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INCREASING CROPPING INTENSITY, PRODUCTIVITY AND PROFITABILITY THROUGH IMPROVED CROPPING PATTERN AGAINST FARMERS' EXISTING CROPPING PATTERN AT MADHUPUR, TANGAIL

M.A.H. Khan[1*], M.M. Rahman[1], T. Tasmima[1], and F. Begum[2]

[1]On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail, Bangladesh,
[2]Oilseed Research Centre, Agricultural Research Institute, Joydebpur, Bangladesh.
*Corresponding author, Email: helim1367@gmail.com

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Abstract

An on-farm trial was conducted at the farmers' field of Madhupur under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during 2021-22 and 2022-23 to develop improved cropping pattern mustard (var. BARI Sarisha-18)-T. *Aus* (var. BRRI dhan48)-T. *Aman* (var. BRRI dhan87) and to compare its productivity and profitability against farmers existing cropping pattern Fallow-*Boro* (var. BRRI dhan29)-T. *Aman* (var. BRRI dhan49) by inclusion of mustard (var. BARI Sarisha-18)-T. *Aus* (var. BRRI dhan48) and T. *Aman* (var. BRRI dhan87) with improved management practices. The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping patterns viz., improved cropping pattern (Mustard-T. *Aus*-T. *Aman*) and farmers' existing cropping pattern (Fallow-*Boro*-T. *Aman*) were the treatment variables of the experiment. The unit plot size was 1000-1200 m^2. The result of the study showed that three crops could be grown successfully in sequence in the tested site. Mean rice equivalent yield of improved cropping pattern was 16.95 t ha^{-1} which was 54 % higher over existing cropping pattern (11.01 t ha^{-1}). Besides, land utilization index, harvest index and profitability of improved cropping pattern was higher than farmers' existing cropping pattern. The mean gross return (Tk. 523830 ha^{-1}) and gross margin (Tk. 334281 ha^{-1}) were higher in improved cropping pattern compared to farmers' existing cropping pattern with only 21% extra cost. The marginal benefit cost ratio (4.44) was also indicated by the superiority of the improved cropping pattern over the farmers' existing cropping pattern.

Introduction

Bangladesh is almost self-sufficient in rice production but other food production such as oil crops, pulses, wheat and vegetables etc. are still largely deficient. Mustard is one of the *Rabi* crops in Bangladesh though the largest area is still under T. *Aman* rice cultivation during monsoon season. However, most of the *Aman* rice area is covered with long duration T. *Aman* varieties which causes a delay in mustard crop sowing, resulting in reduced yield. The present cropping intensity of the country is 198%. The urgent need is to produce more food to feed the teeming populations. Food requirements are estimated to have doubled in the next 25 years. Under such a situation, it is very important to improve the existing cropping pattern. There are some scopes of increasing cropping intensity from existing level of 198% by improving existing cropping patterns by incorporating short duration crops viz., mustard, *Aus* rice, potato, and pulses in the rice-based cropping system (Khatun *et al.*, 2019).

A cropping pattern is the yearly sequence, temporal and spatial arrangement of crops in each land area. The cropping pattern and the changes therein depend on many 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). Bangladesh Agricultural Research Institute (BARI) has developed high yielding brown seeded mustard (*Brassica napus*) variety BARI Sarisha-18 whose yield potential is 30-40% higher than BARI Sarisha-14 and have been recommended for Mustard-T.*Aus*-T.*Aman* cropping sequence. Inclusion of this new variety of mustard with growth duration of 95-100 days in between short duration T. *Aman* rice (115-120 days) and T. *Aus* rice can create opportunity to fit in the Mustard-T. *Aus*-T. *Aman* cropping sequence. There are 10 major cropping patterns which are practiced by the farmers' of Tangail region, among which Fallow-*Boro*-T. *Aman* is one of the major cropping patterns under irrigated high and medium high land of Madhupur upazila, Tangail. This pattern covers around 44% of the net cropped area (DAE, 2021). After the harvest of T. *Aman* and before transplanting of planting of *Boro* the land remains fallow for around 3 months. Mustard is a high value crop which can be easily grown in between two crops. Boosting 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.

Overall productivity as well as profitability of the farmers could be increased considerably by introducing modern varieties and improved management practices. Several reports on different cropping pattern are available in Bangladesh and abroad (Nazrul *et al.*, 2013; Khatun *et al.*, 2019) but little efforts have been made for on-farm evaluation of the improved technologies of Mustard-T. *Aus*-T. *Aman* cropping pattern. The study was therefore initiated with a view to finding out the agroeconomic performance of an improved package of technologies over the existing farmers' practices. Therefore, the present study was designed to evaluate the productivity, profitability and increasing cropping intensity by inclusion of Mustard-T. *Aus*-T. *Aman* rice cropping pattern in Tangail region.

Materials and Methods

The trial was conducted at the farmers' field of Madhupur under On-Farm Research Division, BARI, Tangail during 2021-22 and 2022-23 to increase cropping intensity, productivity and profitability of the farmers by inclusion of mustard (var. BARI Sarisha-18)-T. *Aus* (var. BRRI dhan48) and T. *Aman* (var. BRRI dhan87) in the existing cropping system Fallow-*Boro* (var. BRRI dhan29)-T. *Aman* (var. BRRI dhan49). The experimental site belongs to Madhupur Tracts Agro-ecological Zone (AEZ-28) of Tangail. The geographical position of the experimental site is at approximately 24°64′ N latitude and 90°09′ E longitude with an altitude of 19 m above sea level. The land was medium high, and the soil of the study area was clay loam to clay in texture with well drainage system and almost acidic in reaction having pH range of 4.3 to 6.5. Maximum rainfall was received during the months of April to September. The highest temperature (33.9°C) in August and the lowest in December (10.1°C). The relative humidity was the highest (84.5%) in August and the lowest (75.2%) in March. Monthly mean maximum and minimum air temperature (31.9 and 19.3°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 (RCBD) with six dispersed replications. Two cropping patterns viz., improved cropping pattern and farmers' existing pattern were the treatment variables of the experiment. The unit plot size was 1000-1200 m^2. Mustard was grown during *Rabi* season, and it was the first crop of the sequence. Fertilizer management was followed by (Ahmmed *et al.*, 2018) and intercultural operations like weeding, irrigation and pest management were done to support the normal growth and development of the crops. Mustard var. BARI Sarisha-18 was seeded as broadcast method @ of 6 kg ha^{-1}. The crop was sown during 10 to 19 November 2021 and 14 to19 November 2022 and harvested during 16 to 25 February 2022 and 19 to 24 February 2023, respectively. T. *Aus* rice was the second crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 30 to 35 days old seedlings of rice var. BRRI dhan48 at a spacing of 20 cm × 15 cm during 20 to 25 April 2022 and 18 to 24 April 2023. T. *Aus* rice was harvested during 06 to 10 July 2022 and 02 to 07 July 2023 in two consecutive years. Rice plants were harvested at 30 cm height from soil surface and remaining parts of the plants were incorporated in soil. T. *Aman* rice was the third crop of the sequence. Seedlings of rice were grown in an adjacent plot and transplanting was done with 30 to 35 days old seedlings of T. *Aman* rice var. BRRI dhan87 were transplanted with 20 cm × 15 cm during 25 to 28 July 2022 and 22 to 27 July 2023 in two consecutive years. T. *Aman* rice was harvested during 24 to 27 October 2022 and 23 to 28 October 2023 in two successive years. T. *Aman* rice plant was harvested at 15 cm from soil surface and remaining parts of the plants were incorporated in soil.

Data on the yield of various crops in sequences were recorded and converted to t ha^{-1}. The data of farmer's practice was recorded from adjacent farmers' plots. Agronomic performance like field duration, rice equivalent yield (REY), productivity and land utilization index (LUI) of cropping patterns were calculated.

Rice equivalent yield:

For comparison between crop sequences, the yield of every crop was converted into REY based on 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.

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

Productivity:

Production efficiency value in terms of Kg ha^{-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).

$$\text{Production efficiency (Kg ha}^{-1}\text{day}^{-1}\text{)} = \frac{\sum Y_i}{\sum d_i}$$

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

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:

$$\text{LUI (\%)} = \frac{d_1+d_2+d_3+d_4}{365} \times 100$$

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)

It is the ratio of economic yield and total biological yield of aboveground plant materials. The grain and stover should be at the same moisture content. It has been calculated as per following equation (Rahman *et al.*, 1989).

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

Marginal benefit cost ratio

Marginal benefit cost ratio was done based on 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).

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

Where TVC= Total variable cost

Results and Discussion

Crop management

Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, field duration and turnaround time etc. of improved and existing cropping pattern are shown in Table 1. The mean crop field duration of mustard, T. *Aus* and T. *Aman* rice under improved cropping pattern Mustard (var. BARI Sarisha-18)-T. *Aus* (var. BRRI dhan48)-T. *Aman* rice (var. BRRI dhan87) were 99, 75 and 92 days, respectively while, in existing cropping pattern Fallow- *Boro* (BRRI dhan29)-T. *Aman* rice (BRRI dhan49) were 120 and 102 days for *Boro* and T. *Aman*, respectively. Total field duration of improved cropping pattern and existing cropping pattern were 262-267 and 219-225 days, respectively. The crop duration of T. *Aman* rice under existing cropping pattern was higher (101-103 days) than that of improved cropping pattern (91-92 days) due to use of long duration BRRI dhan49 variety in T. *Aman*. But in improved cropping pattern, short duration of T. *Aman* rice (BRRI dhan87) was cultivated, and it was harvested during 23-28 October in both years. After harvesting T. *Aman* rice mustard was easily sown in optimum time. Turnaround time for improved and existing cropping patterns were 98-103 and 140-146 days, respectively.

Table 1. Agronomic parameters of farmers' existing pattern and improved pattern at MLT site Madhupur, Tangail during 2021-22 and 2022-23

Parameters	Years	Farmers' pattern			Improved pattern		
Crop	2021-22	Fallow	*Boro*	T. *Aman*	Mustard	T. *Aus*	T. *Aman*
	2022-23	Fallow	*Boro*	T. *Aman*	Mustard	T. *Aus*	T. *Aman*
Variety	2021-22	Fallow	BRRI dhan29	BRRI dhan49	BARI Sarisha-18	BRRI dhan48	BRRI dhan87
	2022-23	Fallow	BRRI dhan29	BRRI dhan49	BARI Sarisha-18	BRRI dhan48	BRRI dhan87
Sowing/ planting time	2021-22	Fallow	15-19 Jan.	15-19 Jul.	10-16 Nov.	20-25 Apr.	25-28 Jul.
	2022-23	Fallow	10-15 Jan.	12-16 Jul.	14-19 Nov.	18-24 Apr.	22-27 Jul.
Seedling age (days)	2021-22	Fallow	40-45	30-40	-	30-40	30-35
	2022-23	Fallow	40-45	30-40	-	30-40	30-35
Spacing (cm)	2021-22	Fallow	20 × 15	20 × 15	Broadcast	20 × 15	20 × 15
	2022-23	Fallow	20 × 15	20 × 15	Broadcast	20 × 15	20 × 15
Fertilizer dose (NPKSZnB kg ha^{-1})	2021-22	Fallow	140-15-30-0-3	74-12-40-10-3	90-35-42-26-2-2	140-15-60-15-3	70-15-35-10-4
	2022-23	Fallow	140-15-30-0-3	74-12-40-10-3	90-35-42-26-2-2	140-15-60-15-3	70-15-35-10-4
Harvesting time	2021-22	Fallow	12-16 May.	24-28 Oct.	16-25 Feb.	06-10 Jul.	24-27 Oct.
	2022-23	Fallow	12-15 May	23-27 Oct.	19-24 Feb.	02-07 Jul	23-28 Oct.
Field duration (days)	2021-22	Fallow	118	101	100	75	92
	2022-23	Fallow	122	103	97	74	91
Turnaround time (days)	2021-22	Fallow	86	60	20	58	20
	2022-23	Fallow	79	61	22	59	22

Grain seed^{-1} and by-product yield

Grain seed^{-1} and by-product yield of the study have been presented in Table 2. Seed yield of BARI Sarisha-18 was 2.19 and 2.27 t ha^{-1} and stover yields were 2.29 and 2.37 t ha^{-1} in two successive years, respectively. Two years average result showed that seed and stover yield of BARI Sarisha-18 in improved cropping pattern was 2.23 t ha^{-1} and 2.39 t ha^{-1}. The grain yield of T. *Aus* rice was 4.85 t ha^{-1} in 1st year and 4.93 t ha^{-1} in 2nd year whereas T. *Aman* rice grain yields were 5.63 and 5.74 t ha^{-1} in 1st and 2nd years. Mean grain and straw yields of T. *Aus* rice were 4.89 and 4.94 t ha^{-1}. Two years average, grain and straw yields of T. *Aman* rice (BRRI dhan87) were 5.69 and 5.83 t ha^{-1} in improved cropping pattern, respectively which was 26 and 25% higher than existing pattern T. *Aman* rice (BRRI dhan49) due to change of variety with improved production technologies. Similar results were also obtained by (Nazrul *et al*. 2013). 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-T. *Aus*-T. *Aman* rice cropping pattern under improved practices (IP) gave higher yield as well as by-product yield in two consecutive years. Inclusion of BARI Sarisha-18, BRRI dhan48 and BRRI dhan72 with improved production technologies increased the total yield over the farmers existing practice. Similar results were also obtained by (Nazrul *et al*., 2013).

Table 2. Grain/seed yield and By-product of farmers cropping patterns and improved cropping pattern at MLT site Madhupur, Tangail during 2021-22 and 2022-23

Parameters	Years	Farmers' pattern	Improved pattern

		Fallow	*Boro*	T. *Aman*	Mustard	T. *Aus*	T. *Aman*
Grain seed^{-1} yield (t ha^{-1})	2021-22	-	6.42	4.51	2.19	4.85	5.63
	2022-23	-	6.53	4.55	2.27	4.93	5.74
	Average	-	6.48	4.53	2.23	4.89	5.69
Byproduct yield (t ha^{-1})	2021-22	-	6.72	4.60	2.29	4.89	5.79
	2022-23	-	6.90	4.70	2.37	4.99	5.87
	Average	-	6.81	4.65	2.39	4.94	5.83

Rice equivalent yield

Total productivity of a cropping system was evaluated in terms of REY and it was calculated from yield of component crops. The mean higher rice equivalent yield (16.95 t ha^{-1}) was recorded with the improved cropping system over farmer's traditional cropping system (Table 3). Rice equivalent yield increased by 54% in improved cropping pattern due to inclusion of BARI Sarisha-18 and new high yielding varieties of rice with improved production technologies for the component crops. The lower rice equivalent yield (11.01 t ha^{-1}) was obtained in the farmer's pattern due to two crops *Boro* and T. *Aman* rice with traditional management practices. It is evident from the above findings that improved cropping pattern gave higher yield compared to existing farmers' pattern. Similar results were obtained by Nazrul *et al.* 2017.

Production efficiency

Mean maximum production efficiency (49.69) in terms of Kg ha^{-1} day^{-1} was obtained from farmer's existing cropping pattern which was 3.03% higher over improved cropping pattern (Table 3). Production efficiency of improved cropping pattern was found to be 47.45 and 49.02 Kg ha^{-1} day^{-1} in two consecutive years while in existing cropping pattern it was found to be 49.91 and 49.46 Kg ha^{-1} day^{-1}, respectively. The production efficiency was lower in improved cropping pattern might be due to inclusion of long duration mustard variety as a result average total duration was (43 days) higher than farmer's existing pattern. The lower production efficiency was observed in improved pattern (Table 3). The result indicates that the crops remained in the field for longer time leading to lower production per day. On the contrary, crops remain standing in the field for a shorter time in farmer's practices, leading to higher production efficiency.

Land utilization index

Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The average land utilization index indicated that improved cropping pattern used the land for 72.74% period of the year whereas farmer's pattern used the land for 60.68% period of the year (Table 3). The land utilization index was about 20% higher in improved cropping pattern than farmer's practice due to improved pattern occupied the land for longer duration (265 days) than farmer's pattern (222 days) in a year. This higher land use efficiency in improved cropping pattern is due to cultivation of three component crops in the pattern.

Harvest index

Improved cropping pattern Mustard (Var. BARI Sarisha-18) – T. *Aus* (Var. BRRI dhan48) - T. *Aman* rice (Var. BRRI dhan87) recorded the higher HI (49.43%) over existing cropping pattern Fallow-*Boro* (Var. BRRI dhan29) - T. *Aman* rice (Var. BRRI dhan49). The HI of improved cropping pattern had higher value due to inclusion mustard, T. *Aus* and T. *Aman* varieties which contributed the higher economic and biological yield.

Table 3. Rice equivalent yield, production efficiency, land utilization index and harvest index of farmers' practices and improved pattern at MLT site Madhupur, Tangail during 2021-22 and 2022-23

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency (Kg ha^{-1} day^{-1})	Land utilization index (%)	Harvest index (%)
2021-22	FP	10.93	49.91	60.00	49.12
	IP	16.74	47.45	73.15	49.41
2022-23	FP	11.08	49.46	61.37	48.85
	IP	17.16	49.02	72.33	49.45
Mean	FP	11.01	49.69	60.68	48.99
	IP	16.95	48.23	72.74	49.43

Note: IP= Improved pattern and FP=Farmers' pattern

Profitability analysis

The cost and return analysis were done based on prevailing market price during the crop season as shown in Table 4.

Table 4. Cost and return analysis of farmers' and improved cropping pattern cropping pattern at MLT site Madhupur, Tangail during 2021-22 and 2022-23

Year	Pattern	Gross return (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	MBCR
2021-22	FP	373180	155990	217190	4.35
	IP	517500	189166	328334	
2019-20	FP	378800	156445	222355	4.52
	IP	530160	189932	340228	
Mean	FP	375990	156218	219772	4.44
	IP	523830	189549	334281	

Note: IP= Improved pattern and FP=Farmers' pattern; Unit price (Tk. kg^{-1}): Mustard =80/-, *Boro* rice =30/-, T. *Aus* rice =26/-, T. *Aman* rice = 30/-, stover=2/-, and Rice straw=4/-

The study revealed that mean gross return of the improved and farmers' pattern was Tk 523830 and Tk 375990 ha^{-1}, respectively. The mean gross return of improved cropping pattern was 39% higher than farmers' existing pattern and it might be due to inclusion of high yielding mustard, T. *Aus* and T. *Aman* rice varieties. The mean total variable cost of the improved and farmers' existing cropping pattern was Tk. 189549 ha^{-1} and Tk 156218 ha^{-1}, respectively. About 52% higher gross margin (Tk 1334281 ha^{-1}) was calculated at improved pattern over farmer's existing cropping pattern (Tk 219772 ha^{-1}). The mean MBCR was found 4.44 which indicated the superiority of improved cropping pattern over farmer's existing cropping pattern.

Conclusion

The total crop productivity (in terms of REY), production efficiency and profitability of improved cropping pattern Mustard (Var. BARI Sarisha-18)–T. *Aus* (Var. BRRI dhan48)-T. *Aman* rice (Var. BRRI dhan87) were much higher than that of existing cropping pattern, Fallow- *Boro* (Var. BRRI dhan29)-T. *Aman* rice (Var. BRRI dhan49) due to inclusion of HYV mustard, T. *Aus* and T. *Aman* rice varieties. Thus, Improved cropping pattern mustard (var. BARI Sarisha-18)–T. *Aus* (var. BRRI dhan48)-T. *Aman* (var. BRRI dhan87) 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 and similar areas in Bangladesh with the collaboration of Department of Agricultural Extension (DAE) and BARI for higher impact.

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