pattern (Table 2).

The lower grain yield of DSR in Wheat-Fallow-Rice cropping pattern was due to high weed infestation. The weed infestation was very low in DSR in Wheat-Mungbean-Rice cropping pattern as compared to Wheat-Fallow-Rice cropping pattern, which indicated that inclusion of mungbean in rice-wheat cropping system possibly would be an effective measure of weed control in DSR (Table 4). Grain yield of BRRI dhan39 followed the same trend though the yield differences were insignificant.

In Chuadanga, the grain yield of both the rice varieties, BR11 and BRRI dhan30, significantly differed under different rice-wheat cropping systems. The TPR under both Wheat-Mungbean-Rice and Wheat-Fallow-Rice cropping patterns provided significantly better grain yield than DSR under respective cropping pattern (Table 2). The performance of DSR in Wheat-Mungbean-Rice cropping pattern was also better than in Wheat-Fallow-Rice cropping pattern. The poor yield of DSR in Wheat-Fallow-Rice cropping pattern in Chuadanga was also the result of high weed infestation since the field was remained fallow after wheat.

Inclusion of mungbean in the cropping pattern greatly increased the total REY of the system. The Wheat-Mungbean-Rice cropping pattern where rice was grown either as DSR or as TPR resulted significantly higher total REY than Wheat-Fallow-Rice cropping pattern (Table 2). The differences of rice yield in different cropping patterns also contributed differently to the REY. The lowest REY was computed in Wheat-Fallow-DSR cropping pattern in all the fields except the pattern with BRRI dhan39 in Gazipur, which was similar to Wheat-Fallow-TPR cropping pattern. The interaction effect of planting method and cropping on grain yields of wheat, mungbean and rice was insignificant.

Table 3. Yield components of wheat, mungbean and rice under bed planting and conventional planting methods.

Planting method	Wheat			Mungbean				Rice		
	Panicles (no. m^{-2})	Grains $panicle^{-1}$ (no.)	1000-grain wt (g)	Plants (no. m^{-2})	Pods $plant^{-1}$ (no.)	Grains pod^{-1} (no.)	1000-grain wt (g)	Panicles (no. m^{-2})	Grains $panicle^{-1}$ (no.)	1000-grain wt (g)
Experimental farm, BRRI, Gazipur (1)										
Bed	309	34.9 a	41.9 a	45.7	10.3 a	7.4	33.8	249	118 a	23.6
Flat	296	27.0 b	37.9 b	44.5	8.3 b	7.2	32.8	250	102 b	23.4
CV (%)	6.24	3.46	1.41	8.53	10.04	5.08	2.62	2.63	1.22	6.30
Experimental farm, BRRI, Gazipur (2)										
Bed	297	34.3 a	42.0 a	43.0	10.5 a	7.4	32.9	217	93 a	25.2
Flat	292	27.2 b	37.9 b	43.7	8.2 b	7.3	32.9	217	82 b	25.0
CV (%)	7.60	3.48	1.38	13.05	8.80	3.74	3.04	3.40	1.87	4.13
On-farm, Chuadanga (1)										
Bed	309	34.9 a	41.0 a	38.0	12.9 a	7.6	32.9	246	115 a	24.2
Flat	303	27.2 b	37.0 b	35.8	10.4 b	7.4	32.a	240	101 b	23.9
CV (%)	6.51	4.61	2.09	12.45	11.23	6.16	3.67	4.54	1.87	4.18
On-farm, Chuadanga (2)										
Bed	312	34.8 a	40.9 a	35.7	14.3 a	7.7	32.6	247	117 a	23.6
Flat	304	26.8 b	36.9 b	34.0	10.4 b	7.3	32.7	239	98 b	23.5
CV (%)	7.04	4.08	1.43	10.79	10.77	4.70	3.42	5.74	2.04	4.35

Figures in a column followed by different letters differ significantly at the 5% level by DMRT.

Table 4. Weed vegetation in wheat, mungbean and rice in different rice-wheat cropping pattern.

Cropping pattern			Weed vegetation					
			Wheat		MB		Rice	
Rabi	Kharif -I	Kharif-II	Population (no. m^{-2})	Dry biomass (kg ha^{-1})	Population (no. m^{-2})	Dry biomass (kg ha^{-1})	Population (no. m^{-2})	Dry biomass (kg ha^{-1})
Experimental farm, BRRI, Gazipur (1)								
Wheat	MB	TPR	129	111.0	82 b	73.5 b	155 c	140.0 c
Wheat	MB	DSR	119	100.9	85 b	76.0 b	166 c	149.5 c
Wheat	Fallow	TPR	132	113.8	471 a	981.4 a	256 b	210.0 b
Wheat	Fallow	DSR	134	114.6	465 a	977.8 a	278 a	230.4 a
CV (%)			19.91	15.32	8.77	2.55	5.65	4.79
Experimental farm, BRRI, Gazipur (2)								
Wheat	MB	TPR	132	119.5	86 b	78.0 b	154 c	134.0 c
Wheat	MB	DSR	134	117.2	84 b	75.8 b	166 c	148.4 c
Wheat	Fallow	TPR	120	110.8	471 a	950.5 a	254 b	217.8 b
Wheat	Fallow	DSR	134	118.1	486 a	963.1 a	284 a	241.8 a
CV (%)			13.97	11.39	6.46	4.11	6.87	6.63
On-farm, Chuadanga (1)								
Wheat	MB	TPR	134	114.7	91 b	80.4 b	149 d	130.3 d
Wheat	MB	DSR	132	118.8	93 b	80.5 b	185 c	157.2 c
Wheat	Fallow	TPR	140	123.6	514 a	984.7 a	255 b	223.1 b
Wheat	Fallow	DSR	136	120.4	513 a	974.7 a	329 a	290.2 a
CV (%)			12.02	10.00	6.29	2.91	7.13	5.97
On-farm, Chuadanga (2)								
Wheat	MB	TPR	154	128.3	90 b	83.8 b	158 d	143.5 d
Wheat	MB	DSR	157	134.4	95 b	85.8 b	191 c	174.1 c
Wheat	Fallow	TPR	152	124.0	502 a	981.8 a	252 b	228.1 b
Wheat	Fallow	DSR	162	128.2	494 a	983.9 a	344 a	321.3 a
CV (%)			10.89	7.62	6.45	6.34	6.78	6.11

Figures in a column followed by different letters differ significantly at the 5% level by DMRT.

Economic productivity

Tables 5 and 6 present the costs of production in details. Bed planting reduced TVC of different cropping patterns as compared to the same pattern under conventional method in each location. It was the combined costs of all the crops in the pattern. Moreover, the total costs of the cropping patterns with three crops were more than the cropping patterns with two crops under both bed and conventional methods in both the locations as the cost of mungbean cultivation was added in the TVC. Furthermore, the TVC was higher in the patterns with TPR than similar pattern with DSR, because the production cost of TPR was higher than DSR.

Table 5. Variable cost for wheat, mungbean (MB) direct seeded rice (DSR) and transplant (TPR) Amanrice in different rice-wheat cropping systems under bed and conventional planting, Gazipur.

Activity/resource	Variable cost (Tk ha^{-1})							
	Raised bed				Conventional (flat)			
	Wheat	MB	DSR	TPR	Wheat	MB	DSR	TPR
Seed	1,350	1,200	653	331	1,800	1,200	870	580
Land preparation	2,100	-	-	-	2,100	1,050	2,100	2,100
Bed preparation	2,100	-	-	-	-	-	-	-
Seedling	-	-	-	857	-	-	-	1,500
Sowing/transplanting	1,000	1,000	1,000	1,800	1,750	1,000	1,750	2,625
Fertilizer: Urea	1,056	240	1,056	1,056	1,320	240	1,320	1,320
TSP	2,160	960	1,200	1,200	2,160	960	1,200	1,200
MP	500	300	700	700	500	300	700	700
Gypsum	480		240	240	480	-	240	240
$ZnSO_4$	400		400	400	400	-	400	400
Herbicide (Pre-sowing)*	-	-	1,850	1,850	-	-	1,850	1,850
Weeding	1,050	1,050	1,680 (1,470)	1,575 (1,260)	1,575	1,050	2,170 (1,680)	1,960 (1,575)
Insecticide	-	-	1,290	1,290	-	-	1,290	1,290
Irrigation	1,015	190	214	525	1,800	293	1,106	1,374
Harvesting	1,400	2,625	1,680	1,540	1,725	2,625	1,960	1,890
Threshing	1,050	525	1,050	1,050	1,050	525	1,050	1,050
Total	15,661	8,095	13,013 (10,953)	14,414 (12,249)	16,660	9,250	18,006 (15,666)	20,079 (17,844)

Figures in the parenthesis and without parenthesis for weeding and total variable cost of DSR and TPR are for the pattern Wheat-MB-DSR/TPR and Wheat-Fallow-DSR/TPR, respectively. Price of seed: wheat=15 Tk kg^{-1}; rice=14.50 Tk kg^{-1} and mungbean=40 Tk kg^{-1}. Labour: Gazipur=8.75 Tk $man\text{-}hour^{-1}$, Chuadanga=7.50 Tk $man\text{-}hour^{-1}$. *Pre-sowing herbicide was applied only in fallow plots before 15 days of rice seeding.

The gross returns followed the same trends as mentioned for REY. However, Wheat-Mungbean-Rice cropping pattern, where rice was grown either DSR or TPR, under bed planting resulted the highest gross return (Tk 98,680 ha^{-1} with TPR and Tk 99,470 ha^{-1} with DSR at Gazipur and Tk 112,810 ha^{-1} with TPR and Tk 111,370 ha^{-1} with DSR at Chuadanga), which was followed by same pattern under conventional method in both the locations (Table 7). The lowest gross return was earned by Wheat-Fallow-DSR cropping pattern under conventional method, which followed the Wheat-Fallow-TPR pattern.

Bed planting resulted higher gross margin than the conventional method of similar pattern at each location (Table 7). In on-station trial, the highest gross margin was found by bed planting of Wheat-Mungbean-DSR cropping pattern (Tk 64,760 ha^{-1}) followed by Wheat-Mungbean-TPR pattern (Tk 62,670 ha^{-1}). However, in on-farm trial, the highest was recorded in bed planting of Wheat-Mungbean-TPR cropping pattern (Tk 78,050 ha^{-1}) followed by Wheat-Mungbean-DSR cropping pattern (Tk 77,890 ha^{-1}) under bed planting. This was because of lower yield of DSR than TPR. The gross margins of Wheat-Mungbean-DSR and Wheat-Mungbean-TPR cropping patterns were very similar in each location. The lowest gross margin was recorded by Wheat-Fallow-DSR cropping pattern under conventional method, which followed the Wheat-Fallow-TPR pattern. The cropping patterns with two crops under bed planting and with three crops under conventional gave similar gross margin in both the locations, which indicated that by using bed planting method the gross margin could be increased to a great extent (Table 7). This result might be supported by the results of Chandraand Gupta (2004) and Singh and Beecher (2005).

Table 6. Variable cost for wheat, mungbean (MB) direct seeded rice (DSR) and transplant (TPR) Aman rice in different rice-wheat cropping systems under bed and conventional planting, Chuadanga.

Activity/resource	Variable cost (Tk ha^{-1})							
	Raised bed				Conventional (flat)			
	Wheat	MB	DSR	TPR	Wheat	MB	DSR	TPR
Seed	1,350	1,200	653	331	1,800	1,200	870	580
Land preparation	2,100	-	-	-	2,100	1,050	2,100	2,100
Bed preparation	1,800	-	-	-	-	-	-	-
Seedling	-	-	-	857				1,500
Sowing/transplanting	840	840	840	1,560	1,440	840	1,500	2,250
Fertilizer: Urea	1,056	240	1,056	1,056	1,320	240	1,320	1,320
TSP	2,160	960	1,200	1,200	2,160	960	1,200	1,200
MP	500	300	700	700	500	300	700	700
Gypsum	480	-	240	240	480	-	240	240
$ZnSO_4$	400	-	400	400	400	-	400	400
Herbicide (Pre-sowing)*	-	-	1,850	1,850	-	-	1,850	1,850
Weeding	1,080	1,200	1,550 (1,350)	1,320 (1,140)	1,500	1,350	2,220 (1,980)	1,750 (1,500)
Insecticide	-	-	1,530	1530	-	-	1,530	1,530
Irrigation	1,024	170	194	517	1,800	287	912	1,211
Harvesting	1,260	2,250	1,440	1,350	1,500	2,250	1,620	1,500
Threshing	1,350	450	900	900	1,350	450	900	900
Total	15,370	7,610	12,553 (10,503)	13,811 (11,781)	16,350	8,927	17,362 (15,272)	19,031 (16,931)

Figures in the parenthesis and without parenthesis for weeding and total variable cost of DSR and TPR are for the pattern Wheat-MB-DSR/TPR and Wheat-Fallow-DSR/TPR, respectively. Fertilizer: Urea=6 Tk kg^{-1}, TSP=12 Tk kg^{-1}, MP=10 Tk kg^{-1}, Gypsum=4 Tk kg^{-1} and $ZnSO_4$=40 Tk kg^{-1}. Herbicide: Glysel: 500 Tk L^{-1}. Insecticide: Furadan 5G=105 Tk kg^{-1} and Malathion=240 Tk L^{-1}. **Pre-sowing herbicide was applied only in fallow plots before 15 days of rice seeding.

Table 7. Economic productivity of different rice-wheat cropping systems under bed and conventional planting

Tillage option	Cropping pattern	Total variable cost (000' Tk ha^{-1})	Gross return (000' Tk ha^{-1})	Gross margin (000' Tk ha^{-1})	BCR
Experimental farm, BRRI, Gazipur					
Raised bed	Wheat-MB-TPR	36.01	98.68	62.67	2.74
	Wheat-MB-DSR	34.71	99.47	64.76	2.87
	Wheat-F-TPR	30.01	73.43	43.42	2.45
	Wheat-F-DSR	28.67	73.80	45.13	2.57
Conventional	Wheat-MB-TPR	43.75	86.10	42.35	1.97
	Wheat-MB-DSR	41.58	88.21	46.63	2.12
	Wheat-F-TPR	36.77	67.45	30.68	1.83
	Wheat-F-DSR	34.67	64.71	30.04	1.87
On-farm, Chuadanga					
Raised bed	Wheat-MB-TPR	34.76	112.81	78.05	3.25
	Wheat-MB-DSR	33.48	111.37	77.89	3.33
	Wheat-F-TPR	29.18	86.22	57.04	2.95
	Wheat-F-DSR	27.92	77.92	50.00	2.79
Conventional	Wheat-MB-TPR	42.21	98.81	56.60	2.34
	Wheat-MB-DSR	40.55	95.95	55.40	2.37
	Wheat-F-TPR	35.38	74.92	39.54	2.12
	Wheat-F-DSR	33.71	66.23	32.52	1.96

The local market price: rice=7.5 Tk kg^{-1}, wheat=9 Tk kg^{-1}, mungbean=30 Tk kg^{-1}, wheat straw=1 Tk kg^{-1}, rice straw=1 Tk kg^{-1} and mungbean straw=1 Tk kg^{-1}.

The BCR computed for different cropping patterns under different planting methods showed similar trends as gross margins in both the locations (Table 7). Bed planting increased BCR, because of higher gross return and lower TVC than those of conventional method in every location. The three crops pattern (Wheat-Mungbean-DSR/TPR) under bed planting resulted the highest BCR while the two crops pattern (Wheat-Fallow-DSR/TPR) under conventional method recorded the lowest BCR at each location.

CONCLUSIONS

The total agro-economic productivity and crop diversity of rice-wheat cropping system could be increased to a great extent over conventional method by adopting bed planting and inclusion of a grain legume like mungbean in the system, which made the system more profitable.

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