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 experiments were 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 higher rice 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 improved pattern over the farmer’s existing pattern. Higher rice equivalent yield signified that improved cropping pattern (Wheat - Jute - T. aman) could be appropriate in Netrakona region for rising crop productivity and cropping 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 char 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 this number will rise up 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 a heavily populated country and its population 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 suffers frequently from different normal disasters (Haq et al., 2012; Khatun et al., 2016; Islam et al., 2017a), that may get worse in the long run as 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. Firstly, it may be by increasing cropping intensity by producing more crops on the similar land during whole year and secondly by 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 based cropping patterns (Haque, 1998). Different cropping pattern are available in Bangladesh and abroad and these are well reported. (Soniald Kaur, 1984; Malavia et al., 1986; Khan et al., 2005; Ferdous et al., 2011; Anowat 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 significant enhancement of in general productivity and income 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 huge part 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 24º34’ and 25º12’ north latitudes and between 90º 00’ and 91º 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 and wheat. 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 m². The improved pattern was used in one plot and farmer’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 maturity for 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.

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 efficiency was determined as kg ha⁻¹ day⁻¹ by the whole production in a cropping series divided by the entire time of crops in that sequence (Tomer and Tiwari, 1990).

Production efficiency = \frac{Y_1+Y_2+Y_3}{d_1+d_2+d_3}

Where, \( Y_i \) = Yield of \( i^{th} \) crop and \( d_i \) = Duration of \( i^{th} \) crop of the pattern
Y_2 = Yield of 2^{nd} crop and d_2 = Duration of 2^{nd} crop of the pattern

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

2.7 Determination of Land Use Efficiency

For determination of land use efficiency total 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{d_1 + d_2 + d_3}{365} \times 100

Where d_1, d_2 and d_3 the duration of 1^{st}, 2^{nd} and 3^{rd} 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-material cost 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.

\text{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 in IP was the use of variety with modern cultivation technique for the component crops. Higher wheat yield was documented during 2017 (3.02 tha\(^{-1}\)) and 2018 (3.05 tha\(^{-1}\)) with an average yield of 3.04 tha\(^{-1}\). In improved pattern higher jute yield was recorded during 2017 (2.89 tha\(^{-1}\)) and 2018 (2.93 tha\(^{-1}\)). 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. Khutun 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.
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 4.30 t 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 IP compared to farmers’ practice. The mean rice equivalent yield of IP was 10.58 t ha\(^{-1}\) and that of FP was 3.24 t ha\(^{-1}\) (Table 4). This happened due to inclusion of high yielding variety BRRI dhan49 instead of BR11 and extra two new crops along 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 superior market price of components crops in the IP. Rice equivalent yield was lower in the FP due to use of conventional variety 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–H₂O                 | 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) was recorded from IP in the year of 2017 and 2018 (Table 4). Mean production efficiency (30.28 kg ha⁻¹day⁻¹) was higher in IP and lower (29.45 kg ha⁻¹day⁻¹) in FP. Reddy (1997), Khan et al. (2006) and Nazrul et al. (2013) found that mean production efficiency was always 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 where traditional management are used and indicated that crops remained 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⁻¹ which was 84.25% higher than that of FP (Table 5). The cost of cultivation of IP (131707Tk. ha⁻¹) was superior to FP (85511 Tk. ha⁻¹) due to higher labor and input cost. The net return was considerably superior 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 and increment 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 result 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. aman rice, modern wheat variety (BARI Gom26) could easily be grown which doesn’t hamper or delay jute cultivation. Jute can be easily be grown between wheat and 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               | 149945                 | 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 technologies could be suggested for char areas of
Netrakona region of Bangladesh, especially for the marginal 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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