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IMPROVEMENT OF MUSTARD-*BORO-T. AMAN* RICE CROPPING PATTERN THROUGH REPLACING CROP VARIETIES FOR TANGAIL REGION

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Abstract

The experiment was conducted at the farmers field of FSRD site Atia, Delduar, Tangail during two consecutive years of 2018-19 and 2019-20 to develop improved cropping pattern Mustard (var. BARI Sarisha-14) - Boro (var. BRRI dhan29) - T.Aman rice (var. BRRI dhan72) and to compare its productivity and profitability against existing cropping pattern Mustard (var. Tori-7)- Boro (var. BRRI dhan29) - T.Aman rice (var. BR 11) through changing varieties of mustard and T.Aman rice with improved management practices. The experiment was laid out in a randomized complete block design with six dispersed replications. The improved management practice produced significantly higher yield in Mustard and T. Aman rice, respectively. The result showed that mean rice equivalent yield of improved cropping pattern was 16.80 t ha^{-1} which was 24 % higher than existing cropping pattern (13.50 t ha^{-1}). Besides, production efficiency, land use efficiency, harvest index and profitability of improved cropping pattern was higher than farmers' existing pattern. The mean gross return (Tk. 279720 ha^{-1}) and gross margin (Tk. 104073 ha^{-1}) were higher in improved cropping pattern compared to existing farmer's pattern with only 7.82% extra cost. The marginal benefit cost ratio (4.05) also indicated the superiority of the improved cropping pattern over the farmers' existing pattern.

Keywords: Grain yield, rice equivalent yield, production efficiency, harvest index and profitability.

Introduction

In Bangladesh horizontal expansion is very limited, but increase in crop production could be possible with vertical expansion through increasing crop yield per unit area and by reducing production losses. A cropping pattern is the yearly sequence, temporal and spatial arrangement of crops in a given land area. The cropping pattern and the changes therein depend on a large number of factors like climate, soil type, rainfall, agricultural technology, availability of irrigation facilities and other inputs, marketing and transport facilities and growth of agro-industries (Gadge, 2003).

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Bangladesh Rice Research Institute (BRRI) has recommended the T. *Aman*-Mustard-*Boro* cropping pattern for the irrigated ecosystem (Khan *et al*., 2004) with the inclusion of 70-75 days local mustard variety (Tori-7) in the transition period between T. *Aman* and *Boro* rice. But the farmers harvest poor yield from local var. Tori-7 that could be increased manifold by introducing high yielding varieties (Basak *et al.*, 2007). Bangladesh Agricultural Research Institute (BARI) has developed high yielding yellow seeded mustard (*Brassica campestris*) varieties, BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-17 whose yield potentials are higher than Tori-7 and have been recommended for T. *Aman*-Mustard-*Boro* cropping sequence. Inclusion of these new varieties of mustard with growth duration of 80-85 days in between short duration T. *Aman* rice (115-120 days) and *Boro* rice can create opportunity to fit in the T. *Aman* -Fallow-*Boro* cropping sequence. Mustard- *Boro*-T. *Aman* is one of the existing dominant cropping pattern at FSRD site Atia, which covers around 10.76 % of the cultivated land of the locality (DAE, 2020). To boost up crop production replacement of crop varieties needs to be essential which is possible, if short duration T. *Aman rice variety* is included in the pattern. The crop residue from mustard crop contributed to enrich soil fertility and benefit the succeeding rice crop (Singh and Ghosh, 1999). Therefore, the present study was designed to evaluate the profitability of variety replacing in Mustard-*Boro*-T.*Aman* rice cropping pattern in Tangail region.

Materials and Methods

The trial was conducted to increase crop productivity by replacing varieties of mustard and T.Aman rice in the existing cropping system Mustard (var.Tori-7)-*Boro* (var. BRRI dhan29)-T.*Aman* (var. BR 11) during 2018-19 and 2019-20. The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) of Tangail. The geographical position of the area in between $24^{o}16^{/}$ N latitude and $89^{o}90^{/}$ E longitude. The land was medium high and the soil of the study area was sandy loam in texture with well drainage system and almost neutral in reaction having pH range of 6.0 to 6.9. General soil types predominantly includes Dark Grey Floodplain soils. Organic matter content was low, top soils were acidic to neutral and sub-soils were neutral in reaction. In general, fertility level including N, K and B was low. Maximum rainfall was received during the months of April to September. The highest temperature (33.9^{o}C) in August and the lowest in December (10.1^{o}C). The relative humidity was the highest (84.5%) in August and the lowest (75.2 %) in March. The crop received (140.5 mm) rain from October to March. Monthly mean maximum and minimum air temperature (31.9 and 19.3^{o}C), total rainfall (2018 mm) and relative humidity (82.7 %) were prevailing during the study period.

The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping pattern viz., improved pattern and farmers' existing pattern were the treatments variables of the experiment. The unit plot size was 1000-1200 sq.m. Mustard was grown during *rabi* season and it was the first crop of the sequence. Fertilizer management (FRG, 2018) and intercultural operations like weeding, mulching, irrigation and pest management were done. Mustard var. BARI Sarisha-14 was seeded as broadcast method with seed rate of 6 kg ha^{-1}. The crop was sown during 12 to 16 November, 2018 and 07-12 November 2019 and harvested during 05 to 08 February 2019 and 03-12 February 2010, respectively. *Boro* rice was the second crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 40-45 days old seedlings of rice var. BRRI dhan29 at a spacing of 20 cm × 15 cm during 15 to 18 February 2019 and 08-16 February 2020. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). Boro rice was harvested during 25-30 June 2019 and 24-29 June 2020 in two consecutive years. Rice plant was harvested at 30 cm height from soil surface and remaining parts of the plants was incorporated in soil. T. *Aman* rice was the third crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 25-30 days old seedlings of T. *Aman* rice var. BRRI dhan72 were transplanted with 20 cm × 15 cm during 25-31 July 2019 and 21-25 July 2020 in two consecutive years. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). T. *Aman* rice was harvested during 25 to 30 October, 2019 and 18 to28 October, 2020 in two successive years. T. *Aman* rice plant was harvested at 15 cm from soil surface and remaining parts of the plants was incorporated in soil. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated.

Rice Equivalent Yield (REY): For comparison between crop sequences, the yield of every crop was converted into rice equivalent yield on the basis of prevailing market price of individual crop (Verma and Modgal, 1983). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by market price of that crop divided by market price of rice.

$$\textbf{Rice Equivalent Yield (t ha}^{-1}\textbf{)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

Production Efficiency: Production efficiency value in terms of $kgha^{-1}day^{-1}$ was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

Production Efficiency (kgha^{-1}day^{-1}) = $\frac{\sum Y_i}{\sum d_i}$

Where, Y_i= Yield (kg) of ith crop, d_i= Duration (day) of ith crop of the pattern and i= 1, 2, 3, 4

Land utilization index (LUI): It was worked-out by taking total duration of crops in an individual cropping pattern divided by 365 days (Rahman *et al.*, 1989). It was calculated by the following formula:

Land Utilization Index (%) = $\frac{d_1 + d_2 + d_2 + d_4}{365} \times 100$

Where d_1, d_2, d_3 and d_4 the duration of 1st, 2nd 3rd and 4th crop of the pattern

Harvest index (HI) was calculated as per following equation:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Economic analysis was done on the basis of prevailing market price of the commodities. The inputs used included seed, fertilizer, 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 of prevalent pattern (F) and any potential replacement (E) which was computed as (CIMMYT, 1988).

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

Results and Discussion

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, irrigation, weeding and application of pesticides etc. of improved and existing cropping pattern are shown in Table 1. The mean crop field duration of mustard, *Boro* and T. *Aman* rice under improved cropping pattern: Mustard (var. BARI Sarisha-14)-*Boro* (var. BRRI dhan29)-T. *Aman* rice (var. BRRI dhan72) were 83-84, 127-128 and 85-86 days, respectively while, in existing cropping pattern Mustard (Tori-7)-*Boro* (BRRI dhan29)-T. *Aman* rice (BR11) were 76-77, 127-128 and 108-110 days for Mustard, *Boro* and T. *Aman*, respectively. Total field duration of improved cropping pattern and existing cropping pattern were 296-297 and 311-312 days, respectively. The crop duration of T. *Aman* rice under existing cropping pattern was higher (108-110 days) than that of improved cropping pattern (85-86 days) due to use of long duration BR11 variety in T. *Aman*. But in improved cropping pattern, short duration of T. *Aman* rice (BRRI dhan72) was cultivated and it was harvested during 18-30 October in both years. After harvesting of T. *Aman* rice mustard was easily sown in optimum period. Turnaround times for improved and existing cropping pattern were 68-69 and 51-53 days, respectively.

Grain/Seed and By-product yield

Results of the study have been presented in Table 2. Seed yield of mustard var. BARI Sarisha-14 were 1.79 and 1.75 tha^{-1} and stover yields were 2.41 and 2.50 tha^{-1} in two successive years, respectively. Average seed yield of BARI Sarisha-14 in improved cropping pattern was 1.77 t ha^{-1} which was more than 70 % higher than Tori-7. Grain yield of Boro rice was 6.49 t ha^{-1} in 1^{st} year and 6.56 t ha^{-1} in 2^{nd} year whereas T. *Aman* rice grain yields were 5.42 and 5.36 t ha^{-1} in 1^{st} and 2^{nd} year. Mean grain and straw yields of *Boro* rice were 6.53 and 6.47 t ha^{-1} which was 4.48 and 9.48 % higher over farmers' pattern. Mean grain and straw yield of T. *Aman* rice (var. BRRI dhan72) in improved cropping pattern was 5.39 and 5.30 t ha^{-1}, respectively which was 13 and 9 % higher than existing pattern T. *Aman* rice (BR11) due to change of variety with improved production technologies. Similar results were also obtained by (Nazrul *et al*., 2013 and Khan *et al*., 2006). Farmers' pattern gave lower yield due to imbalance use of fertilizers and poor management practices. It was revealed that the entire component crops of Mustard-Boro-T. *Aman* rice cropping pattern under improved practices (IP) gave higher yield as well as by-product yield in two consecutive years. Inclusion of mustard var.BARI Sarisha-14 and BRRI dhan72 with improved production technologies increased the total yield over the farmers existing cropping pattern practice. Similar results were also obtained by (Nazrul *et al*., 2013). BARI Sarisha 14 is a short duration high yielding mustard variety which can easily be grown in between *Boro* and T. *Aman* rice (Mondal *et al*., 2015).

Field duration

Field duration of cropping pattern mainly depends on individual duration of component crops. In farmer's existing cropping pattern (FECP), (Mustard- *Boro*-T. *Aman*) farmers used Tori-7 as mustard variety, BRRI dhan29 in *Boro* and BR11 in T. *Aman* season. On the other hand in improved pattern BARI Sarisha-14 was used as mustard, BRRI dhan29 in *Boro* and BRRI dhan72 in T. *Aman* season. BARI Sarisha-14 needs 6-8 more days to attained maturity than Tori-7 but BRRI dhan72 matured 22-25 days earlier than BR11. As a result, production efficiency was higher in improved cropping pattern than farmers' existing cropping pattern (Table 1).

Table 1. Agronomic parameters of improved pattern and farmers' existing pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Parameters	Years	Improved Pattern (IP)			Farmers' Pattern (FP)		
Crop	2018-19	Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
	2019-20	Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
Variety	2018-19	BARI Sarisha-14	BRRI dhan29	BRRI dhan72	Tori-7	BRRI dhan29	BR11
	2019-20	BARI Sarisha-14	BRRI dhan29	BRRI dhan72	Tori-7	BRRI dhan29	BR11
Sowing/ planting time	2018-19	12-16 Nov.	15-18 Feb.	25-31 Jul.	10-15 Nov.	06-15 Feb.	08-14 Jul.
	2019-20	07-12 Nov.	08-16Feb.	21-25 Jul.	11-16 Nov.	06-19 Feb.	09-13 Jul
Seedling age (days)	2018-19	-	35-40	25-30	-	40-45	30-35
	2019-20	-	35-40	25-30	-	35-40	30-35
Spacing (cm)	2018-19	Broadcast	25 × 15	25 × 15	Broadcast	25 × 15	25 × 15
	2019-20	Broadcast	25 × 15	25 × 15	Broadcast	25 × 15	25 × 15
Fert. dose (N-P-K-S-Zn-B kg ha^{-1})	2018-19	100-32-40-24-1-1	140-15-45-10-2	70-10-40-10-2	70-15-17	115-24-50-20	90-20-40-20
	2019-20	100-32-40-24-1-1	140-15-45-10-2	70-10-40-10-2	70-15-17	115-24-50-20	90-20-40-20
Harvesting time	2018-19	05-08 Feb.	25-30 Jun.	25-30 Oct.	25-30 Jan.	13-15June	24-31 Oct.
	2019-20	03-12 Feb.	24-29 Jun	18-28 Oct.	24-29 Jan.	14-19 June	22-26 Oct.
Field duration (days)	2018-19	84	127	86	76	127	108
	2019-20	83	128	85	77	128	110
TAT (days)	2018-19	26	12	40	15	12	24
	2019-20	27	11	41	17	14	25

Note: IP= Improved Pattern and FP=Farmers' Pattern.

Table 2. Seed/Grain yield and By-product of Mustard-*Boro*-T.*Aman* rice cropping patterns under improved and farmer's practices at the FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Grain/Seed yield (t ha^{-1})			By-Product yield (t ha^{-1})		
		Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
2018-19	IP	1.79	6.49	5.42	2.41	6.45	5.30
	FP	0.98	6.19	4.98	1.88	6.42	5.17
2019-20	IP	1.75	6.56	5.36	2.50	6.49	5.30
	FP	1.10	6.30	4.56	1.98	6.70	4.85
Mean	IP	1.77	6.53	5.39	2.46	6.47	5.30
	FP	1.04	6.25	4.77	1.69	5.91	4.86

Table 3. Rice equivalent yield, production efficiency, land utilization index and harvest index of improved pattern and farmers' practices at the FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency (kg$ha^{-1}$$day^{-1}$)	Land utilization index (%)	Harvest Index (%)
2018-19	IP	16.84	47.74	78.63	49
	FP	13.50	39.08	85.21	47
2019-20	IP	16.75	47.80	78.36	49
	FP	13.91	37.97	86.30	47
Mean	IP	16.80	47.77	78.50	49
	FP	13.71	38.53	85.76	47

Table 4. Cost and return analysis of improved cropping pattern and farmers' cropping pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk.ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
2018-19	IP	280380	175045	105335	3.60
	FP	224460	159518	64942	
2019-20	IP	279060	176250	102810	4.49
	FP	234360	166300	68060	
Mean	IP	279720	175648	104073	4.05
	FP	229410	162909	66501	

Price (Tk. kg^{-1}): Mustard-50.0, Boro rice-15.0, T.aman-16.0,Stover-1.0 and Straw-2.0.

Rice Equivalent Yield (REY):

Total productivity of a cropping system was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. The mean higher rice equivalent yield (16.80 t ha^{-1}) was recorded with the improved cropping system over farmer's traditional cropping system (Table 3). Rice equivalent yield increased about 23 % due to inclusion of new high yielding varieties with improved production technologies for the component crops. The lower rice equivalent yield (13.71 t ha-1) was obtained in the farmer's pattern with three crops, local variety in mustard & old *Aman* rice and traditional management practices, respectively. It is evident from the above findings that improved cropping pattern gave higher yield compared to existing farmers' pattern. Similar results were obtained by Khatun *et al*. (2016) and Nazrul *et al*. (2017).

Production Efficiency

Mean maximum production efficiency (47.77) in terms of kg $ha^{-1}day^{-1}$ was obtained from improved cropping pattern which was 23.98 % higher over existing cropping pattern (Table 3). Production efficiency of improved cropping pattern was found to be 47.74 and 47.80 kg $ha^{-1}day^{-1}$ in two consecutive years while in existing cropping pattern it was found to be 39.08 and 37.97 kg $ha^{-1}day^{-1}$, respectively. The higher production efficiency in improved cropping pattern might be due to inclusion of high yielding mustard and T. *Aman* rice varieties and improved management practices. Similar trend were noted by Nazrul *et al*. (2013). The lower production efficiency was observed in farmer's pattern (Tables 3). The result indicates that the crops remained in the field for longer time and yields were also lower in farmer's traditional system, leading to lower production per day. On the contrary, crops remain standing in the field for shorter time with higher yield in improved practices, leading to higher production efficiency.

Land use efficiency

Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The average land-use efficiency indicated that improved pattern used the land for 81.24 % period of the year whereas farmer's pattern used the land for 85.76 % period of the year (Table 3). This higher land use efficiency in existing cropping pattern is due to cultivation of long duration component crops in the pattern.

Harvest Index

Improved cropping pattern Mustard (Var. BARI Sarisha-14) - *Boro* (var. BRRI dhan29) - T. *Aman* rice (var. BRRI dhan72) recorded the higher harvest index

(49 %) over existing cropping pattern Mustard (var. Tori-7)- *Boro* (var. BRRI dhan29) - T. *Aman* rice (var. BR 11). The harvest index of improved cropping pattern had higher value due to replacing mustard and T. *Aman* varieties which contributed the higher economic and biological yield.

Profitability Analysis

Profitability analysis was done on the basis of prevailing market price during the crop season. Improved cropping pattern showed its superiority over farmers' existing cropping pattern. The study revealed that mean gross return of the improved and farmers' pattern was Tk.279720 and Tk. 229410, respectively (Table 4) The mean gross return of improved cropping pattern was 22 % higher than farmers' existing pattern and it might be due to replacing of high yielding mustard and T. *Aman* rice varieties.

The mean total variable cost of the improved and farmers' existing cropping pattern was Tk. 175648 and Tk. 162909 ha^{-1}, respectively. About 56 % higher gross margin (Tk. 104073 ha^{-1}) was calculated at improved pattern over existing cropping pattern (Tk. 66501 ha^{-1}). The mean MBCR was found 4.05 which indicated the superiority of improved cropping pattern over existing cropping pattern.

Conclusion

The total crop productivity (in terms of REY), production efficiency and profitability of improved cropping pattern Mustard (var. BARI Sarisha-14) - *Boro* rice (Var. BRRI dhan29) - T. *Aman* rice (var. BRRI dhan72) were much higher than that of existing cropping pattern, Mustard (var. Tori-7)- *Boro* (Var. BRRI dhan29) - T. *Aman* rice (var. BR 11) due to replacing of HYV short duration mustard and T. *Aman* rice varieties. Thus, Improved cropping pattern mustard (var. BARI Sarisha-14)–*Boro* (var. BRRI dhan-29)-T. *Aman* (var. BR 11) is economically as well as agronomically suitable technology. This improved cropping pattern could be demonstrated for large scale production to exhibited areas in the high and medium high land of AEZ-9 and similar areas in Bangladesh with the collaboration of DAE and BARI for higher impact.

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