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ON-FARM EVALUATION OF PRODUCTION POTENTIAL AND ECONOMICS OF FOUR CROPS BASED CROPPING PATTERN

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Abstract

A field experiment was conducted at multi-location testing (MLT) site, Barura under On-Farm Research Division (OFRD), Bangladesh Agricultural Research Institute, Cumilla during 2014-16 to determine the productivity and profitability of cropping patterns, viz. Boro (var. BRRI dhan28)-T.Aus (var. BRRI dhan48)- T. Aman (var. BRRI dhan49)-Fallow (existing cropping pattern) and Boro (var. BRRI dhan28)-T. Aus (var. BRRI dhan48)-T. Aman (var. Binadhan-11)-Mustard (var. BARI Sarisha-14) as improved cropping pattern. The results showed that improved cropping pattern provided higher amount of grain and by-product yield. The highest mean REY (18.08 t ha^{-1}), PE (54.61 kg ha^{-1} day^{-1}), LUE (90.68 %) and SYI (77.12%) was obtained from improved cropping pattern Boro-T.Aus-T. Aman-Mustard and the lowest (14.30 t ha^{-1} in 2014-15 and 13.98 t ha^{-1} in 2015-16) from farmers existing cropping pattern. The highest gross return (Tk. 274800 ha^{-1} in 2014-15 and Tk. 276600 ha^{-1} in 2015-16), gross margin (Tk. 113950 ha^{-1} in 2014-15 and Tk. 106750 ha^{-1} in 2015-16) and BCR (1.70 in 2014-15 and 1.66 in 2015-16) were obtained from improved four crops based cropping pattern (Boro-T. Aus-T. Aman-Mustard). Two years results showed that four crops could be grown one after another in a sequence in the farmers field of Cumilla region for achieving higher system productivity and economic return.

Introduction

Bangladesh is a densely populated country with lower per capita arable land (12 decimal $head^{-1}$) usage. The annual loss of agricultural land is about 0.73% per annum mainly due to construction of houses, roads and industrial infrastructure (BBS, 2019). Thus increase of cropping intensity in rice based cropping system is becoming important for food security and poverty alleviation. A vast area remains fallow after the harvest of T. Aman rice in Cumilla and Chandpur district of Bangladesh. In near future, the main challenge is to increase 50% yield per unit land by manipulating limited resources. In order to produce more food within a limited area, the most important options are to increase the cropping intensity and to increase the production efficiency of the individual crop by using optimum management practices (Mondal *et al.*, 2015). Recently with the development of short duration varieties of rice, mustard, potato, pulse and jute, opportunities have been created to accommodate four crops in same piece of land in a year (Azad *et al.*, 2020).

Cumilla region is highly diversified in respect to topography, agro-ecology, land-use pattern and cropping system. Barura upazila occupies the highest cropping intensity (CI) of 292% followed by Debidwar (265%) and Chandina (250%) under Cumilla district which are much more higher than the national average rendering those upazilas as the most intensive cropping area of the country (Saha *et al.*, 2017). Cumilla is the highest rice growing district in Bangladesh where Boro-T. Aus-T. Aman-Fallow is one of the major cropping patterns in the district covering of an areas of 47,350 ha (DAE, 2019). Rice is a promising cash crop in this region. By changing the variety of T. Aman, a short duration mustard variety can be easily fitted in Boro-T. Aus-T. Aman-Fallow cropping pattern. Thus it is expected that inclusion of mustard in Boro-T. Aus-T. Aman-Fallow cropping pattern would increase cropping intensity and productivity in Cumilla region. Further, adoption of this alternate cropping pattern Boro-T. Aus-T. Aman-Mustard can generate employment and the additional income for the rural poor of the region (Hossain *et al.*, 2017). To utilize the fallow land and to increase mustard production, it may be introduced in the fallow period before boro cultivation in the existing Boro-T. Aus-T. Aman rice -Fallow cropping pattern. Potential adoption of this improved cropping pattern intensifying mustard in Boro-T. Aus-T. Aman-Fallow cropping system can generate employment and the addition of income for the rural poor and save foreign exchange for edible oil import. Considering the above issues, the present study was undertaken to ascertain feasibility of growing four crops in sequence for increasing cropping intensity, productivity and income of farm families of Cumilla region of Bangladesh.

Materials and Methods

The experiment was conducted at Folkamuri, Barura under Cumilla district during 2014-15 and 2015-16. The crop field was sandy loam soil and it belongs to Chandina soil series under the Agro Ecological Zone (AEZ)-19. Initial and final chemical properties of experimental soils are presented in the Table 1. The trial was conducted to derive the economic consequences of four cropping patterns viz. Boro-T. Aus-T. Aman-Mustard (improved cropping pattern) and Boro- T. Aus- T. Aman-Fallow (existing cropping pattern). The experiment was laid out in a Randomized Complete Block design with four dispersed replications. Two plots of 250 decimal were selected. One for the improved pattern and the others for farmers pattern. Boro rice variety BRRI dhan28, T. Aus rice variety BRRI dhan48 and T. Aman rice variety Binadhan-16 were used in both existing and improved cropping pattern. In the improved cropping pattern, Mustard variety BARI Sarisha-14 was introduced against fallow period.

The experimental soil was sandy loam with low organic matter content (2.26%) and soil pH was ranged 5.40-5.47 acidic in nature. The status of N, P, K, B and Zn was low, optimum, low, very high and low, respectively (Table 1). The experimental design was a randomized complete block with six dispersed replications.

Table 1. Initial and final soil properties of the farmer's field at Barura, Cumilla during 2014-15 and 2015-16

Soil Properties	Land type	pH	Organic matter (%)	K	Total N (%)	P	Zn	B
				meq100 ml^{-1}soil		gml^{-1}		
Initial	MHL	5.47	2.26	0.14	0.16	24.5	2.91	0.24
Final	MHL	5.40	2.30	0.16	0.13	18.75	2.95	0.62
Critical Level	-	-	-	0.12	0.12	8. 0	0.6	0.20

Analyzed by: Regional Soil Resource Development Institute Laboratory, Cumilla; MHL: Medium High Land

The agronomic practices used for crop production under existing and improved cropping pattern are presented in Table 2. Land use efficiency, production efficiency, rice equivalent yield and sustainable yield index of cropping patterns were calculated as follows:

Table 2. Agronomic practices employed in existing and improved cropping patterns at MLT site Amratoli, Barura under Cumilla district (average of 2014-15 and 2015 -16)

Parameters	Existing Cropping pattern (ECP)				Improved Cropping Pattern (ICP)			
Crop	Boro rice	T. Aus rice	T. Aman rice	Fallow	Boro rice	T. Aus rice	T. Aman rice	Mustard
Variety	BRRI dhan28	BRRI dhan48	BRRI dhan49	-	BRRI dhan28	BRRI dhan48	Bina dhan-11	BARISarisha-14
Date of transplanting / sowing	26-28 January	10-13 May	15-18 August	-	Seed bed 30Dec. Transplanted 02 -05 Feb	Seed bed, 16 April Transplanted 07-08 May	Seed bed 16 July Trans. 13-15 Aug,	14-15 Nov.
Seed rate (Kg ha^{-1})	40	40	40	-	35	35	35	07
Seedling age/days	35	30	30	-	32	21	28	-
Planting method	Line	Line	Line		Line	Line	Line	Broadcast
Spacing	20 cm×15cm	15 cm×15cm	25 cm ×15 cm	-	20 cm ×15 cm	15 cm ×15cm	20 cm×15 cm	Broadcast
Fertilizer dose (NPKSZnB, Kg ha^{-1})	92-24-24-8-0.5-0	60-20-35-9.0-1.0-0	78-24-60-8-0.5-0	-	120-24-12-6.5-2.8-0	69.1-15-37.5-9.6-1.8-0	82.9-24-35-10.4-6.11-0	115-34-20-28.8-2.51-1.70
Fertilizer application method	All PKS used as basal during final land preparation. N used in 2 equal splits	All PKS used as basal during final land preparation. N used in 2 equal splits	All PKS used as basal during final land preparation. N used in 2 equal splits	-	All PKSZn and 1/3 N used as basal and rest 2/3 N used in 3 equal splits, 21 DAT, 35 DAT and at 45 DAT.	All PKSZn used as basal and N used in 2 equal splits, 15 DAT & at 30-35 DAT.	All PKSZn used as basal and N used in 3 equal splits, 7 DAT, 22 DAT and 5-7 days before panicle initiation stage.	All PKSZn and half N used as basal and rest N used in 20-25 days after seed germination at prior to flowering stage.
Irrigation/ rainfed	Irrigated	Rainfed	Rainfed	-	Irrigated	Irrigated	Irrigated	Rainfed
Insect-pest control	Chemical	Chemical	Chemical	-	IPM	IPM	IPM	IPM
Harvesting date	26-29 April	25-27 July	02-05 Dec.	-	23-25 April	03-05 Aug	09-11 Nov.	01-03 Feb.
Field duration (days)	90-92	75-78	107-110	-	80-82	87-89	87-90	77-78

Land use efficiency: Land use efficiency is worked out by taking total duration of individual crop in a sequence divided by 365 days (Tomer and Tiwari, 1990). It is calculated by following formula.

$$\text{Land use efficiency} = \frac{d_1 + d_2 + d_3}{365} 100$$

Where d_1, d_2 and d_3 the duration of first, second and third crops of the pattern.

Production efficiency: Production efficiency values were calculated by total production in a cropping sequence divided by total duration of crops in that sequence (Tomer and Tiwari, 1990).

$$\text{Production efficiency} = \frac{Y_1 + Y_2 + Y_3 \text{Kg. ha}^{-1}\text{day}^{-1}}{d_1 + d_2 + d_3}$$

Where, Y_1= Yield of first crop and d_1= Duration of first crop of the pattern
Y_2= Yield of second crop and d_2= Duration of second crop of the pattern
Y_3= Yield of third crop and d_3= Duration of third crop of the pattern

Sustainable yield index: Sustainable yield index (SYI) was computed following the formula of Krishna and Reddy (1997) as given below.

$$\text{Sustainable yield index (SYI)} = \frac{Y_{mean} - SD}{Y_{mean}} 100$$

Where, Y_{mean}: Estimated mean yield of a practice over years, SD: Estimated standard deviation and Y_{max}: Observed maximum yield in the experiment over the years.

Rice equivalent yield (REY): For comparison between crop sequences, the yield of all crops was converted into rice equivalent on the basis of prevailing market price of individual crop (Verma and Modgal, 1983).

$$\text{Rice equivalent yield (t ha}^{-1}\text{)} = \frac{\text{Yield of individual crop} \times \text{Market price of that crop}}{\text{Market price of rice}}$$

The economic indices like gross and net returns and benefit cost ratio were also calculated on the basis of prevailing market price of the produces and different operations performed and materials used for raising crops.

Benefit Cost Ratio (BCR) was calculated by the following formula:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return (Tk. ha}^{-1}\text{)}}{\text{Total cost of cultivation (Tk. ha}^{-1}\text{)}}$$

Rice plant was harvested at 12-20 cm height from soil surface and remaining parts of the plant was incorporated with soil. Grain and by- product yields were collected from harvested plants. The data were recorded on different parameters and presented in the table.

Results and Discussion

Grain and by- product yield of Crops in Cropping Patterns

Yield of different crops in improved and existing cropping patterns are presented in Table 3. Improved pattern required 228-332 days against 285-288 days due to inclusion of mustard (var.

BARI Sarisha-14) instead of fallow period in the pattern. Field duration of T. Aman rice (var. Binadhan-11) in the improved cropping pattern was shorter due to change of variety. The yield of T. Aman rice was also lower in the improved pattern than the existing cropping pattern. The yield of Boro rice and T. Aus rice was higher in the improved pattern than the existing cropping in both the years except Boro rice in 2014-15. Improved cropping pattern showed higher grain yield of Boro rice by 6.20 t ha^{-1} in 2014-15 and 6.34 t ha^{-1} in 2015-16 and T. Aman rice by 4.45 t ha^{-1} in 2014-15 and 4.35 t ha^{-1} in 2015-16 over existing pattern except 2015-16 in T. Aman rice. Higher yield of rice possibly due to improved production technologies. Similar results were obtained by Mandal *et al.* (2015), Nazrul *et al.* (2017), Khan (2018). The improved cropping pattern produced higher amount of total by-product yield (18.74 t ha^{-1}) than the farmers' existing pattern (15.49 t ha^{-1}). The by-product yield of improved pattern was higher due to change of variety with improved technologies for the component crops. Similar results were also documented by Hossain *et al.* (2014) and Hossain *et al.* (2017). Mustard (var. BARI Sarisha-14) in improved pattern produced valuable by-products in both the years. So, farmers are able to use the by-product of rice and mustard in domestic purpose and also sale in the local market with high price.

Table 3. Productivity of existing and improved cropping patterns at MLT site Amratoli, Barura under Cumilla district during 2014-15 and 2015 -16

Productivity	Years	ECP (Existing Cropping Pattern)				ICP (Improved Cropping Pattern)			
		Boro rice	T. Aus rice	T. Aman rice	Fallow	Boro rice	T. Aus rice	T. Aman rice	Mustard
Grain yield (t ha^{-1})	2014-15	6.39	3.48	4.43	-	6.20	4.29	4.45	1.69
	2015-16	5.89	3.32	4.77	-	6.34	4.21	4.35	1.47
	Mean	6.14	3.40	4.60	-	6.27	4.25	4.40	1.58
By product yield (t ha^{-1})	2014-15	6.46	4.52	4.68	-	6.23	4.49	4.90	3.16
	2015-16	6.32	4.42	4.58	-	6.19	4.63	4.76	3.12
	Mean	6.39	4.47	4.63	-	6.21	4.56	4.83	3.14

System Productivity

Rice equivalent yield (REY) was different under different cropping sequences. The highest REY (18.08 t ha^{-1}) was recorded from the improved cropping pattern Boro-T. Aus-T.Aman-Mustard and the lowest (14.14 t ha^{-1}) from the existing cropping pattern *i.e.* Boro- T. Aus- T. Aman (Table 4). Rice equivalent yield in the improved cropping pattern was higher compared to existing cropping pattern due to the inclusion of mustard with management practices. Improved cropping pattern increased REY about 27.86% compared to farmers existing cropping pattern. Inclusion of high yielding new variety (Binadhan-11) and improved management practices in the improved pattern increased the T. Aman rice equivalent yield. Lower rice equivalent yield was obtained in the farmer's pattern possibly due to traditional management practices. Similar trend was noted by Naher *et al.* (2016). Maximum production efficiency (54.61 kg ha^{-1} day^{-1}) was obtained from improved cropping pattern in both the years (Table 4). The higher production efficiency of improved cropping pattern might be due to improved management practices. The lowest production efficiency (51.98 kg ha^{-1} day^{-1}) was observed in farmers' existing pattern where improved management practices easily. Similar trends were noted by Nazrul *et al.* (2013) and Khan *et al.* (2005). The average land-use efficiency indicated that improved cropping pattern used the land for 91.52 % in 2014-15 and 89.84 % in 2015-16, period of the years, whereas farmer's existing cropping pattern used the land for 73.47 % in 2014-15 and 75.57 % in 2015-16, period of the years (Table 4). The land use efficiency was higher in improved cropping pattern because of the cultivation of mustard as fourth crop in a fallow land and longest field duration (331 days).The farmers existing pattern occupied the field for 272 days of the year. The values of sustainable yield index (SYI) as a measure of sustainability of the system which was high in the improved cropping system over farmer's practice (Table 4). ICP recorded the highest SYI of 78.28 % in 2014-15 and 75.96 % in 2015-16 followed by ECP (70.23 % in 2014-15 and 68.15 % in 2015-16). It indicates that cropping system involving mustard in fallow period i.e four crop based improved cropping pattern recorded higher SYI compared to three rice crop based farmers existing crop sequence. So, improved pattern is therefore, more stable than farmer's pattern. Short duration mustard variety BARI Sarisha-14 could provide special advantage regarding utilization of fallow period in cropping sequence as well as increased production of mustard. The results are in agreement with the findings of Ram *et al.* (2012).

Table 4. Rice equivalent yield, production efficiency, land use efficiency and sustainable yield index of existing and improved cropping patterns during 2014-15 and 2015 -16

Cropping patterns	Years	Rice equivalent yield (t ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Land use efficiency (%)	Sustainable yield index (%)
ECP	2014-15	14.30	52.57	73.47	70.23
	2015-16	13.98	51.39	75.57	68.15
Mean		14.14	51.98	74.52	69.19
ICP	2014-15	18.32	55.34	91.52	78.28
	2015-16	17.84	53.89	89.84	75.96
Mean		18.08	54.61	90.68	77.12

Market price of Mustard @ 30 Tk kg^{-1}, Rice@ 15 Tk kg^{-1}, Urea @ 16, TSP @ 24, MP @15,Zypsum @10, Zinc Sulphate @ 120 and Boric acid@ 150 Tk kg^{-1}, ECP = Existing cropping pattern, ICP = Improved Cropping Pattern

Economics

Economic analysis was done on the basis of prevailing market price of the commodities. The gross return was different for different cropping patterns. The highest gross return (Tk. 274800 ha^{-1}) in 2014-15 and (Tk. 276600 ha^{-1}) in 2015-16 and gross margin (Tk. 113950 ha^{-1}) in 2014-15 and (Tk. 106750 ha^{-1}) in 2015-16 were obtained in improved Boro-T.Aus-T. Aman-Mustard cropping pattern and the lowest gross return (Tk. 214500 ha^{-1}) in 2014-15 and (Tk. 209700 ha^{-1}) in 2015-16 and gross margin (Tk. 76950 ha^{-1}) in 2014-15 and (Tk. 72150 ha^{-1}) in 2015-16 were found in existing cropping pattern (Table 5). The highest total cultivation cost (Tk. 160850 ha^{-1} in 2014-15 and 2015-16) was recorded from cropping sequence Boro-T. Aus-T. Aman-Mustard, due to the inclusion of mustard in improved cropping pattern and the lowest (Tk. 137550 ha^{-1} in 2014-15 and 2015-16) from the existing cropping sequence Boro-T. Aus- T. Aman-Fallow. The highest (1.70) BCR in 2014-15 and (1.66) BCR in 2015-16 was recorded in improved Boro-T. Aus-T. Aman-Mustard cropping pattern compared to the farmers existing cropping pattern Boro- T. Aus- T. Aman-Fallow (1.55) in 2014-15 and in (1.52) in (2015-16). Others (Mondal *et al.*, 2014, Khan *et al.,* 2020 and Bhowal *et al.,* 2019) agreed that the four crop based cropping pattern would play a vital role to ensure food security of the country in upcoming days.

Table 5. Cost and return analysis of existing and improved cropping pattern at MLT site Amratoli, Barura under Cumilla district during 2014-15 and 2015-16

Cropping pattern	Years	Gross return (Tk. ha^{-1})	Total Cost of cultivation (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio
ICP	2014-15	274800	160850	113950	1.70
	2015-16	276600	160850	106750	1.66
	Mean	271200	160850	110350	1.68
ECP	2014-15	214500	137550	76950	1.55
	2015-16	209700	137550	72150	1.52
	Mean	212100	137550	74550	1.54

Conclusion

Two years study revealed that four crops based cropping pattern such as Boro (var. BRRI dhan28)-T. Aus (var. BRRI dhan48)- T. Aman (var. Binadhan-11)-Mustard (var. BARI Sarisha-14) is agronomically feasible and economically profitable compared to the existing farmers cropping pattern Boro (var. BRRI dhan28)-T. Aus (var. BRRI dhan48)-T. Aman (var. BRRI dhan49)-Fallow. So, the farmers of Cumilla region could be suggested to grow mustard under four crops based cropping pattern for getting maximum profit.

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