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Feasibility of Introducing Rice Based Four Crops Pattern in Rangpur Region of Bangladesh

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Abstract

An experiment was conducted at Bangladesh Rice Research Institute (BRRI) Farm at Rangpur during July 2014 - June 2016 to introduce a 4-crops pattern with the aim of increasing cropping intensity, productivity, income and soil fertility. The experimental design was RCB with 3 replications. Four cropping patterns were tested which were: CP_1 = T. Aman (BRRI dhan62)-Potato (Cardinal)-Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48), CP_2 = T. Aman (BRRI dhan62)-Mustard (BARI Sorisha-14)-Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48), Farmers' improved practice (FIP) = T. Aman (BR11)-Potato (Cardinal)-Maize (NK 40) and Farmers' general practice (FP) = T. Aman (BR11)-Boro (BRRI dhan28)- Fallow. In T. Aman 2014, BRRI dhan62 produced 3.87 and 3.85 t ha^{-1} grain yields under CP_1 & CP_2 (4 crops systems), respectively; BR11 gave grain yield of 4.62 and 4.36 t ha^{-1} in FIP and FP (3 and 2 crop system), respectively. In T. Aman 2015, BRRI dhan62 produced grain yield of 4.23 and 4.19 t ha^{-1} in CP_1 and CP_2, and BR11 gave grain yield of 5.95 and 5.92 t ha^{-1} in FIP and FP, respectively. After T. Aman, potato yield was 24.66 t ha^{-1} in CP_1 and 24.17 t ha^{-1} in FIP during 2014-15. In CP_2, 2nd crop mustard yield was 1.16 t ha^{-1} and 3rd crop mungbean yield was only 0.98 t ha^{-1}. In CP_1, 3rd crop mungbean yield was only 0.83 t ha^{-1}. After potato in FIP, maize yield was 8.38 t ha^{-1}. After T. Aman (BR11) in FP, grain yield of BRRI dhan28 was 5.42 t ha^{-1}. The yield of BRRI dhan48 in CP_1 and CP_2 (as 4th crop) was 4.5 t ha^{-1}. Similar results of different crops were obtained in 2015-16. The rice equivalent yield (REY) was found to be 30.05 & 35.95 t $ha^{-1}yr^{-1}$ in CP_1 during 1st and 2nd year followed by FIP (23.92 & 29.82 t $ha^{-1}yr^{-1}$, respectively). The REY was higher in 2nd year compared to 1st year. In 2014-15 the highest net return of Tk.2,42,560 ha^{-1} was observed in CP_1 followed by FIP (Tk.1,58,380 ha^{-1}); in 2015-16, the highest net return was in CP_1 (Tk.2,16,960 ha^{-1}) followed by FIP (Tk.1,24,620 ha^{-1}). Potato based cropping pattern was thus, the most suitable and profitable pattern in this area. T. Aman (BRRI dhan62)-Potato (Cardinal)-Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48) may, therefore, be the most suitable and profitable cropping pattern in medium high lands of Rangpur region.

Keywords: Cropping pattern, profitability, rice equivalent yield, gross return, gross margin.

1. Introduction

Bangladesh is a densely populated country in the world with an area of 1,47,570 sq. km with population of about 165 million which is also increasing at a rate of 1.37% per year (BBS, 2015). In Bangladesh, total cultivable land is 7.9 million hectare and it is shrinking day by day. The annual loss of agricultural land is about

0.73% due to construction of roads, houses, industrial infrastructure and therefore, there is a very little scope of increase cultivable land. But cropping intensity may be increased from the existing level of 192% (BBS 2015) by incorporating short duration crop varieties of rice, potato, mustard, mungbean and maize in existing rice based cropping pattern in Rangpur region.

Increase of cropping intensity in rice based cropping system is very important for food security, poverty alleviation and livelihood improvement. The main challenge of the new millennium is to increase 50% yield per unit land area through manipulating the limited land resource. In order to produce more food in limited area, the most important options are: i) increasing cropping intensity by producing three or more crops over the same piece of land in a year and ii) increasing production efficiency of the individual crop by using optimum management practices.

Although, Bangladesh is nearly self-sufficient in rice production, other foods such as wheat, pulses, oil crops etc. are still deficit to a large extent. Recently, with the development of short duration varieties of rice, opportunity has been created to accommodate mustard, potato, pulses, maize etc. following rice in same piece of land in a year. Mustard production can be increased up to 20-23% only by replacing traditional variety with high yielding short duration varieties like BARI Sarisha-14 and BARI Sarisha-15 in the existing rice based cropping system (OFRD, 2014). Pulses are short duration important legume crops which are generally grown with less fertilizer since they can meet their N requirement by symbiotic fixation of atmospheric N in soil (Islam, 1991). Pulses also supply a substantial amount of N to the succeeding non-legume crops grown in rice based cropping system (Sharma and Prasad, 1999).

Thus development of short duration crop varieties by research organizations created and produces more yields of these crops on limited land. The present experiment was therefore, undertaken to evaluate the feasibility of increasing cropping intensity and productivity by growing four crops in a year in the same piece of land by incorporating short duration crop varieties in the existing rice based cropping systems of Rangpur region.

2. Materials and Methods

2.1 Experimental sites and seasons

The experiment was conducted in medium high land of BRRI regional station farm, Rangpur (latitude 24° 88' & 26° 33'N and longitude 88° & 90° E, AEZ 3) from July 2014 to June 2016. The soil was loamy with pH 6.6, organic matter 1.8%, total N 0.1%, P 31 ppm, K 0.14 m equi/100 g soil, S 6.34 ppm and Zn 3.74 ppm.

2.2 Experimental design and treatments

The experiment was laid-out in a randomized complete block design (RCBD) with 3 replications. The unit plot size was 8 m × 6 m where the field layout was permanent and all plots were divided with 20 cm height and 25 cm width strong levee to avoid soil fertility contamination. The tested cropping pattern was: CP_1 = T. Aman-Potato-Mungbean-T. Aus, CP_2 = T. Aman- Mustard -Mungbean-T. Aus, FIP = T. Aman-Potato-Maize, FP = T. Aman-Fallow-Boro.

2.3 Fertilizer management and cultural practices

One t ha^{-1} farm yard manure was applied in the experimental plots prior to starting experiment. The planting schedules, seed rate, spacing, and fertilizer rates and other agronomic practices are shown in Appendix 1.

N, P, K, S and Zn were applied from Urea, TSP, MoP, Gypsum and $ZnSO_4$, respectively; B was applied from Boric acid in potato, mustard, mungbean and maize. Thiovit (S containing fungicide as growth stimulating agent), Mancozeb (to control late blight), Acimix (to control soil born pest) were applied in potato.

Rajdhan was applied in rice and maize to control stem borer. Acimix was also applied in mustard and mungbean to control aphid and other pests. Soil from each plot was collected prior and after cultivation and tested to indicate major soil nutrients status.

2.4 Climatic conditions

Rangpur region is comparatively cold prone area with prolong winter. Sometimes, temperature goes below the critical level (10°C) during winter rice cultivation. Winter starts from mid November and continued up to mid March. Monthly maximum and minimum air temperature, total rainfall, relative humidity and solar radiation data are presented for each year in Fig.1A & B and 2A & B. The monthly mean maximum temperature was the highest (33.1°C) in July 2014 and the lowest monthly mean temperature (11.4°C) was recorded in January 2015 (Fig. A). The minimum and maximum rainfall varied from 1.4 to 342 mm per month which was not uniformly distributed. The highest monthly total rainfall (342 mm) was recorded in August 2014 (Fig. B). Again the monthly mean maximum temperature was the highest (32.8°C) in July 2015 and the lowest monthly mean temperature (10.8°C) was recorded in January 2016 (Fig. A). The monthly rainfall varied from 0 to 676 mm which was not uniformly distributed. The highest monthly total rainfall (676 mm) was recorded in August 2015 (Fig. B).

2.5 Sampling techniques, yield estimation and statistical analysis

Standard data collection technique and procedure were followed for each crop. For rice, 5.0 m^2 (excluding border) area was harvested at maturity for determining grain yield. Grain moisture was measured from each plot sample and yield was determined at 14% moisture content. Twelve hills were harvested from each plot to measure plant height, tiller number m^{-2}, and to calculate yield components, harvest index and sterility. For other crops, total plot (48 m^2) was harvested to determine yield.

2.6 Rice equivalent yield (REY)

To compare and evaluate different cropping pattern, the yield of all non rice crops was converted into rice equivalent on the basis of yield and prevailed market price of respective crop (Verma and Modgal, 1983).

$$\text{REY (t ha}^{-1}\text{yr}^{-1}\text{)} = \text{Individual crop yield} \times \frac{\text{Unit price of that crop}}{\text{Unit price of rice crop}}$$

2.7 Economic analysis

To determine the gross margin, total inputs (total variable cost) and outputs cost were calculated considering the prevailed market price. Gross return, gross margin and BCR were determined. Data collected from harvested rice and analysis of soil was analyzed by using Crop-stat program.

3. Results and Discussion

3.1 Yield of crops

In T. Aman 2014, BRRI dhan62, the shortest growth duration (100 days) variety produced 3.87 & 3.85 t ha^{-1} grain yield in CP_1 and CP_2 (four crops system), respectively. In FIP and FP (3 and 2 crops system), BR11 gave grain yield of 4.62 & 4.36 t ha^{-1}, respectively (Table 1).

After T. Aman (BRRI dhan62) harvest, the yield of 2nd crop potato in CP_1 was 24.66 t ha^{-1} (early). After BR11 harvest in FIP, the potato yield was 24.17 t ha^{-1} (late). There was no yield difference in early and late in that condition, but the market price of early potato was higher (Tk. 5 kg^{-1}). In CP_2, 2nd crop mustard yield was 1.16 t ha^{-1}. Second crop mungbean yield in CP_1 was only 0.98 t ha^{-1}. In CP_2, 3rd crop mungbean yield was only 0.83 t ha^{-1}. In FIP, 3rd crop maize yield was 8.38 t ha^{-1}. In FP, 2nd crop BRRI dhan28 gave 5.42 t ha^{-1} grain yields (Table 2). The grain yield of 4th crop BRRI dhan48 in CP_1 and CP_2 (in T. Aus season) was 4.5 t ha^{-1} with 105 days growth duration.

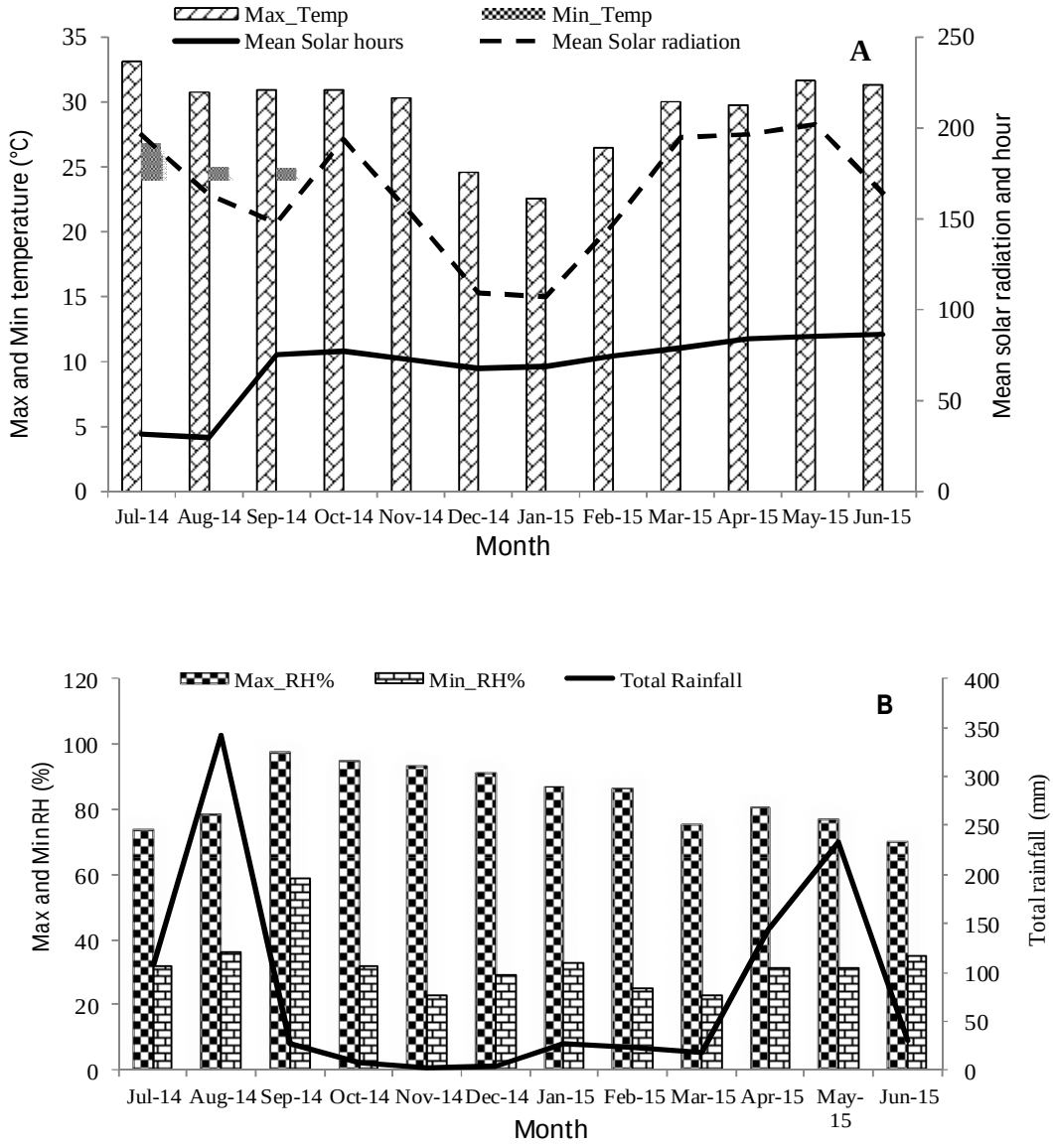

Figure 1. Weather data of BRRI Rangpur Station from July 2014 to June 2015 (Monthly Average)

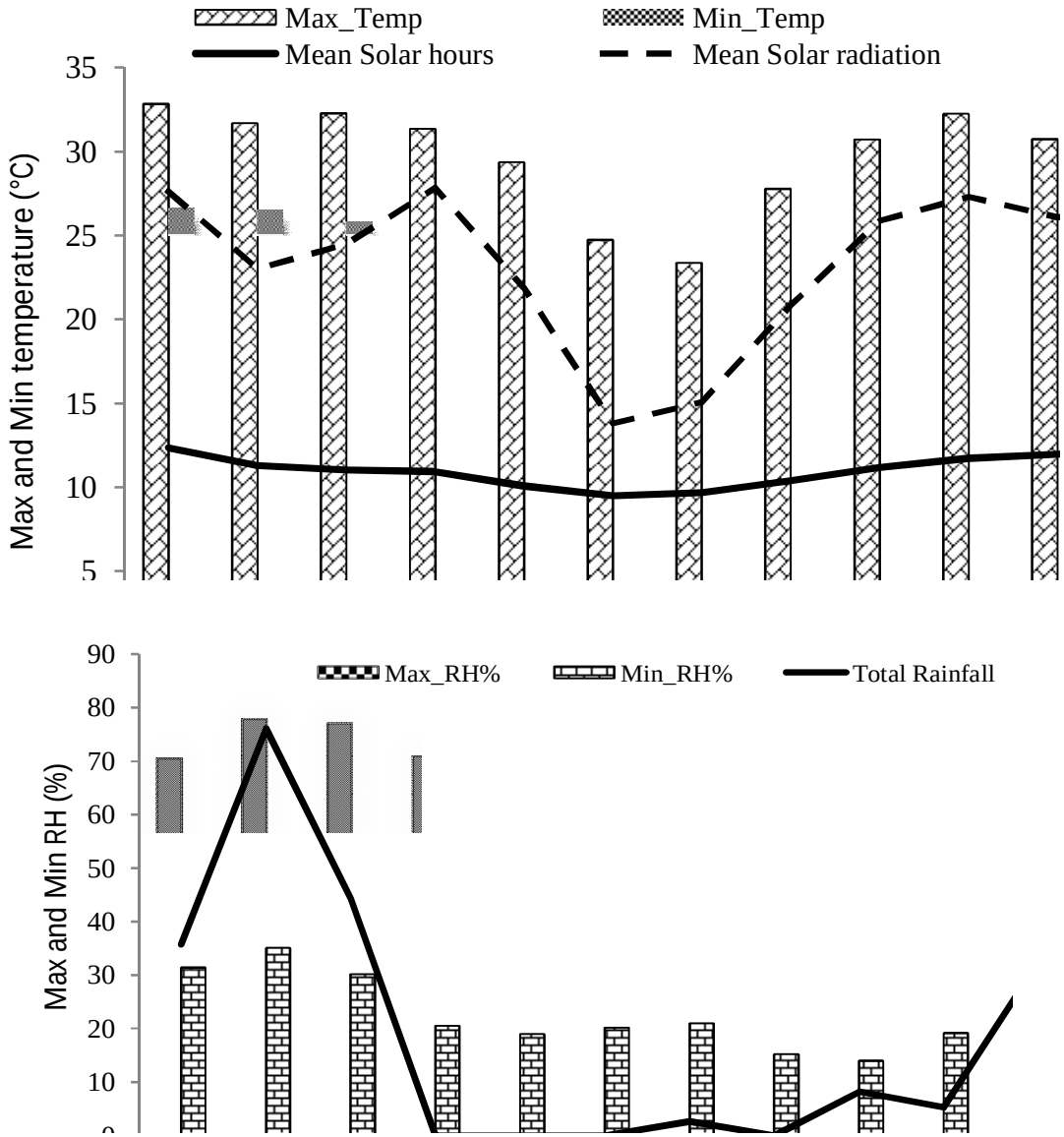

Figure 2. Weather data of BRRI Rangpur Station from July 2015 to June 2016 (Monthly Average)

3.2 Rice equivalent yields, gross return, gross margin and BCR

CP_1 obtained the highest rice equivalent yield (30.05 t $ha^{-1}yr^{-1}$) with the highest economic return followed by FIP (23.92 t $ha^{-1}yr^{-1}$, Table 2). Poor yield of mustard and mungbean resulted the lower REY of 13.94 even with 4 crops (CP_2).

Total cost of production and net return under different cropping pattern were estimated and presented in Table 3. The result showed that the highest net return was observed (Tk.242,560 ha^{-1}) in CP_1 (4 crops with early potato and BRRI dhan62) followed by FIP (Tk.1,58,380 ha^{-1}). The highest BCR was also observed in CP1 followed by FIP (Table 3).

Table 1. Grain yield and yield components of BRRI dhan62 and BR11, T. Aman, 2014

C. Pattern	Plant ht. (cm)	Tiller $hill^{-1}$	Panicle m^{-2}	Grain $panicle^{-1}$	1000 GW (g)	Yield (t ha^{-1})	Sterility (%)	HI
CP_1	101	11	250	71	23.05	3.87	17.2	0.46
CP_2	99	12	250	61	23.15	3.85	22.8	0.46
FIP	95	10	200	89	23.71	4.62	19.3	0.48
FP	95	9	200	87	23.61	4.36	24.9	0.47
$LSD_{0.05}$	2.92	1.2	20.73	15.36	NS	NS	8.49	NS
CV%	1.50	6.33	9.8	9.83	3.09	7.05	13.36	3.0

* CP_1 and CP_2: BRRI dhan62, FIP and FP: BR11

Table 2. Rice equivalent yield under different cropping pattern, 2014-15, BRRI Rangpur

C. pattern	1st crop yield (t ha^{-1})	2nd crop yield (t ha^{-1})	3rd crop yield (t ha^{-1})	4th crop yield (t ha^{-1})	REY (t $ha^{-1}yr^{-1}$)
CP_1	BRRI dhan62 = 3.87	Potato = 24.66*	Mungbean = 0.98	BRRI dhan48 = 4.5	30.05
CP_2	BRRI dhan62 = 3.85	Mustard = 1.16**	Mungbean= 0.86	BRRI dhan48 = 4.5	13.94
FIP	BR11 = 4.62	Potato = 24.17	Maize = 8.38	-	23.92
FP	BR11= 4.36	Boro= 5.42	-	-	9.78

Considering that, *1.0 t Potato= 0.94 t rice (early), 0.63 t rice (late) **1.0 t Mustard = 2.5 t rice, 1.0 t Mungbean = 3.13 t rice, 1 t Maize = 0.5 t rice (Rice= Tk.16 kg^{-1}, Potato= Tk.15 kg^{-1} -early, Potato= Tk.10 kg^{-1} -late, Mustard= Tk.40 kg^{-1}, Mungbean= Tk.50 kg^{-1} & Maize= Tk.8 kg^{-1} at harvest).

Table 3. Total cost of production and net return under different cropping pattern (Tk. ha^{-1}), BRRI Rangpur, 2014-15

C. pattern	1st Crop		2nd Crop		3rd Crop		4th Crop		Total		GM	BCR
	TVC	GR	TVC	GR	TVC	GR	TVC	GR	TVC	GR		
CP_1	74080	92320	176000	370720	35200	49120	65440	81120	350800	593280	242560	1.69
CP_2	74080	92320	41600	46480	35200	43120	65440	81120	216400	263040	46720	1.22
FIP	77920	93100	180560	246560	65440	67200	-	-	323840	399280	158380	1.23
FP	77920	93100	101680	106800	-	-	-	-	179520	187680	15580	1.05

TVC= Total variable cost, GR= Gross return and GM= Gross margin

Table 4. Soil fertility status as influenced by different cropping pattern, BRRI Farm, Rangpur, 2014-15

Treat	pH	OM%	Total N%	P (ppm)	K (meqi/100 g soil)	S (ppm)	Zn (ppm)
Initial soil	6.60	1.86	0.10	31.15	0.14	6.34	3.74
CP_1	6.35	1.94	0.10	57.13	0.17	23.84	2.44
CP_2	6.35	2.33	0.11	50.95	0.16	15.78	2.90
FIP	6.59	1.73	0.08	40.52	0.14	10.63	2.50
FP	6.43	2.44	0.12	42.34	0.13	13.62	3.41
$LSD_{0.05}$	NS	NS	NS	NS	NS	9.67	NS

3.3 Effect of cropping pattern on soil nutrient status

There was no significant change in soil pH, organic matter, total N, P, K and Zn content were observed. Increasing tendency was observed in S in different treatments (Table 4) compared to initial soil.

3.1.1 Crop yields

In T. Aman 2015, BRRI dhan62 in CP_1 and CP_2 (four crops system) gave 4.23 and 4.19 t ha^{-1} grain yields, respectively. In FIP and FP (3 and 2 crops system), the common variety BR11 gave 5.95 and 5.92 t ha^{-1} grain yield, respectively (Table 5).

As 2nd crop Potato in CP_1 gave the yield of 25.83 t ha^{-1} (early) and FIP, the potato yield was 26.80 t ha^{-1}(late). In FP_2, 2nd crop mustard yield was only 0.93 t ha^{-1}. As 3rd crop mungbean in CP_1, the yield was only 0.61 t $ha^{-1}$and in CP_2, the yield was only 0.71 t ha^{-1}. In FIP 3rd crop maize yield was 8.75 t ha^{-1}. In FP, 2nd crop BRRI dhan28 gave grain yield of 6.21 t ha^{-1} (Table 6). The 4th crop yield of BRRI dhan48 in CP_1 and CP_2 (T. Aus season) were 3.63 and 3.80 t ha^{-1}, respectively.

3.1.2 Rice equivalent yields, net return and BCR

The highest rice equivalent yield (REY) was observed in CP_1 (35.95 t $ha^{-1}yr^{-1}$) followed by FIP (29.82, Table 7). The lowest REY was observed in CP_2 (13.87 t $ha^{-1}yr^{-1}$, 4 crops) and FP (12.13). The lowest REY CP_2 was mainly due to lower yield of mustard (0.93 t ha^{-1}) and mungbean (0.71 t ha^{-1}). Similarly, the highest gross margin (GM) was observed in CP_1 (Tk.2,16960 ha^{-1}) followed by FIP (Tk.1,31,620 ha^{-1}, Table 7) and the lowest GM was observed in CP_2 (Tk.19040 ha^{-1} and FP 20,900 Tk. ha^{-1}). Similarly, the highest BCR was found in CP_1 followed by FIP. So, even growing 4 crops with mustard and mungbean did not increase the RYT and gross margin.

3.1.3 Effect of cropping pattern on soil properties

There was no significant change in soil pH and total N, little change in soil organic matter. The amount of P, K, S and Zn were increased in all treatments compared with initial soil and in some treatments compared with previous year soil analysis results (Table 8), it might be due to the residual effect of applied fertilizers in different crops.

The study was conducted where there is a scope to introduce 4 crops in same land in a year. The main limitations for introducing 4 crops in a cropping pattern are the tight schedule for crop establishment, natural calamities (rain, cold, high temperature, excess/ inadequate moisture in the soil etc.) and seed availability of different crops. However, it is possible to introduce 4 crops in a cropping pattern if we overcome those limitations. A number of reports on different cropping patterns are available in Bangladesh (Khan *et al*., 2005, and Nazrul *et al.*, 2013) where an additional crop could be introduced without much changes or replacing the existing ones for considerable increase of the overall productivity as well as profitability of the farmers.

Table 5. Grain yield and yield components of BRRI dhan62 and BR11, Rangpur, T. Aman 2015

Treat.	Plant ht. (cm)	Tiller hill^{-1}	Panicle m^{-2}	Grains panicle^{-1}	1000 grain weight (g)	Yield t ha^{-1}	Sterility (%)	Harvest index
CP_1	99	12	283	52	22.57	4.23	30.3	0.43
CP_2	101	11	267	57	22.43	4.19	28.9	0.42
FIP	112	16	317	78	24.60	5.95	20.4	0.50
FP	113	16	292	97	24.77	5.92	21.3	0.48
$LSD_{0.05}$	2.54	3.83	55.52	13.27	1.05	0.26	3.94	0.068
CV %	8.67	2.79	28.34	12.70	2.00	8.17	5.65	6.46

Table 6. Rice equivalent yield (REY) under different cropping pattern, 2015-16, BRRI Rangpur

C. pattern	1st crop yield (t ha^{-1})	2nd crop yield (t ha^{-1})	3rd crop yield (t ha^{-1})	4th crop yield (t ha^{-1})	REY (t ha^{-1})
CP_1	BRRI dhan62=4.23	* Potato=25.83	Mungbean= 0.61	BRRI dhan48= 3.63	35.93
CP_2	BRRI dhan62=4.19	**Mustard= 0.93	Mungbean= 0.71	BRRI dhan48= 3.80	13.87
FIP	BR11= 5.95	Potato=26.80	Maize= 8.75	-	29.82
FP	BR11= 5.92	Boro= 6.21	-	-	12.13

Price: Rice =14 kg^{-1} (Bold), and 16.25 kg^{-1} (Fine grain), Potato= 15 kg^{-1} (early), Potato= 9.40 kg^{-1} (late), Mustard= 50 kg^{-1}, Mungbean= 60 kg^{-1}, Maize=12.5 kg^{-1}, Assuming, *1 ton Potato= 0.99 ton rice (early), 0.62 ton rice (late), ** 1 ton Mustard=3.31 t rice, 1 ton Mungben= 3.97 ton rice, 1 ton Maize= 0.83 ton rice.

Table 7. Total cost of production and net return under different cropping pattern (Tk. ha^{-1}), BRRI Rangpur, 2015-16

CP	1st crop		2nd crop		3rd crop		4th crop		Total (Tk.)		GM (Tk. ha^{-1})	BCR
	TVC	GR	TVC	GR	TVC	GR	TVC	GR	TVC	GR		
CP_1	64720	67840	74160	78880	180560	388240	35200	36640	354640	571600	216960	1.61
CP_2	64720	67200	74160	78240	41600	46560	35200	42720	215680	234720	19040	1.09
FIP	66660	100480	180560	252400	68640	109600	-	-	323360	462480	131620	1.43
FP	66660	100080	101680	104160	-	-	-	-	175840	204240	20900	1.16

*TVC= Total variable cost, GR= Gross return GM= Gross margin and BCR= Benefit cost ratio

Table 8. Soil fertility as influenced by different cropping pattern, BRRI Rangpur, 2015-16

C. pattern	pH	OM	Total N	P (ppm)	K (meqi/ 100 g soil)	S (ppm)	Zn (ppm)
Initial soil	6.60	1.86	0.10	31.15	0.14	6.34	3.74
CP_1	6.43	2.63	0.13	69.44	0.24	13.97	3.92
CP_2	6.47	2.55	0.12	59.01	0.19	14.84	3.76
FIP	6.33	2.57	0.12	72.54	0.26	12.57	4.64
FP	6.56	2.73	0.14	53.13	0.18	11.19	4.26
$LSD_{0.05}$	NS	0.29	NS	10.56	0.08	4.17	0.81

The lower yield of BRRI dhan62 and BR11 in T. Aman 2014 was mainly due to severe rat damage and the yield loss was not estimated. Moreover, poor tiller production as well as panicle m^{-2} resulted the poor yield of BR11 in 2014. Low yield of mustard was due to pod degeneration and uneven growth and for mungbean there were poor crop establishment, wilting, yellow mosaic virus and hairy cater pillar infestation. Moreover, the prevailing cold, foggy weather and low solar hours (Fig. 1 & 2 A) in rabi season might affected the growth and yield of mustard and mungbean. The poor yield performance of mustard and mungbean affected the total REY and gross margin of 2014-15. Such type of biotic and abiotic stress reduced the crop yield and even 4 crops were not profitable (CP_2). It gave lower REY and less gross margin compared to farmers' improved practice.

There was no yield difference in early potato (1 November sowing) and late potato (20 November sowing) in that condition but the market price of early potato was higher. That was the main advantage of cultivating early potato followed by short duration rice variety.

However, 4 crops like BRRI dhan62-potato-mungbean-BRRI dhan48 gave the highest REY, gross return and profit. There are some results which support the present results. The highest average gross return (Tk.5,00,480 ha^{-1}) and net return (Tk.2,63,760 ha^{-1}) were reported in 4 crops ((T. Aman-Potato-Mungbean-T. Aus) followed by (T. Aman-Mustard-Mungbean-T. Aus. Four crops based pattern can be recommended for higher productivity, soil enrichment and economic benefit. The cost benefit analysis showed that inclusion of potato, mustard and Aus rice in the existing pattern showed higher benefit (Mondal *et al*., 2015).

The gross return and gross margin were higher in improved pattern compared to that of existing farmer's pattern with only 149 and 151% extra cost at FSRD site. The higher rice equivalent yield (22.41 and 21.82 t ha^{-1} yr^{-1}) indicated the superiority of the improved pattern over the farmer's existing pattern at both sites. Higher rice equivalent yield with improved cropping pattern (4 crops) was reported suitable in Tangail region for increasing crop productivity as well as cropping intensity (Rahman *et al*., 2015).

Inclusion of mungbean in the wheat-rice cropping sequence showed higher production cost but it gave higher system productivity, gross return, and gross margin , this cropping sequence gave on an average 57% higher wheat equivalent yield compared to the existing wheat rice sequence followed by blackgram included cropping sequence (Hossain *et al*., 2016). The net return (Tk. 198320 ha^{-1}) of improved cropping pattern were 24.93% higher compared to that of farmers' pattern with 45.44% extra cost (Khatun *et al.*, 2016). The maximum economic return in terms of gross return (Tk.2,26,000 ha^{-1}) and gross margin (Tk.87,440 ha^{-1}) were recorded (OFRD, 2016). Higher gross return (Tk.5,27,840 ha^{-1}) and gross margin (Tk.2,50,720 ha^{-1}) were obtained in improved Potato-Boro-T. Aus-T. Aman cropping pattern and lower gross return

(Tk.4,19,120 ha^{-1}) and gross margin (Tk.1,80,880 ha^{-1}) found in existing cropping pattern. (OFRD, 2016).

Generally, the cropping pattern with higher intensity consumed the higher amount of fertilizers. In the present study, there was no big changes in soil fertility occurred after completing 2 years experiments mainly due to use of organic manure (@1 t ha^{-1}) with maintaining the recommended fertilizer rates in all crops regularly. However, the highest gross return was estimated in 25% higher dose of fertilizer recommended guide (FRG) 2012 (Tk.703520. ha^{-1}) and lowest was obtained from 25% lower of FRG 2012 (Tk.6,18,320 ha^{-1}).Inclusion of new crops in the existing pattern and replacing old and traditional varieties by modern improved varieties enhanced productivity and profitability. Higher REY was obtained in alternate cropping pattern due to introduction of new crop and varieties which increase 13% over existing cropping sequence (OFRD, 2015-16). Alternate cropping pattern gave higher rice equivalent yield (REY, 16.55 t $ha^{-1}yr^{-1}$) against existing cropping pattern (11.03 t $ha^{-1}yr^{-1}$). Higher rice equivalent yield was obtained in alternate cropping pattern due to introduction of new crops and varieties. REY was found to increase by 50% over existing cropping sequence. (OFRD, 2016). Alternate cropping patterns was agronomically feasible economically profitable than existing patterns, rice equivalent yield, productivity and profitability was higher than the farmers' existing patterns (OFRD, 2017).

4. Conclusions

Comparing two years' results, variations in grain yields of different crops, market price of inputs and outputs were observed. Only two years' results are inadequate to draw a conclusion for such type of study. However, higher gross return and gross margin, higher cropping intensity and productivity indicated the superiority of the improved cropping pattern over farmers' practice. T. Aman (BRRI dhan62)-Potato (Cardinal)-Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48) was found to be the most suitable and profitable cropping pattern in medium high lands of Rangpur region.

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