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Transforming Single Crop System into Double Cropping Pattern in Upper Catena of Haor Area: An Approach to Increasing Cropping Intensity, Productivity and Profitability

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Abstract

Changing single cropping patterns to two cropping patterns can play a potential role in achieving a country's food security. With this view to increase crop productivity, production efficiency, land-use efficiency, and economic return through intensifying cropping intensity as well as crop diversity by transforming a single cropping pattern into two crops, the experiment was conducted in Old Meghna Estuarine Floodplain Soils under the Agro-Ecological Zone (AEZ) 19 at the Multi-location Testing (MLT) Site, Nikli under On-Farm Research Division (OFRD) of Bangladesh Agricultural Research Institute (BARI), Kishoreganj, for three consecutive years 2017-18, 2018-19 and 2019-20. Two crops pattern Mustard-Boro rice-Fallow was tested at on-farm condition over the existing single crop pattern only Boro rice after the floodwater receded. Findings revealed that the mean crop duration of 198 days was required for one cycle in a year in an improved cropping pattern, implying that two crops-based cropping patterns were agronomically feasible to replace the existing cropping pattern. Total seed/grain yield in terms of REY of improved cropping pattern was 11.27 t/ha/year, 62% higher than the existing pattern (6.96 t/ha/year). The improved cropping pattern's mean production efficiency (64.15 kg/ha/day) and land-use efficiency (50.32%)

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were 5% and 61%, higher than the existing cropping pattern. Results showed that the improved pattern with management practices provided an average gross return of 54, gross margin of 91 and benefit-cost ratio (BCR) of 21%, respectively higher than the farmer's pattern. Three years' results revealed that 27% extra cost provides ample scope for considerable improvement of the productivity of improved pattern with the inclusion of Mustard before Boro rice.

Keywords *Cropping intensity · Cropping pattern · Productivity · Gross margin · Haor area*

1. Introduction

Haor is a low-lying river basin in Bangladesh that generally remains underwater for about six months during the monsoon season, from April-May to September-October (Sharma, 2010). Haor covers about 859000 ha in the northeastern districts of Kishoreganj, Sunamganj, Netrakona, Moulivibazar, Sylhet, Hobiganj and Brahmanbaria to 20 million people, i.e. about 13% of the total population of Bangladesh (Ali et al., 2019). Kishoreganj is quite different from other districts of Bangladesh for its unique natural beauty characterised by haors, rivers, plain land and char areas. The total cultivated area of Kishoreganj is 386121 hectares, of which about 102057 hectares of cultivated land are single-cropped, 50874 hectares are double-cropped, and 55100 hectares are tripled cropped areas with a cropping intensity of 182 per cent (DAE, 2020). The average cropping intensity in haor areas of Kishoreganj is about 104% (DAE, 2019). The country is losing 0.49% of cultivable land every year for high population pressure and other purposes (Hasan et al., 2013). Cultivable land is declining daily, so escalating cropping intensity with more production and bringing the barren land under cultivation is the prerequisite for sustainable food security in Bangladesh. Thus, an increase in cropping intensity in rice-based

The cropping system is becoming essential for food security and poverty alleviation. To ensure the food security of the increased population, the country needs to be increased food production by increasing cropping intensity. To produce more food within a limited area, the most important options are to increase the cropping intensity and increase the individual crop's production efficiency by using optimum management practices (Mondal et al., 2015). Flash flood comes late in the upper catena part of the haor but wakes up quickly, and 10-15% of haor areas become suitable for crop cultivation in the last week of September to the second week of October (Mohiuddin and Sarker, 2019). At that time, farmers are waiting to cultivate boro rice with irrigation by deep tube well up to December second week to the first week of January. As a result, the vast area remains fallow for a long time, about 80-90 days after the floodwater receded. There is an excellent scope for introducing a short-duration crop like mustard during the fallow period to increase cropping intensity and crop productivity. Mustard is a short (76-90 days) high-value edible oilseed crop that may easily be fitted in an upper catena of haor areas before boro rice in existing fallow-boro rice-fallow cropping pattern. Potential adoption of mustard in the fallow-boro rice-fallow cropping system would generate employment and additional income for the farmers by utilising fallow lands in the haor areas. Moreover, several studies on different cropping patterns are available in Bangladesh and India that an additional crop could be introduced without any changes or replacing the existing ones for considerable increases in productivity as well as the profitability of the farmers (Azad *et al*., 1982; Malavia *et al*., 1986; Soni and Kaur, 1984; Khan *et al.,* 2005; Nazrul *et al*., 2013; Kamrozzaman *et al.,* 2015).

2. Objectives

Although the country is nearly self-sufficient in rice production, other foods such as vegetables, pulses, oil crops etc., are still in deficit to a large extent. Therefore, crop diversification will increase cropping intensity, raise productivity, and improve farmers' economic conditions. Farmers in haor areas have been facing problems in existing cropping patterns. In contrast, they have a great potential to conduct two crops in the same piece of land in a year because 30% of lands are high and medium-high land under irrigation. But no attempt has been made for on-farm verification of two crops based on improved cropping pattern Mustard-Boro rice-Fallow in an upper catena of haor areas. Bearing the above statement in mind, the present study was, therefore, undertaken with the following objective

i. to estimate the compound growth rate of area, production and yield of mustard
ii. to find out the agronomic practices of mustard -Boro rice-Fallow cropping pattern;
iii. to examine the feasibility of mustard -Boro rice-Fallow cropping pattern in farmers' field conditions;
iv. to compare productivity and profitability of improved pattern against farmer's existing cropping pattern.

Table 1. Area, production and yield of mustard in Bangladesh

Year	Area (000' acre)	Production (000' M.T)	Yield (kg/ha)
2002	735	218	732.59
2003	690	210	751.74
2004	597	191	790.23
2005	536	183	843.30
2006	520	189	897.75
2007	577	228	976.01
2008	578	203	867.49
2009	601	222	912.37
2010	623	246	975.31
2011	682	262	948.88
2012	728	194	658.21
2013	727	296	1005.67
2014	803	359	1104.27
2015	787	362	1136.14
2016	831	363	1078.95
2017	760	352	1144
2018	667	312	1155.38
2019	764	358	1157.41
Compound growth rate (%)	0.11%	2.41%	2.30%

3. Materials and methods

The study was carried out for three consecutive years, 2017-18, 2018-19 and 2019-20, at a farmer's field, Nikli, Kishoreganj (241555.95'N latitudes and 905558.026' E longitude) located in Agro-Ecological Zone (AEZ)-19; under Old Meghna Estuarine Floodplain Soils. This trial was conducted to derive the economic consequences of two cropping patterns, viz. IP: improved pattern (Mustard-Boro rice-Fallow) and FP: farmer's pattern (Fallow-Boro rice-Fallow) by incorporating high-yielding varieties with improved management practices. In the improved pattern, mustard var. BARI Sarisha-14 was introduced during the fallow period. Boro rice var. BRRI dhan29 was used in both farmer's and improved patterns, respectively. The agronomic parameters and cultural operation for crop production under improved and farmer's practices are presented in Table 2. All farmers' field operations, management practices, and improved patterns were closely monitored, and the data were recorded for agro-economic performance. Agronomic performance viz. land-use efficiency, production efficiency, equivalent rice yield and benefit-cost ratio of cropping patterns were calculated. Land use efficiency is calculated by taking the total duration of an individual crop in a sequence divided by 365 days (Tomer and Tiwari, 1990). The following formula calculates it:

Land use efficiency= $\frac{d_1 + d_2}{365} \times 100$ Where d_1 and d_2 are the duration of the first and second crop of the pattern

Production efficiency: Production efficiency values in Kg./ha/day were calculated by total production in a cropping sequence divided by the entire duration of crops in that sequence (Lal et al., 2017; Tomer and Tiwari. 1990).

$$\text{Production Efficiency} = \frac{Y_1 + Y_2}{d_1 + d_2}\ kg/ha/day$$

Where Y_1= Yield of first crop and d_1= Duration of the first crop of the pattern; and Y_2= Yield of second crop and d_2= Duration of the second crop of the pattern.

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

$$\text{Rice equivalent yield (t/ha/yr)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

The economic indices like gross return, gross margin and marginal benefit-cost ratio were also calculated based on the prevailing market price of the product. The economic analysis involved collecting data on prices and quantities of inputs used and output produced. The inputs used included seed, fertiliser, labour and insecticides. The MBCR of the farmer's prevalent pattern and any replacement for it can be computed as the marginal value product ((MVP) over the marginal value cost (MVC). The marginal product of a prevalent pattern (F) and any potential replacement (E) for it was computed as (CIMMYT, 1988).

$$\text{Marginal Benefit-Cost Ratio (MBCR)} = \frac{\text{Gross return (E) - Gross return (F)}}{\text{TVC (E) - TVC (F)}} = \frac{MVP}{MVC}$$

4. Results and Discussion

Mustard is the most dominant oilseed crop in Bangladesh and has experienced an expansion in the area, production and yield over time while facing the fierce competition for land to produce cereals, e.g., rice, wheat and maise. The total cropped area of mustard has increased from 735 thousand acres in 2002 to 764 thousand acres in 2019; production from 218 thousand metric tons to 358 thousand metric tons; and yield from 732 kg/ha to 1157 kg/ha during the same period (BBS, 2020). Mustard covers 80% of the area under oilseed crops (Miah et al., 2015). The production of high-yielding variety mustard rose sharply, while local one rose slower.

Results of three years of improved cropping pattern (Mustard- Boro rice- Fallow) and farmer's existing pattern (Fallow- Boro rice- Fallow) are presented in Tables 2 to 5.

Grain/ Seed yield

The total field duration of improved cropping pattern (IP) is 174-191 days against 110-117 days of existing farmer's pattern, indicating that mustard can easily be fitted before boro rice cultivation at upper catena of haor areas. The grain yield of boro rice in an improved cropping pattern (6.5 t/ha) was significantly higher than the farmer's existing pattern (6.43 t/ha) might be due to improved management and the residual effect of the mustard crop. Mustard seed yield at improved cropping pattern was 1.4 t/ha, 1.97 t/ha and 1.85 t/ha in the first, second and third year, respectively, with an average of 1.74 t/ha. Similar results were also obtained by Nazrul et al. (2013) and Khan et al. (2005) in the case of rice-based cropping sequences.

By-product yield

The improved cropping pattern produced a lower average rice by-product yield (3.55 t/ha) than the farmer's existing pattern (3.9 t/ha) (Table 3). It might be due to the residue of fertilisers used in mustard. In the case of mustard, the average straw yield was found to be 3.0 t/ha (Table 2), and this straw of mustard was sold as good fodder and fuel in the haor areas.

Rice equivalent yield

The improved cropping crop (IP) component crops gave higher rice equivalent yields against grain yield and by-product yields. The mean rice equivalent yield of the improved cropping pattern was (11.27 t/ha), which was 65.75% higher than the farmer's traditional cropping pattern (6.96 t/ha) in terms of grain as well as by-product yield (Table 4). Including a crop with high-yielding varieties and improved management practices in the improved pattern increased the equivalent rice output. This finding was supported by Nazrul *et al.* (2017). The lower rice equivalent yield was obtained in the farmer's pattern with only one crop and traditional management practices in the haor areas.

Production efficiency

The improved cropping pattern's lower production efficiency was observed (Table 5). The result indicates that two crops, i.e. boro rice and mustard, remained in the field for extended periods. In the farmer's pattern, only boro rice remained for a short period, and that's why production efficiency was higher for the farmer's existing system (61.32 kg/ha/day) than for the improved pattern (61.14 kg/ha/day).

Land use efficiency

Land use efficiency is the effective use of land in a cropping year, which mainly depends on crop duration in the pattern. The average land-use efficiency indicated that the improved pattern used the land for 50.14% of the year, whereas the farmers' pattern used the land for 31.05% of the year. Land use efficiency was 61.47% higher in the improved pattern than in the farmers' pattern. This higher land-use efficiency in the improved pattern is due to the cultivation of mustard as a component crop in the fallow period.

Financial analysis

From the financial point of view, the improved cropping pattern (IP) showed its superiority over the farmer's existing cropping pattern (FP). The Gross return of the improved cropping pattern was Tk.214668, which was about 54% higher than the farmer's pattern (Table 5). The average total production cost per hectare of the improved pattern (TK. 121188) was higher than that of the farmer's pattern (TK. 95115) due to the cultivation of an additional crop (mustard) and improved management practices. The gross margin of the improved cropping pattern was 91% higher than the farmer's existing pattern due to the higher yield advantages of the component crop. Though the cost of cultivation in the improved cropping pattern was much higher, BCR was also higher (1.77) than in the farmers' pattern (1.46) due to the higher yield and the high price of mustard. The mean marginal benefit-cost ratio (MBCR) was 2.91, which indicated the superiority of the two crops' patterns over the farmers' patterns. The marginal benefit-cost ratio (MBCR) also showed that the inclusion of mustard in the existing pattern might be profitable and acceptable to the farmers. These results are supported by Mondal et al. (2015). They reported that the inclusion of T.Aus, potato, mustard and mungbean in the existing pattern was profitable and acceptable to the farmers and grown successfully one after another in the one-year cycle.

5. Conclusion

Three years study revealed that mustard could be easily fitted in the existing pattern with higher rice equivalent yield and higher benefit. Besides, the cultivation of two crops, Mustard (var. BARI Sarisha-14)-Boro rice (var. BRRI dhan29)- Fallow pattern in a year in the same piece of land could be created more employment opportunities, as well as increased production of rice and mustard for the farmers at the same time cropping intensity and productivity, could be improved.

Table 2: Agronomic practices of improved cropping patterns (IP) and farmer's existing cropping patterns (FP) during 2017/18-2019/20

Parameters	Improved pattern (IP)			Farmer's pattern (FP)		
	Mustard	Boro rice	Fallow	Fallow	Boro rice	Fallow
Variety	BARI Sharisha-17	BRRI dhan29	Fallow	Fallow	BRRI dhan29	Fallow
Date of Sowing/ Transplanting	24 October - 03 November	19 January-04 February	-	-	25 December-10 January	-
Seed rate (kg/ha)	8	50	-	-	50	-
Planting method	Broadcast	Line	-	-	Line	-
Spacing (cm) (Row x Hill)	Broadcast	25 x 15	-	-	25 x 15	-
Fertilizer dose (kg/ha) ($NPKSZ_nB$)	115-32-40-25-2-2	140-18-53-8-3-2	-	-	150-25-60-10-5-5	-
Fertiliser application method	Half of N and all $PKSZ_n$ used as basal during final land preparation, and the rest of N fertiliser should be applied before flower initiation at 15 to 20 DAS.	All $PKSZ_n$ with one-third nitrogen was used as basal during final land preparation. Rest of one-third N was used at 15-20 DAT, and another one-third applied 5-7 days before panicle initiation.	-	-	All $PKSZ_n$ with one-third nitrogen was used as basal during final land preparation. Rest of one-third N was used at 15-20 DAT, and another one-third applied 5-7 days before panicle initiation.	-
Wedding (no.)	-	2	-	-	2	-
Insect-Pest control	IPM	IPM	-	-	Chemical	-
Harvest time (Time)	10 January-04 February	25 April-15 May	-	-	13-20 April	-
Field duration (days)	78-90	96-101	-	-	110-117	-

Note- FP: Farmer's pattern, IP: Improved pattern

Table 3: Yield of different crops under improved cropping pattern (IP) and farmer's existing cropping pattern (FP) in haor area during 2017/18-2019/20.

Parameters	year	Improved cropping pattern (IP)			Farmer's cropping pattern (FP)		
		Mustard	Boro	Fallow	Fallow	Boro	Fallow
Grain yield (t/ha	2017-18	1.4	5.56	-	-	6.0	-
	2018-19	1.97	6.8	-	-	6.0	-
	2019-20	1.85	7.15	-	-	7.3	-
	Average	1.74	6.5	-	-	6.43	-
Straw yield (t/ha)	2017-18	2.8	2.86	-	-	3.6	-
	2018-19	3.0	3.5	-	-	3.7	-
	2019-20	3.2	4.3	-	-	4.4	-
	Average	3.0	3.55	-	-	3.9	-

Table 4: Rice equivalent yield, production efficiency and land-use efficiency of an improved pattern (IP) and farmer's pattern (Average of 2017/18- 2019/20)

Parameters	Years	Mustard-Boro-Fallow (IP)	Fallow-Boro-Fallow (FP)	Increased (%)
Rice equivalent yield (t/ha)	2017-18	8.36	6.32	32.28
	2018-19	12.51	6.82	83.43
	2019-2020	12.87	7.74	66.28
	Average	11.27	6.96	61.93
Land use efficiency (%)	2017-18	47.67	30.14	58.18
	2018-19	50.41	30.96	62.83
	2019-2020	52.33	32.06	63.25
	Average	50.14	31.05	61.47
Production efficiency (kg/ha/day)	2017-18	48.05	57.46	-16.38
	2018-19	67.99	60.35	12.66
	2019-2020	67.38	66.15	1.86
	Average	61.14	61.32	-0.29

Table 5: Cost and return of improved and farmer's existing cropping pattern in haor area during 2017/18-2019/20.

Years	Parameters	Improved cropping patterns (IP)	Farmer's cropping pattern (FP)	Increased over FP (%)
2017-18	Grass return (Tk./ha)	186915	139040	34.43
	Total cost (Tk./ha)	111378	99761	11.64
	Total variable cost (Tk./ha)	100378	88761	13.09
	Gross margin (Tk./ha)	86537	50279	72.11
	BCR	1.68	1.39	20.86
2018-19	Grass return (Tk./ha)	225090	122760	83.36
	Total cost (Tk./ha)	128806	88153	46.12
	Total variable cost (Tk./ha)	117480	76827	52.91
	Gross margin (Tk./ha)	107610	45933	134.28
	BCR	1.75	1.39	25.90
2019-20	Grass return (Tk./ha)	232000	154800	49.87
	Total cost (Tk./ha)	123380	97430	26.63
	Total variable cost (Tk./ha)	112400	86450	30.02
	Gross margin (Tk./ha)	119600	68350	74.98
	BCR	1.88	1.59	18.24
Mean	Grass return (Tk./ha)	214668	138867	54.59
	Total cost (Tk./ha)	121188	95115	27.41
	Total variable cost (Tk./ha)	110086	84013	31.03
	Gross margin (Tk./ha)	104582	54854	90.66
	BCR	1.77	1.46	21.23
MBCR	2017-18	4.12	-	-
	2018-19	2.52	-	-
	2019-20	2.97	-	-
	Mean	2.91	-	-

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