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On-farm Evaluation and System Productivity of Wheat-Jute-T. *aman* Rice Cropping Pattern in *Char* Area of Bangladesh

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Abstract

A study was conducted for two consecutive years to determine the yield and system productivity of two cropping patterns viz. IP: (Wheat - Jute - T. *aman*) improved pattern with improved management practices and FP: (Fallow - Fallow - T. *aman*) farmers' pattern with farmers' management practices in *char* (adjacent to the river) area of Netrakona region of Bangladesh. The experimentswere laid out in a randomized complete block design with 10 dispersed replications at a farmer's field. The two years mean data showed that the total component crops of IP (wheat-jute-T. *aman* rice) gave higher yield as well as a by-product in both years. The higherrice equivalent yield (10.52 and 10.63 tha^{-1}), production efficiency (30.13 and 30.43 kg ha^{-1} day^{-1}) land-use efficiency (87.13 and 87.84%)and benefit cost ratio (2.15 and 2.11) pointed out the dominance of the improvedpattern over the farmer's existing pattern. Higher rice equivalentyield signified that improved cropping pattern (Wheat - Jute -T. *aman*) could be appropriate in Netrakona region for rising crop productivity andcropping intensity.The higher production efficiency, land use efficiency and benefit cost ratio indicated the superiority of the improved pattern over the farmers' practices.It can be concluded that farmers of the *cha*r area of the Netrakona region might follow wheat (var. BARI Gom-26) - jute (var. O-9897) - T. *aman* (var. BRRI dhan49) cropping system in *char* land for higher productivity and profitability.

Keywords: *Char* land, agronomic performance, land use efficiency, production potential, economic return

1. Introduction

Changes in climate, population expansion, food scarcity, poverty, starvation, accelerated land cover change and environmental degradation are the foremost challenges of the 21st century (Neamatollahi *et al.,* 2017).In the world about 1 billion people keep on hungry every day due to the inadequate food supply and thisnumber will riseup to 2 billion by 2050 (FAOSTAT, 2014). For the developing countries of Asia and Africa, this situation insists on the increasing momentum in agricultural production with more than 70 percent increase in the coming decades (Neamatollahi*et al.,* 2017). To enhance agriculture productivity improved cropping patterns and better management practices are essential. Land and water resources are becoming very limited due to the rapid change in population and urbanization. Subsequently, to determine the optimal use of the available resources improved cropping pattern has been developed for exploiting the net profit subjected to some limitations (Osama *et al.,* 2017).

Bangladesh is aheavily populated countryand itspopulation is about 200 million. Besides, the cultivable land is in a decreasing trend and it is about 1% per year. Bangladesh covers about 14.84 M ha (million hectares) of total land and among this 3.74 M ha (25% of the total) is not appropriate for cultivation due to deployment for urban areas, commercial buildings, countryside homesteads, roads etc (Quasem, 2011). Bangladesh also suffersfrequently from differentnormaldisasters (Haq *et al.,* 2012; Khatun *et al.,* 2016; Islam *et al.,* 2017a), that may get worse in the long runas a result of climate change (Hossain *et al.,* 2016; Rokonuzzaman *et al.,* 2018). Therefore, to declare food security for increasing people in the future we need to produce huge food on a reduced amount of land (Islam *et al.,* 2015a&b). Two techniques need to be adopted to achieve this issue. Firstlyit may be by increasing cropping intensity by producing more crops on the similar land during whole year and secondlyby augmenting productivity of each crops (FAOSTAT, 2013; Dobermann *et al.,* 2013; Datta *et al.,* 2015; Ladha *et al.,* 2016; Datta *et al.,* 2017; Islam *et al.,* 2017b). Bangladesh agriculture mostly consists of rice basedcropping patterns (Haque, 1998). Different cropping pattern are available in Bangladesh and abroad and these are well reported. (Soniand Kaur, 1984; Malavia *et al.,* 1986; Khan *et al.,* 2005; Ferdous *et al.,* 2011;Anowar*et al.,* 2012;Nazrul *et al.,* 2013; Anowar *et al.,* 2015; Khatun *et al.,*2016 and Anwar *et al.,* 2017) where a supplementary crops may be incorporated without substituting the accessible ones for significantenhancement of in general productivity andincome of the farmers (Islam, 2012a &b).

The *char* areas of the Netrakona region occupy 8547 acre of land out of 78915 acres and it is dominated by Fallow-Fallow- T. *aman* rice (rainfed rice) cropping pattern. A hugepart remains uncultivated for an extensive time after the harvest of T. *aman* rice such as BR11 (100-110 days main field duration). This is mainly due to water shortage after T. aman harvest and waterlogging condition during monsoon.Only rice production is not sufficient and profitable for the farmers of this area. So an adaptation of alternative cropping patterns to support the most efficient use of the limited natural resources is a prime need for recent days. Wheat is such a promising crop, which can be easily grown after T. *aman* harvest with residual soil moisture and requires less water in some cases.Jute is a fiber crop that can be grown after harvesting of Wheat during monsoon.So the proposed cropping pattern of this area may be wheat-jute- T. *aman*. Considering these observations, the present study was designed to introduce to utilize uncultivated land properly during *rabi* (winter season) and *kharif I* (monsoon) season minimizing water stress and waterlogging condition with improved cropping pattern Wheat-Jute-T. *aman* as well as increase the production and meet the demand of that area.

2. Material and Methods

2.1 Site Description

The experiments were done in farmer's field under the *char* areas of Netrakonawhich is located in between 24°34' and 25°12' north latitudes and between 90° 00'and 91° 07' east longitudes of Bangladesh during two consecutive years 2017 and 2018. The experimental site (Netrakona) is under a moist subtropical monsoon type of climate. The mean minimum and maximum temperature and rainfall for the experimental period are shown in Fig. 1. The physicochemical properties of the soil before the beginning of the experiment are shown in Table 1.

2.2 Experimental Design and Treatments

Treatments consisting of two cropping patterns viz. FP: farmers' pattern (Fallow - Fallow - T.*aman*) and IP: improved pattern (Wheat - Jute - T. *aman*) by incorporation of recent high yielding varieties of Jute, T. *aman*rice andwheat. Modern management practices were used for crop production. The experiments were set up using a randomized complete block design with 10 dispersed replications. The individual plot size was 100 m^2.The improved pattern was used in one plot andfarmer's pattern was practiced in other plots. Wheat var. BARI Gom-26 and jute var. O-9897 were introduced in the improved pattern against the fallow period. The variety BRRI dhan49 of T. *aman* rice was introduced instead of BR11.

2.3 Crop Management

The agronomic practices and cultural operation for crop production under improved and farmers' practices are presented in Table 2. All field operation and management practices of both farmers' and improved patterns were closely monitored and the data were recorded for agro-economic performance.

2.4 Data Collection

Ten plants were chosen from every plot randomly at maturityfor data collection and yield of wheat, T. *aman* rice and jute were calculated. Plot-wise yield for each crop was determined on an area basis (kg ha^{-1}). Agronomic performance viz. rice equivalent yield, production efficiency, and land use efficiency were calculated.

2.5 Estimation of Rice Equivalent Yield (REY)

Based on the existing market price of the individual crops, the yield of every single crop was converted into rice equivalent yield for making the relationship between crop sequences (Verma and Modgal, 1983). The gross return, net return and benefit cost ratio were also evaluated based on the market price of each produces.

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

2.6 Estimation of Production Efficiency

Production efficiencywas determinedas kg $ha^{-1}day^{-1}$by the whole production in a cropping series divided by the entiretime of crops in that sequence (Tomer and Tiwari, 1990).

$$\text{Production efficiency} = \frac{Y1+Y2+Y3}{d1+d2+d3}$$

Where, Y_1= Yield of 1^{st}crop and d_1= Duration of 1^{st}crop of the pattern

Y_2= Yield of 2nd crop and d_2= Duration of 2nd crop of the pattern

Y_3= Yield of 3rd crop and d_3= Duration of 3rd crop of the pattern

2.7 Determination of Land Use Efficiency

For determination of land use efficiencytotal length of individual crop in a sequence is divided by 365 days (Tomer and Tiwari, 1990). It is calculated by following formula.

Land use efficiency $=\frac{d1+d2+d3}{365} \times 100$

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

2.8 Benefit Cost Ratio (BCR)Analysis

Average data of two crop cycles were calculated for the economic assessment of two dissimilar cropping cycles. The production expenses of these crops were determined by calculating the material and non-materialcost of production. Using the prevailing average market prices for the yield of these crops in Bangladesh the gross return was calculated. Gross margin was designed by deducting total expenses from the gross income which was worked out by dividing the gross income with total expenditure. Benefit cost ratio (BCR)was calculated with the following formula.

Benefit Cost Ratio (BCR) = $\frac{\text{Gross return}}{\text{Total variable cost of production}} \times 100$

3. Results and Discussion

3.1 Grain/Fibreyield of the cropping patterns

Grain/fibreyield of different cropping pattern have been presented in Table 3. It was revealed that the cropping pattern wheat-jute-T. *aman* rice under improved practices (IP) gave higher yield and by-product during both years. The reason behind improvement of yield inIP was theuse of variety with modern cultivation technique for the component crops. Higher wheat yield was documented during 2017 (3.02 tha^{-1}) and 2018 (3.05tha^{-1}) with an average yield of 3.04tha^{-1}. In improved pattern higher jute yield was recorded during 2017 (2.89tha^{-1}) and 2018 (2.93tha^{-1}). T. *aman* rice yield was different in both patterns and higher yield (3.23 and 3.25 tha^{-1} in 2017 and 2018) was recorded in farmers' practice over improved (3.13 and 3.15 tha^{-1}) due to single crop cultivation in farmers' practice. Khatun et al. (2016) and Khan et al. (2006) conducted experiments and found more yield in single crop cultivation than improved cropping pattern for a specific crop.

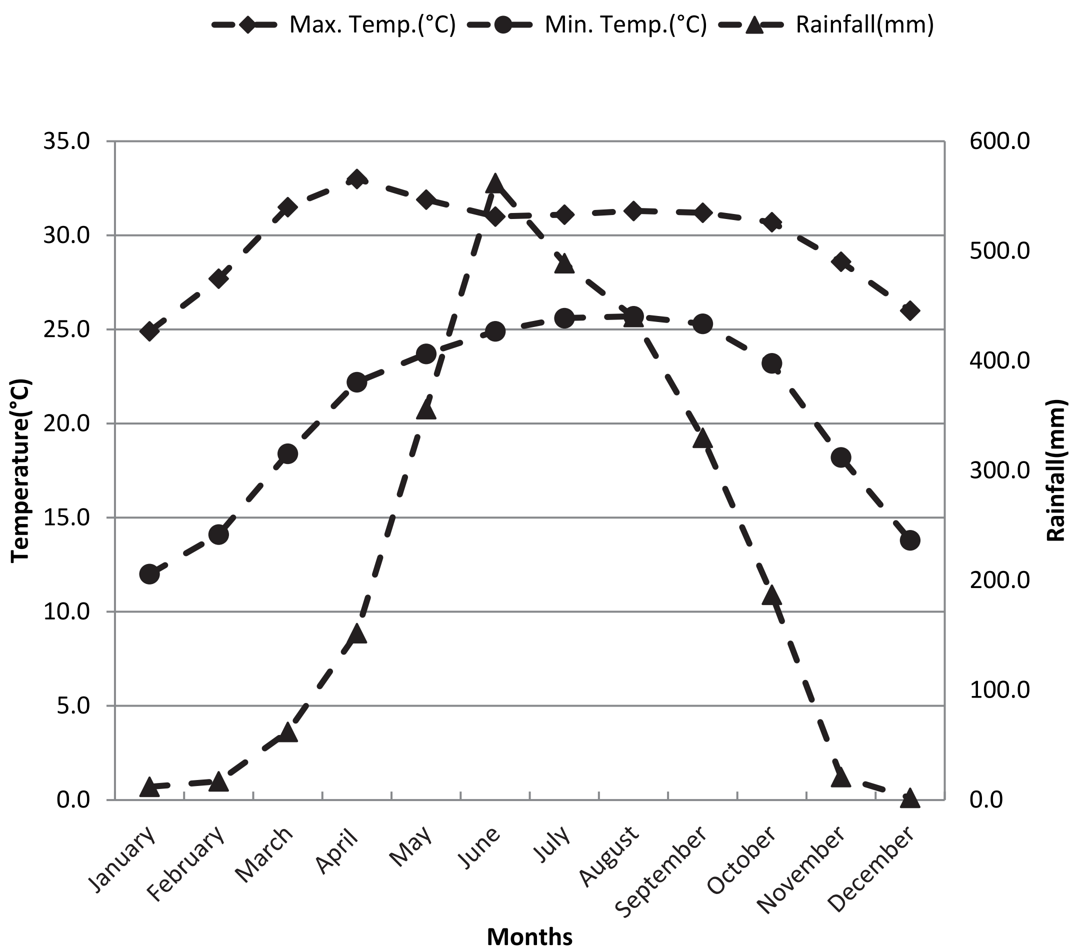

Figure 1. Average maximum temperature, minimum temperature and annual rainfall during the cropping seasons 2017and 2018

3.2 By-product Yield of the Cropping Patterns

By-product yield of the component crops was measured from biomass yield (Table 3). Higher amount of total by-product yield of the component crops (14.1 and 14.2 t ha^{-1} in 2017 and 2018) produced in the improved cropping pattern than that of the farmers' pattern (4.26 and 4.30t ha^{-1}). Nazrul (2016) stated the reason behind the higher by-product yield of improved pattern than that of farmers' pattern and reason behind it is the incorporation of new variety with improved technologies for the component crops. Beside this the component crops wheat and jute of improved pattern produced high demandable as well as more profitable by-product whereas it was difficult for the farmers to sell the rice by-product (rice straw) in the local market with proper price.

3.3 Rice Equivalent Yield

Rice equivalent yield was higher in IPcompared to farmers' practice. The mean rice equivalent yield of IP was10.58t$ha^{-1}$and that of FPwas 3.24tha^{-1} (Table 4). This happened due to inclusion of high yielding variety BRRI dhan49 instead of BR11 and extra two new cropsalong with modern cultivation techniques in the improved pattern increased the T.aman rice equivalent yield. Besides rice equivalent yield was higher in improved pattern due to superiormarket price of components crops in the IP. Rice equivalent yield was lower in the FP due to use of conventionalvariety and management practices.

Table 1. Average of soil nutrient status of the experimental areas of Netrakona region during 2017 and 2018

Soil property	Values
Soil texture	Sandy loam
pH–H_2O	5.65
Ec (µs/cm)	143
Organic matter (%)	1.51
Total N (%)	0.084
Available P (ppm)	33.66
Available K (meq/100g)	0.144
Available S (ppm)	59.64

3.4 Production Efficiency

Highest production efficiency (30.13 and 30.43 kg ha-1day-1) wasrecorded from IP inthe year of 2017 and 2018, (Table 4). Mean production efficiency (30.28 kg ha-1day-1)was higher in IP and lower (29.45kg ha-1day-1) in FP. Reddy (1997), Khan et al. (2006) and Nazrul et al. (2013) found that mean production efficiency wasalways superior in IP compared to FP. The higher production efficiency of improved cropping pattern indicated that the component crops remain in the field for long duration with higher yield under modern cultivation practices. On the other hand, the lowest production efficiency observed in FP wheretraditional management are used and indicated that cropsremained in the field for shorter time with lower yield under traditional system.

Table 2. Management practices of improved vs farmers' existing cropping pattern during 2017 and 2018

Parameter	Farmers' pattern	Improved pattern
Variety	T. aman (BR11)	Wheat (BARI Gom 26)- Jute (O-9897)- T. aman (BRRI dhan49)
Date of sowing	12-15 August	Wheat 21-24 November (2017), Jute 4-8 April (2017) and 2-4 April (2018), Aman 5-10 August (2017) and 5-8 August (2018)
Seed rate (kg ha^{-1})	20-25	Wheat 120, Jute 7, Aman 25
Planting method	Line	Line for all crops
Spacing (cm)	20×15	Wheat30×5, Jute 20×5, Aman 25× 15
Fertilizer dose (N P K S Zn kg ha^{-1})	92-24-60-8-0.5	120-30-60-15-1 (Wheat), 110-15-40-8-0.5 (Jute), 115-35-40-4-0.5 (T.aman)
Weeding	1	Wheat 1,Jute 2, T.aman 2
Irrigation	Rainfed	Rainfed
Harvesting time (date)	15-20 Nov	10-14 March, 2018 , 3-25 July (2017), 20-22 July (2018) 10-15 November (2017), 15-18 Nov. (2018)
Field duration (days)	100-110	110-115 (Wheat) , 100-108(Jute), 90-95 (T.aman)

3.5 Land Use Efficiency

Land use efficiency is the efficient utilization of land in a cropping year and it mainly depends on crop duration. The average land-use efficiency of IP was 87.49% whereas it was 30.30% for FP (Table 4). This superior land use efficiency in IP was due to cultivation of wheat and jute in bare period that's why field was occupied by the crops for a longer period (300-318 days), whereas the farmers practice occupied the field for 100-110 days of the year.

Table 3. Productivity of improved and farmers' existing patterns during 2017 and 2018

Year	Cropping pattern	Grain/Fibre yield (t ha^{-1})			By product yield (t ha^{-1})		
		Fallow/Wheat	Fallow/Jute	T.*aman*	Fallow/Wheat	Fallow/Jute	T.aman
2017	IP	3.02	2.89	3.13	3.54	6.37	4.12
	FP	-	-	3.23	-	-	4.26
2018	IP	3.05	2.93	3.15	3.59	6.42	4.15
	FP	-	-	3.25	-	-	4.30
SE±		0.02	0.02	0.03	0.03	0.03	0.04
Mean	IP	3.04	2.91	3.14	3.57	6.39	4.14
	FP	-	-	3.24	-	-	4.28

IP= Improved practice, FP=Framers' practice

3.6 Cost Benefit Analysis

Based on the existing market price during the crop season, cost and return analysis were done. From the economic point of view, IP showed its superiority over FP during both years.The average gross return of the IP was 277057.5Tk. ha-1which was84.25% higher than that of FP (Table 5).Thecost of cultivation of IP (131707Tk. ha-1) was superior toFP (85511 Tk. ha-1) due to higher labor and input cost. The net return was considerablysuperior in the IP (145600.5 Tk. ha-1) than FP (64184 Tk. ha-1). Inclusion of wheat and jute in these cropping systems during fallow season andincrement of system productivity results in increased gross margin. In the FP 126.85 % supplementary net return was attained by adding 54.02% extra cost. The marginal benefit cost ratio was determined for both IP and FP. The results revealed that a higher benefit cost ratio (2.13) was found in IP over the FP (1.76). Farmers showed a highly positive response to cultivate jute and T. aman in this season and they opined that due to lack of knowledge they were not interested to grow Jute before as they experienced water logging conditions during monsoon.The farmers also added that the yield performances of the BARI Gom26, Jute (O-9897) and BRRI dhan49 were acceptable. After harvest of T. amanrice, modern wheat variety (BARI Gom26) could easily be grown which doesn't hamper or delay jutecultivation. Jute can be easily be grown between wheatand T. aman rice.

Table 4. Rice equivalent yield, production efficiency and Land use efficiency of improved and farmers' existing patterns during 2017 and 2018

Year	Cropping pattern	Rice equivalent yield (t ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Land use efficiency (%)
2017	IP	10.52b	30.13b	87.13b
	FP	3.23c	29.36d	30.14d
2018	IP	10.63a	30.43a	87.84a
	FP	3.25c	29.54c	30.45c
	SE±	0.04	0.05	0.06
Mean	IP	10.58	30.28	87.49
	FP	3.24	29.45	30.30

IP= Improved practice, FP=Framers' practice

Table 5. Cost benefit analysis of improved and farmers' existing patterns during 2017 and 2018

Year	Cropping pattern	Gross return (Tk ha^{-1})	Cost of cultivation (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
2017	IP	283515	131957	151558	2.15
	FP	151290	85761	65529	1.76
2018	IP	270600	131457	139643	2.11
	FP	149445	85261	62839	1.75
Mean	IP	277057.5	131707	145600.5	2.13
	FP	150367.5	85511	64184	1.76

IP= Improved practice, FP=Framers' practice

4. Conclusion and Recommendations

Considering most of the parameters discussed above, improved cropping pattern wheat (var. BARI Gom26) -Jute (var. O-9897)-T. *aman*(var. BRRI dhan49) with modern technologiescould be suggested for *char* areas of

Netrakona regionof Bangladesh, especially for themarginal farmers. The findings may be used for researcher, extension workers and also for national policy maker for large scale production but further observation is required before dissemination of the technology.

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