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Evaluation of Water Productivity for Different Rice Based Cropping Sequences in Gazipur

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ABSTRACT

Declining trend of water resources for Boro rice cultivation in different areas lead researchers and farmers to find out alternate cropping sequences. A field experiment was conducted in silty clay soil to evaluate the water productivity and profitability of different rice based cropping sequences during 2006-07 to 2008-09 at the BRRI farm, Gazipur. Three cropping sequences viz T. Aman-Boro-Fallow, T. Aman-Wheat-Mungbean and T. Aman-Potato-Mungbean and three water regimes assigned differently for each component crops were evaluated in a split-plot design. Among the cropping sequences, T. Aman-Potato-Mungbean with one irrigation at vegetative and two in reproductive stages for T. Aman rice, three irrigation each at 20, 40 and 60 DAS for potato and two irrigations for mungbean gave significantly higher rice equivalent yield of 33.40, 22.59 and 28.44 t ha^{-1} in 2006-07, 2007-08 and 2008-09 respectively. The variation in yield equivalence was mostly governed by potato crop grown in Rabi season. The maximum water productivity of 23.41, 18.57 and 23.62 kg ha^{-1} mm was recorded in rainfed for T. Aman and mungbean and one irrigation for potato in 2006-07, 2007-08 and 2008-09 respectively. The higher yield of potato raised the water productivity in T. Aman-Potato-Mungbean cropping sequence. Maximum net return of Tk 2,28,056, 2,75,389 and 4,05,986 and maximum BCR values from T. Aman-Potato- Mungbean cropping sequence with T_3 irrigation regimes of the respective crops during 2006-7, 2007-8 and 2008-9 respectively indicated that the sequence would be suitable for getting higher yield and economic return.

Key words: Cropping sequence, rice equivalent yield, water productivity

INTRODUCTION

Water is a major component for rice production. To produce one kg rice, 3000 litre of water is needed (Bhuiyan *et al.*, 1995). At present, about 80% of groundwater is used for irrigation, of which 73% is used exclusively by Boro farmers (Rahman and Ahmed, 2008). Availability of fresh water has been declining day by day. Approximately 50% of fresh water is used for rice cultivation (Guerra *et al.*, 1998). The average area coverage's for Aus (pre-monsoon), T. Aman (wet season) and Boro (dry season) rice are 0.9, 5.05 and 4.6 Mha, with corresponding production of 2.29, 14.69 and 27.0 MMT respectively (BBS, 2009). Among the three seasons, Boro mainly depends on irrigation that needs nearly one-third of the total production cost. The major cropping patterns of agriculture in Bangladesh mostly consist of rice based cereal crops (Haque, 1998). More than 60% of the total cropped areas are covered by Boro-Fallow-T. Aman rice cropping sequence (FRG 1997). About 2.4 Mha crop land is occupied by this cropping sequence in Bangladesh (Ladha *et al.*, 2003; Dawe *et al.*, 2004; Bhuiyan *et al.*, 2004). It is alarming that, lowering of groundwater has been occurred in some intensive cropped area in north-west region of Bangladesh due to climate change situation. Due to shortage of irrigation water farmers are likely to change their cropping pattern by shifting Boro rice with non-rice crops. However, a lot of information is available on rice based crop sequences/cropping systems for different soil and agro-climatic conditions of the country. Scant information is available on the relative effect of different irrigation levels for individual crops under a particular crop sequence. Total water requirement as well as water productivity for a particular cropping pattern is also lacking. Therefore, the present experiment was planned to find out suitable cropping sequence and the amount of water required for the component crops, and to determine the productivity and profitability of the system.

MATERIALS AND METHODS

Field experiments were conducted at BRRI farm, Gazipur during 2006-07 to 2008-09. The treatment

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comprised three levels of irrigation and three rice based crop sequences, laid out in split plot design with crop sequences in main plot and irrigation in sub plot, replicated three times. Different rice based crop sequences/cropping system were: P_1 = T. Aman-Boro-Fallow, P_2 = T. Aman-Wheat-Mungbean, and P_3 = T. Aman-Potato-Mungbean. Table 1 shows the irrigation treatments of different crops and the fertilizer managements that were followed. Table 2 shows the variety of different crops, seeding time and harvesting times.

Rainfall data measured by Tru-check rain gauges were used to estimate effective rainfall by using the water use- rainfall ratio method (Dastane, 1974). In this method, rainfall total for a certain group of days during the growing season was computed. The number of days in a group was based broadly on the soil type. For the study area, a 5-day grouping was used as the soil type is silty clay and falls under 5-day grouping.

Table 1. Irrigation treatments and fertilizer managements used in different rice based cropping systems.

Crop	Irrigation	Fertilizer
T. Aman	T_1=Rainfed T_2=One irrigation at vegetative and one in reproductive stage T_3=One irrigation at vegetative and two in reproductive stage	150 + 100 + 70 + 33 + 50 kg ha^{-1} urea, TSP, MP, gypsum and zinc sulphate
Boro	T_1=Continuous standing water T_2=Saturation level T_3=Irrigation after three days of disappearing standing water	220 + 120 + 85+ 28+ 50 kg ha^{-1} urea, TSP, MP, gypsum and zinc sulphate
Wheat	T_1=One irrigation (17 – 21 DAS) T_2=Two irrigations (17- 21 DAS + 55 – 60 DAS) T_3=Three irrigations (17 - 21 DAS + 55 – 60 DAS +70 – 75 DAS)	220 + 180 + 50 +120 kg ha^{-1} urea, TSP, MP, gypsum
Potato	T_1=One irrigation (20 – 25 DAS) T_2=Two irrigations (20- 25 DAS + 40 – 45 DAS) T_3=Three irrigations (20- 25 DAS + 40 – 45 DAS +60 – 65 DAS)	250 +150 + 250 + 120 + 8 + 10 kg ha^{-1} urea, TSP, MP, gypsum, zinc sulphate and boron
Mungbean	T_1=Rainfed T_2=One irrigation T_3=Two irrigations	50 + 85 +35 kg ha^{-1} urea, TSP, MP

Table 2. Variety, seeding time and harvesting time of different crops used in different rice based cropping systems.

Crop	Variety	Sowing time	Harvesting time
T. Aman	BRRI dhan33	22 July	22 October
Boro	BRRI dhan29	12 January	29 April
Wheat	Gourav	22 November	20 March
Potato	Cardinal	26 November	3 March
Mungbean	BARI Mug 6	7, 23 March	30 April and 1, 18, 25 May

The grouping always starts with a rainy day and rainfall for consecutive 5-day periods was added. The potential evapotranspiration and seepage and percolation rates for the same three days were taken together and used to compute effective rainfall using the equation:

$$ERF = \frac{ET + S\ \&\ P}{RF} \times 100 \quad \text{---------- Eq. (1)}$$

Where ERF is the effective rainfall in percent with a maximum value of 100; RF is the total amount of rainfall; ET is the potential evapotranspiration and S & P is the seepage and percolation losses of water for the 5-day period. Figure 1 presents monthly rainfall during the study period.

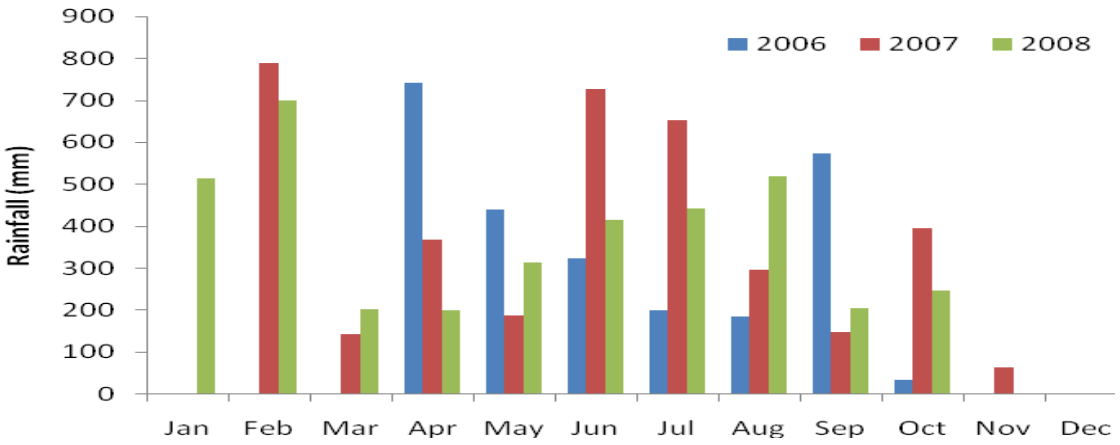

Fig. 1. Monthly rainfall (mm) during 2006-08.

Equivalent yield was calculated by the following equation:

$$EY_{rice} \frac{\text{Price of crop (Tk/t)} \times \text{Yield (t/ha)}}{\text{Price of rice (Tk./t)}} \quad \text{---------- Eq. (2)}$$

Water productivity (WP) was computed by the following equation:

$$WP = \frac{Yield\ (\frac{kg}{ha})}{water\ applied\ (mm)}$$

RESULTS AND DISCUSSION

Cropping sequence. Rice equivalent yield (REY) varied significantly (P<0.05) among the three cropping sequences in 2006-07, 2007-08 and 2007-08 (Fig. 2). The maximum REY of 29.43, 20.95 and 26.34 t ha^{-1} was recorded in T. Aman-Potato-Mungbean sequence in 2006-07, 2007-08 and 2007-08 respectively. Average over the year, the REY of T. Aman-Potato-Mungbean cropping sequence was 56.4% higher than T. Aman-Wheat-Mungbean and 63.3% higher than T. Aman-Boro-Fallow sequence. Inclusion of potato after T. Aman rice instead of Boro rice increased the total productivity of the system. The minimum REY of 8.69, 9.97 and 9.47 t ha^{-1} was recorded in T. Aman-Boro-Fallow sequence in the year 2006-07, 2007-08 and 2007-08 respectively. Sharma and Sharma (2005) also reported higher productivity in T. Aman-Potato-Mungbean cropping system.

Irrigation regimes. Rice equivalent yield productivity of different cropping sequences varied significantly (P<0.05) by irrigation regimes in 2006-07, but in 2007-08 and 2008-09, the variation was not significant (Fig. 3). In 2006-07, the highest rice equivalent yield (18.3 t ha^{-1}) was recorded in T_3 irrigation regimes arranged for different crops of the different cropping sequences. The lowest (15.04 t ha^{-1}) REY was recorded in T_1 irrigation regimes. Due to heavy rainfall in February, June and July, irrigation treatment was affected (Fig. 1).

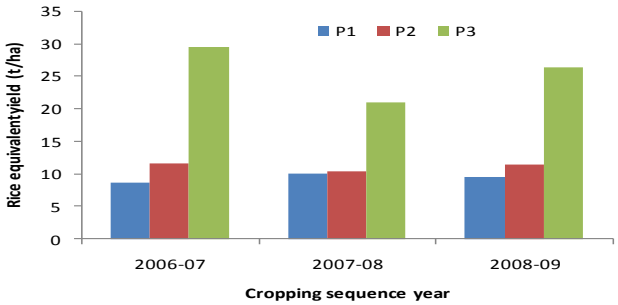

Fig. 2. Rice equivalent yield under different cropping sequences.

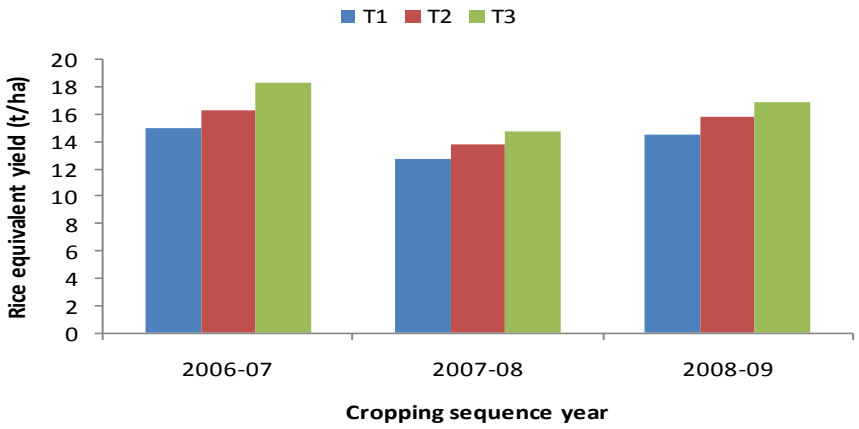

Fig. 3. Rice equivalent yield of different irrigation regimes of different cropping sequences.

Interaction of cropping sequence and irrigation regimes. Table 3 presents the yields of different crops and their equivalence to rice yield under different crop sequences with different levels of irrigation. Rice equivalent yield was significantly ($P<0.05$) different by different cropping sequences with different irrigation regimes in all the three years. Among the treatment combination, T. Aman-Potato-Mungbean with T_3 irrigation regimes assigned for the respective crops gave significantly higher rice equivalent yield of 33.40, 22.59 and 28.44 t ha^{-1} in 2006-07, 2007-08 and 2008-09 respectively. It might be due to the cumulative effect of all the component crops yields those yielded maximum. The maximum T. Aman rice yield of 4.07, 3.35 and 3.87 t ha^{-1} was recorded under one irrigation at vegetative and two irrigations at reproductive stage (T_3) in 2006-07, 2007-08 and 2008-09 respectively. The maximum potato yield of 14.33, 28.78 and 25.59 was recorded under three irrigations each at 20, 40 and 60 days after sowing (T_3) in 2006-07, 2007-08 and 2008-09 respectively. The maximum mungbean yield of 1.01, 1.17 and 1.17 t ha^{-1} was recorded under two irrigations (T_3) in 2006-07, 2007-08 and 2008-09 respectively. The variations in yield equivalence were mostly governed by Rabi crops. The highest yield equivalence was in T. Aman-Potato-Mungbean cropping system, due to much higher yield of potato than wheat. Potato was also reported as a suitable Rabi crop in rice based cropping sequence (BRRI, 2006). Paul *et al.* (2013) also reported maximum productivity in Rice-Potato-Mungbean cropping system.

Irrigation water used and water productivity. Table 4 shows irrigation water used and water productivity of different cropping systems. Total water used and water productivity were significantly influenced by cropping systems and irrigation treatments in all the three years. The maximum total water of 1714, 1694 and 1786 mm was consumed by T. Aman-Boro-Fellow cropping sequence under T_1 irrigation regimes assigned for the respective crops in the cropping year 2006-07, 2007-08 and 2008-09 respectively. The higher amount of total consumed water was mostly governed by the Boro rice production under continuous standing water. In Rabi season, among the three crops cultivated in different cropping sequences, Boro rice used higher amount of total water than wheat and potato. The cropping sequence T. Aman-Wheat-Mungbean and T. Aman-Potato-Mungbean used almost similar amount of total water during the three growing seasons.

Water productivity was significantly influenced by cropping systems and irrigation regimes in all the three years. Among the cropping sequences, the maximum water productivity of 22.77, 18.32 and 23.05 kg ha^{-1} mm was recorded in T. Aman-Potato-Mungbean crop sequence in 2006-07, 2007-08 and 2008-09 respectively. Water productivity of T. Aman-Potato-Mungbean crop sequence under three irrigation regimes were not significantly differed in all the three years. However, the maximum water productivity of 23.41, 18.57 and 23.62 kg ha^{-1} mm was recorded in T_1 irrigation regimes assigned for T. Aman, potato and mungbean crops in 2006-07, 2007-08 and 2008-09 respectively. The higher yield of potato raised the water productivity in T. Aman-Potato-Mungbean cropping sequence.

Table 3. Aman rice equivalent yield (t ha^{-1}) of different crops in various rice based cropping systems, during 2006-07, 2007-08 and 2008-09.

Crop sequence with water treatment		Yield of crops (t ha^{-1})			Aman rice equivalent yield (t ha^{-1})		
		T. Aman season	Rabi/Boro season	Aus season	Rabi/ Boro season	Aus season	Total equivalent yield (TEY)
				2006-07			
T. Aman-Boro-Fallow	T_1	3.19	5.28	-	-	-	8.47
	T_2	3.52	5.07	-	-	-	8.59
	T_3	3.64	5.39	-	-	-	9.03
T. Aman-Wheat-Mungbean	T_1	3.64	2.77	0.60	4.99	2.10	10.73
	T_2	3.64	3.02	0.67	5.44	2.35	11.42
	T_3	3.75	3.52	0.69	6.34	2.42	12.50
T. Aman-Potato-Mungbean	T_1	3.95	10.50	0.88	18.90	3.08	25.93
	T_2	4.07	11.93	0.98	21.47	3.43	28.97
	T_3	4.07	14.33	1.01	25.79	3.54	33.40
$LSD_{0.05}$							2.42
				2007-08			
T. Aman-Boro-Fallow	T_1	3.26	6.53	-	-	-	9.79
	T_2	3.33	6.34	-	-	-	9.67
	T_3	3.82	6.62	-	-	-	10.44
T. Aman-Wheat-Mungbean	T_1	3.24	2.89	0.55	4.82	1.53	9.59
	T_2	3.64	2.95	0.59	4.92	1.64	10.2
	T_3	3.77	3.47	0.65	5.78	1.81	11.36
T. Aman-Potato-Mungbean	T_1	3.05	23.30	1.03	12.94	2.86	18.85
	T_2	3.21	27.96	0.96	15.53	2.67	21.41
	T_3	3.35	28.78	1.17	15.99	3.25	22.59
$LSD_{0.05}$							2.8
				2008-09			
T. Aman-Boro-Fallow	T_1	3.58	5.78	-	-	-	9.36
	T_2	3.77	5.66	-	-	-	9.43
	T_3	3.85	5.98	-	-	-	9.63
T. Aman-Wheat-Mungbean	T_1	3.61	2.85	0.71	4.75	1.97	10.33
	T_2	3.75	3.04	0.94	5.07	2.61	11.43
	T_3	3.97	3.28	1.21	5.47	3.36	12.80
T. Aman-Potato-Mungbean	T_1	3.59	20.79	1.10	17.32	3.06	23.97
	T_2	3.68	23.25	1.29	19.37	3.58	26.63
	T_3	3.87	25.59	1.17	21.32	3.25	28.44
$LSD_{0.05}$							3.2

Price of crops kg^{-1} during 2006-07: rice=Tk 10, wheat=Tk 18, potato=Tk 18, mungbean=Tk 35. Price of crops kg^{-1} during 2007-08: rice=Tk 18, wheat=Tk 30, potato=Tk 10, mungbean=Tk 50. Price of crops kg^{-1} during 2008-09: rice=Tk 18, wheat=Tk 30, potato=Tk 15, mungbean=Tk 50.

Table 4. Total water used (mm) and water productivity of different rice based cropping systems during 2006-07, 2007-08 and 2008-09 at BRRI farm, Gazipur.

Crop sequence with water treatment		Total water use (mm) (inclusive rainfall, mm)			Water productivity (kg ha^{-1} mm)		
		2006-07	2007-08	2008-09	2006-07	2007-08	2008-09
T. Aman-	T_1	1714	1694.0	1786	4.95	5.78	5.53
Boro-	T_2	1374	1484.0	1386	6.26	6.52	6.35
Fallow	T_3	1604	1559.0	1616	5.65	6.70	6.31
T. Aman-	T_1	1099	1113.0	1061	9.77	8.62	9.28
Wheat-	T_2	1315	1263.0	1143	8.68	8.08	9.05
Mungbean	T_3	1445	1317.0	1196	8.66	8.63	9.72
T. Aman-	T_1	1109	1015.0	1091	23.41	18.57	23.62
Potato -	T_2	1311	1199.0	1066	22.15	17.86	22.21
Mungbean	T_3	1483	1219.0	1213	22.75	18.53	23.33
$LSD_{0.05}$		130.4	110.6	93.7	3.2	2.5	3.8
CV%		12.5	13.4	14.2	10.6	11.2	10.8

Table 5. Benefit-cost ratio (BCR) of different rice based cropping systems during 2006-07, 2007-08 and 2008-09 at BRRI farm, Gazipur.

Crop sequence with water treatment		Return per year (Tk ha^{-1})	Cost of cultivation	Net return (Tk)	BCR
		2006-07			
T. Aman-Boro-	T_1	84667	42672	41995	0.98
Fallow	T_2	85867	40272	45595	1.13
	T_3	90267	41314	48953	1.19
T. Aman-	T_1	107260	46952	60308	1.30
Wheat-	T_2	114210	48652	65558	1.35
Mungbean	T_3	125010	49652	75358	1.53
T. Aman-	T_1	259300	102084	157216	1.54
Potato -	T_2	289740	103984	185756	1.79
Mungbean	T_3	333990	105934	228056	2.15
		2007-08			
T. Aman- Boro-	T_1	176220	50532	125688	2.49
Fallow	T_2	174060	48944	125116	2.56
	T_3	187920	52414	135506	2.59
T. Aman-	T_1	172620	56196	116424	2.07
Wheat-	T_2	183600	60642	122958	2.03
Mungbean	T_3	204480	62124	142356	2.29
T. Aman-	T_1	339300	124827	214473	1.72
Potato- Mungbean	T_2	385380	128791	256589	1.99
	T_3	406620	131231	275389	2.10
		2008-09			
T. Aman- Boro-	T_1	168480	57600	110880	1.93
Fallow	T_2	169740	55484	114256	2.06
	T_3	176940	55484	121456	2.19
T. Aman-	T_1	185940	72257	113683	1.57
Wheat-	T_2	205740	74007	131733	1.78
Mungbean	T_3	230400	75757	154643	2.04
T. Aman-	T_1	431460	102084	329376	3.23
Potato-	T_2	479340	103984	375356	3.61
Mungbean	T_3	511920	105934	405986	3.83

Economics of different cropping systems/crop sequences. A wide variation in net return was observed among the crop sequences (Table 5). The maximum net return of Tk 2,28,056, 2,75,389 and 4,05,986 was recorded in T. Aman-Potato-Mungbean crop sequence under T_3 irrigation regimes of the respective crops during 2006-07, 2007-08 and 2008-09 respectively. It was followed by T_2 irrigation regimes of the same crop sequence. Maximum net return in T. Aman-Potato-Mungbean crop sequence was also reported by Paul *et al.* (2013). The maximum benefit cost ratio of 2.15 and 3.83 was recorded from T. Aman–Potato–Mungbean crop sequence under T_3 irrigation regimes of the respective crops in 2006-07 and 2008-9 respectively. In 2007-08, the maximum benefit cost ratio of 2.59 was recorded in T. Aman-Boro-Fallow crop sequence under T_3 irrigation regimes due to lower cost of cultivation.

CONCLUSIONS

The cropping sequence T. Aman-Potato-Mungbean with T_3 irrigation regimes assigned for the respective crops gave the highest rice equivalent yield. The variation in yield equivalence was mostly governed by potato. The highest water productivity was obtained from T. Aman-Potato-Mungbean with T_1 irrigation regimes. Maximum net return and maximum BCR values from T. Aman-Potato-Mungbean cropping sequence with T_3 irrigation regimes indicated that the combination would be suitable for getting higher yield and economic return.

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