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Development of Maize-T. Aus-T. Aman cropping pattern against Maize-Fallow-T. Aman rice

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Abstract

The field experiment was conducted at MLT site Pirganj, Rangpur and Hatibandha' Lalmonirhat for two consecutive years 2015-16 and 2016-17 to introduce T. Aus in the fallow period and to study the comparative agronomic performance and economic return of two cropping sequences (viz. improved cropping pattern; Maize -T. Aus - T. Aman rice and existing cropping pattern; Maize-Fallow-T. Aman rice) for increasing cropping intensity, productivity and land use efficiency. The experiment was laid out in randomized complete block design with six dispersed replications. Two years mean data showed that the improved management practices for the pattern provided significantly higher yield in improved pattern. Higher rice equivalent yield (REY) of cropping system (mean value 17.34 t ha^{-1}) was recorded with the improved pattern over existing pattern at MLT site Pirganj. REY increased 4.60 t ha^{-1} by inclusion of T. Aus with improved production technologies for the component crops. Similar results were also found in Hatibandha. The gross return of the improved pattern was BDT 346764 ha^{-1} which was more than 33.56% higher than farmers' pattern of BDT 259640 ha^{-1} at MLT site Pirganj and in Hatibandha gross return of the improved pattern was BDT 342800 ha^{-1} which was more than 27.77% higher than farmers' pattern of BDT 268300 ha^{-1}. The gross margin was higher in improved cropping pattern in both locations than existing pattern due to addition of T. Aus.

Key words: Land use efficiency, cropping intensity, economic return

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Introduction

The 21st century faces multiple challenges like climate change, population growth, food shortage, poverty, hunger, accelerated land cover change and environmental degradation (Neamatollahi *et al.,* 2017). Due to the inadequate food supply, about 1 billion people stay hungry every day in the world and the figure will increase to 2 billion by 2050. This scenario enforces the increasing momentum in agricultural production with more than 70 percent increase for the developing countries of Asia and Africa in coming decades (Neamatollahi *et al.,* 2017). In this regard, improved cropping pattern, better management practices are essential to enhance agriculture productivity. Due to the rapid change in population and urbanization, land and water resources are becoming very limited. Subsequently, crop optimization has received extensive attention in recent years and improve cropping pattern have been developed to determine the optimal use of the available resources for maximizing the net benefits subjected to some constraints (Osama *et al.*, 2017). Land and water are the key factors for sustainable agricultural development of a nation.

Bangladesh is one of the most densely populated countries of the world. The population will increase to about 200 million (Planning Commission). On the other hand, the cultivable land is decreasing by 1% every year. The total land area of Bangladesh is about 14.84 M ha (million hectares), of which 3.74 M ha (25% of the total) is not available for agriculture due to use for urban areas, industrial buildings, rural homesteads, roads and other infrastructure. The net area of Bangladesh for crop cultivation declined to 7.84 M ha in 2011 from 8.85 M ha in 1985 (BBS, 2012). Bangladesh also suffers regularly from several natural calamities (Haq *et al*., 2012; Islam *et al.,* 2017a; Khatun *et al.,* 2016), which may worsen in the future due to climate change (Rokonuzzaman *et al.*, 2018; Hossain *et al*., 2016). Thus, Bangladesh needs to produce more food on less land to assure future food security for millions of people every year (Islam *et al.,* 2015a&b). To achieve this, the two techniques that need to be adopted more frequently are an increase in the cropping intensity by producing two or more crops on the same land all-year round, and an increase in the productivity of individual crops, particularly their ability to utilize basic or limiting resources such as water and nutrients (FAOSTAT, 2013; Dobermann *et al*., 2013; Datta *et al.,* 2015; Ladha *et al.,* 2016; Datta *et al*., 2017; Islam *et al.,* 2017b).

The major cropping pattern of agriculture in Bangladesh mostly consists of rice based cereal crops (Haque, 1998). Most areas of Bangladesh at present under two crops based cropping pattern, but there prerequisite to increase crop number to meet up the demand. A number of reports on different cropping pattern are available in Bangladesh and abroad (Soni and Kaur, 1984; Malavia *et al*., 1986; Khan *et al*., 2005, Ferdous *et al.,* 2011, Anowar *et al.,* 2012, Anowar *et al.,* 2015, Nazrul *et al*., 2013, Khatun *et al*., 2016 and Anwar *et al.,* 2017) where an additional crops 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 and pheromone traps used in Bangladesh (Islam, 2012a,b). The areas where Maize-Fallow-T.aman cropping patterns were practiced there are a great scope of introducing T.aus rice. Keeping these views in mind, the present study was designed to introduce T.aus rice in the fallow period.

Materials and Methods

The experiment was conducted at the farmers' field condition in khalashpir, Pirgonj, Rangpur (Latitude: $25^{0}24.249$ N, Longitude: $089^{0}11.946$ E) and Hatibandha, Lalmonirhat(Latitude: $25^{0}52.564$ N, Longitude: $089^{0}20.0211$ E) during two consecutive years2015-17. There were two treatments viz., T_1= Existing cropping pattern Maize-Fallow-T. aman rice, T_2 = Devloped cropping pattern Maize-T. aus-T. aman rice. The area mostly falls under medium-high land and high land areas of the Agro-Ecological Zone (AEZ) 3 (Tista mender Floodplain). Small un-replicated trials on farmers' fields, known as "dispersed experiments", were established under local farm conditions (Ferdous *et al.* 2016; Ferdous *et al.,* 2017a,b). The land was divided into two equal plots (each of 660 m^2) where one plot was maintained either improved pattern, whereas the other plot was maintained existing pattern in khalashpir, Pirgonj, Rangpur and Hatibandha, Lalmonirhat. The details of crop management practices followed for each crop at khalashpir, Pirgonj, Rangpurand Hatibandha, Lalmonirhat location is provided in Tables 1 and 2 respectively.

After physiological maturity, 10 randomly selected plants from each plot were harvested and yield of Maize, T. aus rice and T. aman rice were measured. Yield for each crop was determined plot-wise and converted into yield on an area basis (kg ha^{-1}). Benefit-cost analysis was conducted to estimate the economic feasibility of Maize, T. aus rice and T. aman rice crop. The production costs of these crops included the cost of field preparation, seed, planting, irrigation, fertilizers, crop protection measures and harvesting. The gross income was estimated using the prevailing average market prices for the yield of these crops in Bangladesh. Net income was calculated by subtracting total expenditure from the gross income which was computed by dividing the gross income with total expenditure (Mahamood et al., 2016, Ferdous et al. 2017c,d, 2018).

Table 1. Crop management practices in improved cropping pattern and existing cropping pattern at MLT site of Pirganj in Rangpur.

Observation	**Existing cropping pattern**			**Improved cropping pattern**		
Crop	**Maize**	**Fallow**	**T. Aman**	**Maize**	**T. Aus**	**T. Aman**
Variety	Kaveri 50	-	BR 11	BHM-9	BRRI dhan 48	BRRI dhan 57
Spacing	60cm x20cm	-	25 cm x15 cm	60cm x 20cm	25 cm x15 cm	25 cm x15 cm
Unit plot size	1320 m^2			1320 m^2		
Fertilizer dose (N-P-K-S-Zn-B Kg ha^{-1})	184-32-75-21-3-1.20	-	134-30-40-13-2-0.70	235-42-80-27.2-3.58-1.2	76-12-33-9-1.2-0	114-35-80-22-0-0
Date of sowing/ transplanting	25Nov-10 Dec	-	25July-15 Aug	20-25 Nov	07-12 May	15-20 Aug
Harvesting date	01-15 May		10-20 Nov	30 April-05 May	08-15 Aug	10-15 Nov

Table 2. Crop management practices in improved cropping pattern and existing cropping pattern at MLTsite of Hatibandha in Lalmonirhat

Observation	**Existing cropping pattern**			**Improved cropping pattern**		
Crop	**Maize**	**Fallow**	**T. Aman**	**Maize**	**T. Aus**	**T. Aman**
Variety	Kaveri 50	-	sawrna	3S 981	BRRI dhan 48	BRRI dhan 56
Spacing	60cm x 20cm	-	25 cm x15 cm	60cm x 20cm	20 cm x15 cm	25 cm x15 cm
Unit plot size	1320 m^2			1320 m^2		
Fertilizer dose (N-P-K-S-Zn-B Kg ha^{-1})	175-30-70-20-2-1	-	130-20-30-11-2-0.5	235-42-80-27.2-3.58-1.2	76-12-33-9-1.2-0	114-35-80-22-0-0
Date of sowing/ transplanting	30Nov-10 Dec	-	20July-10 Aug	18-22 Nov	05-10 May	14-20 Aug
Harvesting date	05-15 May		05-15 Nov	28 April-02 May	06-12 Aug	10-16 Nov

Productivity of different cropping systems was compared in terms of rice equivalent yield (REY). Land use efficiency and rice equivalent yield of cropping patterns were calculated. Land use efficiency was worked-out by taking total duration of crops in an individual cropping pattern divided by 365 days. It was calculated by the following formula:

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

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

Production efficiency value in terms of kg ha-1day-1was calculated by total main production a cropping pattern divided by total duration of crops in that pattern (Lal *et al.,* 2017; Tomar and Tiwari, 1990).

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 prices of individual crop (Lal et al., 2017). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by market price of that crop divided by market price of rice.

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

Results and Discussion

Yield of the Cropping Patterns: Results of the study have been presented in Table 3 & 5. It was revealed that the entire component crops of Maize-T. aus-T. Aman rice cropping pattern under improved practices (IP) gave higher yield as well as by-product yield in two consecutive years at both the locations. The yield of improved pattern was higher due to inclusion of t.aus ricewith improved production technologies for the component crops. Similar results were also obtained by Anwar et al., 2017, Khatun et al., (2016), Kamrozzaman et al., (2015) and Nazrul *et al*. (2013). BRRI dhan48 is a short duration high yielding T.aus rice variety which can easily be grown during the fallow period (Mondal *et. al*., 2015). Inclusion of mustard with improved variety in Maize-T.aus-T. Aman rice cropping pattern practice increased the total yield over the farmers existing cropping pattern practice. Grain yields of T. aman rice in case of improved cropping pattern were 3.90 and 3.83t ha^{-1} at MLT site Pirganj and 3.74 and 3.75 t ha^{-1} at MLT site Hatibandha in two consecutive years respectively. Grain yield of maize were 9.96 and 9.87 t ha^{-1} at MLT site Pirganj and 9.80 and 12.07t ha^{-1} at MLT site Hatibandha in two consecutive years respectively. Grain yield of T. aus rice were 4.02 and 4.15 t ha^{-1} at MLT site Pirganj and 3.58 and 3.91 t ha^{-1} at MLT site Hatibandha in two consecutive years respectively.

Rice equivalent yield: Total productivity of a cropping system was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. Higher rice equivalent yield (REY) of cropping system (mean value 17.34 t ha^{-1}) was recorded with the improved pattern over existing pattern at MLT site Pirganj (Table 4). REY increased 4.36 t ha^{-1} by inclusion of T.aus rice with improved production technologies for the component crops. Similar results were also found in Domar (Table 6). It is noted that inclusion of additional crop during the fallow period produced higher REY than farmer's practice. Similar results were also obtained by different research group (Khatun *et al*., 2016; Kamrozzaman *et al.,* 2015; Ferdous *et al*. 2011, Anowar *et al.* 2012, Nazrul *et al*., 2013).

Crop Duration: On an average, cropping pattern comprises existing cropping pattern and improved cropping pattern took 257 and 326 days excluding seedling age of T.aus and T. Aman rice to complete the cycle. It is observed that T.aus rice could be easily fitted in the cropping pattern with turn-around time of 39 days in a year.

Land use efficiency: Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. Results of the study have been presented in Table 4 & 6.

Table 3. Productivity of farmers' and improved cropping pattern at MLT site of Pirganj in Rangpur

Year	Cropping pattern	Crop	Variety	Field duration	Grain or seed yield (t ha^{-1})	Straw or Stover yield (t ha^{-1})
2015-16	Existing cropping pattern	Maize	Kaveri 50	159	10.14	-
		Fallow	-	-	-	-
		T.aman	BR 11	105	3.97	4.93
	Improved cropping pattern	Maize	BHM-9	153	9.96	-
		T. Aus	BRRI dhan48	87	4.02	4.42
		T.aman	BRRI dhan 57	85	3.90	4.80
2016-17	Existing cropping pattern	Maize	Kaveri 50	158	10.67	-
		Fallow	-	-	-	-
		T.aman	BR 11	105	3.85	4.81
	Improved cropping pattern	Maize	BHM-9	150	9.87	-
		T. Aus	BRRI dhan48	90	4.15	5.19
		T.aman	BRRI dhan 57	88	3.83	4.78

Table 4. Rice-equivalent yield and land use efficiency of farmers' and improved cropping pattern at MLT site of Pirganj in Rangpu

Year	Cropping pattern	REY (t ha^{-1})	Land use efficiency (%)
2015-16	Existing cropping pattern	12.83	72.32
	Improved cropping pattern	17.29	89.04
2016-17	Existing cropping pattern	13.12	72.05
	Improved cropping pattern	17.39	89.86
Mean	Existing cropping pattern	12.98	72.19
	Improved cropping pattern	17.34	89.45

Table 5. Productivity of farmers' and improved cropping pattern at MLT site of Hatibandha in Lalmonirhat

Year	Cropping pattern	Crop	Variety	Field duration	Grain or seed yield (t ha^{-1})	Straw or stover yield (t ha^{-1})
2015-16	Existing cropping pattern	Maize	Kaveri 50	154	10.68	-
		Fallow	-	-	-	-
		T.aman	Sawrna	95	3.72	4.65
	Improved cropping pattern	Maize	3S 981	153	9.8	-
		T. Aus	BRRI dhan48	82	3.58	4.48
		T.aman	BRRI dhan56	91	3.74	4.69
2016-17	Existing cropping pattern	Maize	Kaveri 50	160	11.67	-
		Fallow	-	-	-	-
		T.aman	Sawrna	95	3.89	4.86
	Improved cropping pattern	Maize	3S 981	155	12.07	-
		T. Aus	BRRI dhan48	86	3.91	4.89
		T.aman	BINAdhan 7	87	3.75	4.68

Table 6. Rice-equivalent yield and land use efficiency of farmers' and improved cropping pattern at MLT site of Hatibandha inLalmonirhat.

Year	Cropping pattern	REY (t ha^{-1})	Land use efficiency (%)
2015-16	Existing cropping pattern	12.91	68.22
	Improved cropping pattern	16.04	89.32
2016-17	Existing cropping pattern	13.92	69.86
	Improved cropping pattern	18.25	89.85
Mean	Existing cropping pattern	13.42	69.04
	Improved cropping pattern	17.15	68.22

Mean land use efficiency indicated that improved cropping pattern used the land for 89.52% period of the year, whereas ECP used the land for 70.62% period of the year. The improved cropping pattern leads to higher land use efficiency due to longer period field occupied by the crops (326 days), whereas the farmers practice occupied the field for 257 days of the year. Similar results were also obtained by Khatun *et al.* (2016) and Alam *et al.* (2017).

Economic analysis**:** Economic analysis done based on prevailing market price during the crop Season. Improved cropping pattern showed its superiority over farmers' pattern during two consecutive years at both the locations. Results of the study have been presented in Table 7 & 8.

Table 7. Cost benefit analysis of farmers' and improved cropping pattern at MLT site of Pirganj in Rangpur

Year	Cropping pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Whole pattern GM (Tk. ha^{-1})	Benefit over existing pattern
2015-16	Existing cropping pattern	256710	110990	145720	41900
	Improved cropping pattern	345780	158160	187620	
2016-17	Existing cropping pattern	262570	112110	150460	37537
	Improved cropping pattern	347747	159750	187997	
Mean	Existing cropping pattern	259640	111550	148090	39718
	Improved cropping pattern	346764	158955	187809	

On an average, gross return of the improved pattern was BDT 346764 ha^{-1} which was more than 33.56% higher than farmers' pattern of BDT 259640 ha^{-1} at MLT site Pirganj (Table 7) and in Hatibandha gross return of the improved pattern was BDT 342800 ha^{-1} which was more than 27.77% higher than farmers' pattern of BDT 268300 ha^{-1} (Table 8). The production cost of the improved pattern (BDT 158950 ha^{-1}) was higher than farmers' pattern (BDT 111550 ha^{-1}) due to labor intensive, cost of fertilizer and other inputs (Table 7). Similar results were also found in Hatibandha. The net return was substantially higher in the improved pattern (BDT 187809 ha^{-1}) than farmers' pattern of BDT 148090 ha^{-1} at MLT site Pirganj and in Hatibandha it was also substantially higher in the improved pattern (BDT 206591 ha^{-1}) than farmers' pattern of BDT 167008 ha^{-1}.

Table 8. Cost benefit analysis of farmers' and improved cropping pattern at MLT site of Hatibanda in Lalmonirhat

Year	Cropping pattern	Gross Return (Tk. ha^{-1})	Total Variable Cost (Tk. ha^{-1})	Whole pattern GM (Tk. ha^{-1})	Benefit over existing pattern
2015-16	Existing cropping pattern	258200	98986	159214	34958
	Improved cropping pattern	320700	126528	194172	
2016-17	Existing cropping pattern	278400	103599	174801	44209
	Improved cropping pattern	364900	145890	219010	
Mean	Existing cropping pattern	268300	101293	167008	39583
	Improved cropping pattern	342800	136209	206591	

The higher net return of the improved pattern was achieved mainly higher yield advantages of the component crops. Inclusion of new crop (T. Aus rice) as well as improvement of management practices in the improved cropping pattern increased the economic return. Similar results were also obtained by Khatun *et al.* (2016).

Conclusion

From the above results showed that improved cropping pattern was more profitable compared to existing pattern. Considering higher rice-equivalent yield, net monetary return and more sustainability of the improved cropping pattern (Maize-T. Aus-T. Aman rice) with additional crop and improved technologies could be suggested for medium high land of the Teesta Meander Floodplain Agro-ecological Zone (AEZ- 3) of Bangladesh.

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