ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 45(3): 279-292, September 2020

DEVELOPMENT OF POTATO-BORO-T. AMAN RICE CROPPING PATTERN AGAINST FALLOW-BORO-T. AMAN RICE CROPPING PATTERN AT MYMENSINGH

M. A. H. KHAN[1], N. SULTANA[2], N. AKTER[3]
S. AKHTER[4] AND M. A. I. KHAN[5]

Abstract

The experiment was conducted at Multiplication Testing Site (MLT) Trishal of On-Farm Research Division, Bangladesh Agricultural Research Institute, Mymensingh during 2017-18 and 2018-19 to evaluate the agro-economic performance of improved cropping pattern for increasing cropping intensity and system productivity as compared to farmers' existing cropping pattern. The experiment was laid out in randomized complete block design with six dispersed replications. Two cropping patterns viz. improved pattern Potato (BARI Alu-25)-Boro (BRRI dhan28)-T. Aman rice (BRRI dhan49) and farmers existing cropping pattern Fallow-Boro (BRRI dhan29)- T. Aman rice (BRRI dhan49) were treatments variables of the experiment. Two years mean data showed that Potato-Boro-T. Aman rice cropping pattern produced higher tuber/grain yield as well as higher rice equivalent yield (30.53 t $ha^{-1}yr^{-1}$), production efficiency (149 kg ha^{-1} day^{-1}), land utilization index (74 %) and labour employment (367man-days ha^{-1} yr^{-1}) than Fallow-Boro-T. Aman rice cropping pattern. This pattern also increased system productivity, production efficiency, land utilization index and labour employment by 158, 166, 26 and 51% higher over exiting pattern. The mean gross return (Tk. 481800 ha^{-1}) and gross margin (Tk.235329 ha^{-1}) of improved cropping pattern were 139 and 237% higher, respectively compared to existing pattern with 87% extra cost. The mean marginal benefit cost ratio (2.45) indicated superiority to improved cropping pattern over existing pattern. Experimental findings revealed that there is potential for greater adoption of intensified cropping systems with increased productivity and profitability as compared to rice–rice systems in Mymensingh.

Keyword: Grain yield, system productivity, land use efficiency, profitability, gross return.

Introduction

Increased population, food scarcity, poverty, starvation and environmental degradation are the primary 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

[1,2]Senior Scientific Officer, [3,4]Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Mymensingh, Bangladesh, [5]Assistant Professor, Major General Mahmudul Hasan Adarsha College, Tangail, Bangladesh.

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 available resources and 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 161.40 million which is increasing annually at the rate of 1.37%. Besides this, in Bangladesh total cultivable land is 8.59 million hectare and it is decreasing about 0.73% per annum due to construction of houses, roads and industrial infrastructure (BBS, 2017). Food requirement of the country is estimated to be doubled in the next 25 years (Islam and Haq, 1999). There is no other alternative but demand has to be met from our limited and shrinking land resources. The main challenge of the new millennium is to increase 50% yield per unit land area through manipulating the land resources. In order to produce more food within a limited area, the most important options are to increase the cropping intensity producing three or more crops over the same piece of land in a year and to increase the production efficiency of the individual crop by using optimum management practices (Mondal *et al*., 2015). The production of the cropping patterns could be increased by changing cultivars and improving cultural management practices. There is some scope of increasing cropping intensity from existing level of 195% by incorporating short duration crops viz. potato, mustard, mungbean and T.Aus rice in the rice based existing cropping system.

Actually, rice based monoculture exists in agriculture of the country. Only rice based cropping pattern has been facing a number of problems like reduction of soil fertility, pests and diseases outbreaks in the crop fields, decline in water table, reduced production of non-rice crops, erodes biodiversity, creates nutritional imbalance (Rahman, 2010). Crop diversification is considered as a strategy of reducing the reported problems. It is also considered as an effective approach to utilize scarce land and valuable water resources, which makes agriculture sustainable and environment friendly (Kumari *et al.*, 2010).

Mymensingh district is located under Agro Ecological Zone (AEZ) 8, 9 & 28. Total cultivable land of the district is 3,32,737 ha in which 25,029 ha are single cropped and 2,34,043 ha are double cropped area (78% of total cultivable land). The cropping intensity of this area is 192% and about 74% lands are under irrigation (DAE, Mymensingh 2018). The existing ten major cropping patterns of Mymensingh among which Fallow-*Boro*-*T.Aman* rice is ranked first and which covers about 66 % of the total cultivable land (DAE, Mymensingh 2018). Only rice cultivation is not profitable for the farmers of this region due to it requires huge amount of irrigation water for *Boro* rice as well as soil native fertility decline for monoculture of rice (Sarker *et al*., 2020). 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. A huge part of land remains fallow 2 to 3 months after harvest of *T.Aman* rice in Mymensingh region. The cropping intensity of this region is therefore really low compared to other regions of the country. It is possible to increase cropping intensity in this region by using short duration crop varieties which are developed by BARI and other research institutes. BARI Alu-25 is such a promising crop, which can be easily grown after *T.Aman* rice harvest with residual soil moisture. The cropping intensity and productivity may be increased by improving existing cropping patterns through introducing new high yielding short duration crop varieties along with modern cultivation technologies. Nazrul *et al.* (2017) found that improved pattern (Mungbean-T.Aus -T.Aman rice) provided higher grain yield, contributed more REY, gave maximum sustainable index, production efficiency, land use efficiency and higher profit compared to farmers pattern (Fallow- *T.Aus-T.Aman* rice). Moreover, a number of reports on different cropping pattern are available in Bangladesh and India that an additional crop could be introduced without much changes or replacing the existing ones for considerable increases of productivity as well as profitability of the farmers (Soni and Kaur, 1984; Malavia *et al.,* 1986; Kamrozzaman *et al*., 2015; Nazrul *et al.,* 2017 and Khan *et al.* 2018). Therefore, the experiment was undertaken to evaluate the agro-economic performance of improved cropping pattern Potato-*Boro-T.Aman* rice for increasing cropping intensity and system productivity as compared to farmers' existing cropping pattern Fallow-*Boro-T.Aman* rice.

Materials and Methods

The experiment was carried out at the farmers' field of Multilocation Testing Site (MLT) under On-Farm Research Division of Bangladesh Agricultural Research Institute, Trishal, Mymensingh under irrigated condition to increase cropping intensity and productivity by incorporating potato in the existing cropping system (Fallow-Boro-T.Aman rice) during 2017-18 and 2018-19. The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) of Mymensingh. The geographical position of the area is between 24°45′ N latitude and 90°24′ E longitude. The land was medium high and the soil of the study area was sandy loam in texture with well drainage system. Maximum rainfall was received during the months of April to October in both years. The meteorological data of the experimental site revealed that the highest temperature prevailed (32.8 ^{0}C) in August and the lowest (11.2^{0}C) in December 2017 and (12.2 ^{0}C) in January 2019 in two consecutive years. The crop received 306.3 mm and 240.6 mm rain showers from October to March in two successive years. Monthly mean maximum and minimum air temperature (30.6 & 21.0°C) and mean total rainfall (2042 mm) were prevailing during the study period (Appendix I). Initial and after completion of the two cycle soil sample was collected and analyzed (Table 1).

General soil types predominantly include 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.

The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping pattern viz., improve pattern *Potato* (var. BARI Alu-25)-*Boro* (var. BRRI dhan28)-*T.Aman* rice (var. BRRI dhan49) and farmers' existing pattern Fallow- Boro (var. BRRI dhan29)-T.Aman rice (var. BRRI dhan49) were the treatments variables of the experiment. The unit plot size was 600-800 Sq.m. Fertilizer management was followed by FRG (2012) and intercultural operations like weeding, mulching, irrigation and pest management were done properly to support the normal growth and development of the crop. In improved pattern potato was the first crop of the sequence. The potato seeds were sowing 60 cm × 25 cm apart rows at the rate of 1600 kg ha^{-1} on 12-17 November, 2017 and 14-18 November 2018 and harvested on 26-31 January, 2018 and 27-31January 2019. *Boro* rice was the second crop of the improved cropping sequence. Seedlings of *Boro* rice were grown in adjacent plot and transplanting was done with 35-40 days old seedlings at a spacing of 20 cm × 15 cm on 07-11 February, 2018 and 08-13 February, 2019, respectively in improved pattern. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done accordingly. *Boro* rice was harvested on 13-18 May 2018 and 17-23 May, 2019, respectively. 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 improved cropping sequence. Seedlings of *T.Aman* rice were grown in adjacent plot and transplanting was done with 25-30 days old seedlings. *T.Aman* rice was transplanted with 20 cm×15 cm spacing on 25-30 July 2018 and 07-11August 2019, respectively. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done properly for normal growth and development of the crop. *T.Aman* rice was harvested on 01-04 November, 2018 and 07-11November, 2019, respectively. T.Aman rice plant was harvested at 15 cm height from soil surface and remaining parts of the plants was incorporated in soil.

In the farmers' pattern, *Boro* rice was the first crop of the sequence. Seedlings of *Boro* rice were grown in adjacent plot and 40-45 days old seedlings were transplanted at a spacing of 20 cm×15 cm on 20-25 January, 2018 and 25-30 January, 2019. *Boro* rice was harvested on 15-20 May 2018 and 19-24 May, 2019 in two consecutive years. *T.Aman* rice was the second crop of the farmers' cropping sequence. Seedlings of *T.Aman* rice were grown in adjacent plot and 30-35 days old seedlings of *T.Aman* rice was transplanted with 20 cm×15 cm spacing on 02-07 August 2018 and 06-10 August 2019, respectively. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done accordingly farmers' own management. *T.Aman* rice was harvested on 07-12 November, 2018 and 10-16 November, 2019.

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 two cropping pattern, the yield of every crop was converted into rice equivalent 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.

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

Production efficiency: Production efficiency value in terms of 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).

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

Where, Y_i= Yield (kg) of i^{th} crop, d_i= Duration (day) of i^{th} crop of the pattern and i= 1, 2, 3

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:

$$\textbf{Land Utilization Index (\%)} = \frac{d_1 \times d_2 \times d_3}{365} \times 100$$

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

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).

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

Results and Discussion

Crop management: Crop management practices under improved cropping pattern potato-B*oro*-*T*.A*man* and farmers existing cropping pattern Fallow-B*oro*-*T*.A*man* rice are shown in Table 1. Mean field duration of improved cropping

Table 1. Crop management practices of improved cropping pattern Potato-Boro-T.Aman rice (IP) and farmers' existing cropping pattern Fallow-Boro-T.Aman rice (FP) in Mymensingh during 2017-18 and 2018-19

Parameters	Years	Improved Cropping Pattern (IP)			Farmers' Existing Pattern (FP)		
Crop		Potato	Boro rice	T.Aman rice	Fallow	Boro rice	T.Aman rice
Variety	2017-18	BARI Alu-25	BRRI dhan28	BRRI dhan49	-	BRRI dhan29	BRRI dhan49
	2018-19	BARI Alu-25	BRRI dhan28	BRRI dhan49	-	BRRI dhan29	BRRI dhan49
Sowing/ planting time	2017-18	12-17 Nov.	07-11 Feb.	25- 30 Jul.	-	20-25 Jan.	02- 07 Aug.
	2018-19	14-18 Nov.	08-13 Feb.	07-11 Aug.	-	25-30 Jan	06-10 Aug
Seedling age (days)	2017-18	-	35-40	25-30	-	40-45	30-35
	2018-19	-	35-40	25-30	-	40-45	30-35
Harvesting time	2017-18	26-31 Jan.	13-18 May	01-04 Nov.	-	15-20 May	07-12 Nov.
	2018-19	27-31 Jan	17-23 May	07-11 Nov.		19-24 May	10-16 Nov.
Field duration (days)	2017-18	76	97	98	-	116	98
	2018-19	75	99	93	-	115	97
Turnaround time (days)	2017-18	11	11	72	-	73	78
	2018-19	11	7	80	-	75	78

pattern took 269 days while existing cropping pattern required 213 days for completion of one cycle. Average turnaround time was 95 days for improved cropping pattern whereas, it was 152 days for existing cropping pattern. It is indicated that potato could be easily fitted in two rice crop based existing cropping pattern.

Yield performance: Tuber yield of potato and grain and straw yield of *Boro* and *T.Aman* rice of improved and farmers' existing cropping pattern are presented in Table 2. Tuber yields of potato were 28.38 and 28.98 t ha^{-1} in two consecutive years, 2017-18 and 2018-19, respectively. Two years average tuber yield of potato was 28.68 t ha^{-1}. Grain yields of *Boro* rice were 5.94 and 6.12 t ha^{-1} and straw yields were 6.42 and 6.47 t ha^{-1} during 2017-18 and 2018-19, respectively. Mean grain and straw yields of *Boro* rice were 6.03 and 6.45 t ha-^{1}, respectively. Grain yields of *T.Aman* rice were 5.30 and 5.46 t ha^{-1} and straw yields were 5.45 and 5.51 t ha^{-1} in the two successive years. Mean grain and straw yields of *T.Aman* rice were 5.38 and 5.48 t ha^{-1}.

In farmers' existing cropping pattern, grain and straw yields of *Boro* and *T.Aman* rice have been presented in Table 2. In the existing pattern, grain yields of *Boro* rice were 6.49 and 6.68 t ha^{-1} and straw yields were 6.84 and 6.93 t ha^{-1} in two successive years. Mean grain and straw yields of *Boro* rice were 6.59 and 6.89 t ha-^{1}, respectively. Grain yields of *T.Aman* rice were 5.15 and 5.31 t ha^{-1} and straw yields were 5.45 and 5.41t ha^{-1} in the two consecutive years. Mean grain and straw yields of *T.Aman* rice were 5.23 and 5.43 t ha^{-1}. Average tuber yield of potato was recorded 28.68 tha^{-1} which might be due to varietal yield potential. Average grain yield of *Boro* rice in Potato-*Boro*-*T.Aman* rice cropping pattern was 8.50 % lower than farmers' existing cropping pattern might be due to varietal potentiality. Average grain yield of *T.Aman* rice was 2.87% higher in *Potato-Boro-T.Aman* rice over Fallow-*Boro-T.Aman* rice cropping pattern might be due to modern management practices and balanced fertilization. The result is in conformity with the findings of Sultana *et al*. (2014) for the variety BRRI dhan28 in *Mustard-Boro-T.Aman* cropping pattern at Mymensingh region.

Table 2. Yield of different crops under improved cropping pattern (IP) and farmers' existing cropping pattern (FP) in Mymensingh during 2017-18 and 2018-19

Parameters	Years	Improved Cropping Pattern (IP)			Farmers' Cropping Pattern (FP)		
		Potato	Boro rice	T.Aman rice	Fallow	Boro rice	T.Aman rice
Tuber/Grain yield (t ha^{-1})	2017-18	28.38	5.94	5.30	-	6.49	5.15
	2018-19	28.98	6.12	5.46	-	6.68	5.31
	Mean	28.68	6.03	5.38	-	6.59	5.23
Straw yield (t ha^{-1})	2017-18	-	6.42	5.45	-	6.84	5.45
	2018-19	-	6.47	5.51	-	6.93	5.41
	Mean	-	6.45	5.48	-	6.89	5.43

System productivity: Total productivity of cropping sequence was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. Rice equivalent yields (REY) of improved cropping pattern (Potato-*Boro*-*T.Aman* rice) were estimated 30.16 and 30.90 t $ha^{-1}yr.^{-1}$ which were 159.11 and 157.71% higher over existing cropping pattern in two successive years (Table 3) . The mean rice equivalent yield (REY) of improved cropping pattern was 30.53 t $ha^{-1}yr^{-1}$ which was 158% higher over existing cropping pattern (11.82 t $ha^{-1}yr^{-1}$) due to introduction of new crop (potato) and improved management practices. Higher rice equivalent yield indicates higher system productivity and efficiency of potato-Boro-T.Aman rice cropping pattern over existing rice-rice cropping pattern. This findings are supported by Mondal *et al*. (2015), Nazrul *et al*. (2017) and Khan *et al*. (2018).

Production efficiency: The higher production efficiency in terms of kg $ha^{-1}day^{-1}$ was calculated from improved cropping pattern than existing cropping pattern in Table 3. Average production efficiency of improved cropping pattern was found 149 kg $ha^{-1}day^{-1}$ which was 166 % higher over farmers' existing cropping pattern (56 kg $ha^{-1}day^{-1}$). The higher production efficiency in improved cropping pattern due to inclusion of high yielding extra crop like Potato in fallow land as well as improved management practices. Similar trend are noted by Nazrul *et al*. (2017) and Khan *et al.* (2018).

Land Utilization Index (LUI): Land utilization index is the effective use of land in a cropping year which mostly depends on crop duration. Land utilization index (LUI) indicated that improved cropping pattern utilized the land by 74 and 73% for 1st and 2nd cycle, respectively whereas existing cropping pattern utilized the land by 59 and 58 % for 1st and 2nd cycle, respectively. Mean land utilization index of improved cropping pattern was higher (74%) than that of existing cropping pattern (59%) due to cultivation of more component crops in improved pattern as well as crops occupied the field for longest duration (269 days) than the farmers' pattern (213 days) of a year (Table 3). Similar trend of the findings are cited by Nazrul *et al*. (2017) and Khan *et al.* (2018).

Labour employment generation: Human labour was employed for land preparation, sowing, and transplanting, fertilizing, weeding, pesticide application, harvesting, carrying, threshing, cleaning and drying. It was observed that mean total number of human labour was used for crops production under improved cropping pattern was 367 man-days $ha^{-1}year^{-1}$ which was generated 51% higher labour employment than that of existing cropping pattern. It was also generated employment of women, children and aged people due to inclusion of potato (Table 3).

Table 3. Rice equivalent yield (REY), production efficiency (PE), land utilization index (LUI) and labour employment (LE) of *Potato-Boro-T.Aman rice* (IP) and *Fallow-Boro-T.Aman ric*e (FP) in Mymensingh during 2017-18 and 2018-19

Year	Cropping Pattern	REY ($tha^{-1}yr^{-1}$)	PE ($kgha^{-1}day^{-1}$)	LUI (%)	Labour employment (man-days ha^{-1} yr^{-1})
2017-18	Improved Pattern	30.16	146	74	365
	Farmer’s Pattern	11.64	55	59	240
2018-19	Improved Pattern	30.90	152	73	369
	Farmer’s Pattern	11.99	57	58	245
Mean	Improved Pattern	30.53	149	74	367
	Farmer’s Pattern	11.82	56	59	243
% increased/decreased over FP		158	166	26	51

Note: REY=Rice equivalent yield, PE=production efficiency, LUI= land utilization index, IP= Improved Pattern and FP= Farmers’ Pattern.

Profitability analysis: The cost and return analysis of improved and existing cropping pattern are presented in Table 4. It is indicated that higher return was found in improved cropping pattern (*Potato-Boro-T.Aman* rice) than farmers’ existing pattern (Fallow-*Boro-T.Aman* rice). Two years mean gross return (Tk. 481800 ha^{-1}) of improved cropping pattern which was 139% higher than that of existing cropping pattern (Tk. 201855 ha^{-1}) might be due to inclusion of additional crop like HYB Potato. Mean total variable cost of improved cropping pattern was 87 % higher than farmers’ existing cropping pattern might be due to higher cultivation cost of potato. Average gross margin was substantially higher in improved cropping pattern (Tk. 235329 ha^{-1}) than farmers’ pattern (Tk. 69854 ha^{-1}). The higher gross margin of the improved pattern was achieved mainly due to higher yield advantages of the component crops specially for Potato crop. The average gross margin of improved cropping pattern was 237 % higher over existing cropping pattern by adding 87% extra cost in the improved pattern. These findings are supported by Sarker *et al*. (2014) who reported that Wheat-Mungbean-*T.Aman* rice produced the higher economic benefit in terms of BCR. The mean marginal benefit cost ratio (MBCR) was calculated 2.45 which further indicated superiority to improved cropping pattern over farmers’ pattern. Thus, addition of potato in the existing pattern might be agronomically viable, economically profitable and environmentally sustainable for the farmers’ in the study area.

Table 4. Gross return, total variable cost, gross margin and marginal benefit cost ratio (MBCR) of *Potato-Boro-T.Aman rice* (IP) and *Fallow-Boro-T.Aman rice* (FP) in Mymensingh during 2017-18 and 2018-19

Year	Cropping Pattern	Gross return (Tk.ha^{-1})	Total variable cost (Tk.ha^{-1})	Gross margin (Tk.ha^{-1})	MBCR
2017-18	Improved Pattern	476140	245343	230797	2.44
	Farmer's Pattern	199180	131873	67307	
2018-19	Improved Pattern	487460	247599	239861	2.46
	Farmer's Pattern	204530	132129	72401	
Mean	Improved Pattern	481800	246471	235329	2.45
	Farmer's Pattern	201855	132001	69854	
% increased/decreased over FP		139	87	237	-

Note: MBCR= Marginal Benefit Cost Ratio, Price: Potato = Tk. 10.00 kg^{-1}, Rice = Tk. 15.00 kg^{-1} Rice straw = Tk. 2.00 kg^{-1}

Apparent soil nutrient balance: Total N, P, K and S uptake by different crops at the farmer's field are presented in Fig.1. The partial net balance of N was negative in both the patterns and ranged from -72 to -135 kg ha^{-1}. Nitrogen replenishment through chemical fertilizer and organic matter addition either singly or in combination was not enough to balance N removal by crops presumably due to substantial loss of the applied N from the soil. The P balance was favourable as expected due to individual crop basis fertilization. Excess amount of P accumulated in soil and positive effect of P was reflected in the improved pattern. Moreover, generally P uptake is less by crops than other elements like N and K due to heavy weight component to others. In farmers' pattern, P balance was also positive. However, the partial net balance of K was negative and ranged from -44 to -106 kg ha^{-1}. This may lead to K depletion in the long run. There was a positive balance of S in both the patterns and ranged from 7 to 9 kg ha^{-1} due to less amount uptake by crops. These results are supported by Khan *et al*. (2018) who reported the similar trend of nutrients in Wheat-Mungbean-*T.Aman* rice cropping pattern.

Changes in soil properties: The status of soil pH, organic matter content, total N, available P, K, S, Zn and B in initial soil as well as after completion of two cropping cycle are shown in Table 5. Soil chemical analysis of improved cropping pattern revealed that total N content of the soil decreased slightly due to N replenishment through chemical fertilizer and organic matter was not enough to balance N removal by crops and substantial loss of N from the soil. K content also decreased in improved cropping pattern due to light textured soil potato crop is more responsive to K fertilizer and this may lead to K depletion in the long run. Initially the pH of the soil was 5.97 but after completion of two cropping cycle the soil pH slightly decreased to near 5.96. It was also found that the fertility status of soil i.e. available P, S and Zn contents in soil were increased slightly over the initial soil due to addition of biomass. However, N and K in the improve pattern tended to be lower than the farmers one, which indicated to add more K in soil to improve K content. Rao and Bhardwaj (1980) conclusively proved that optimum fertilizer, especially P had more pronounced residual effect on the succeeding cereals. Organic matter added to soil through incorporation of non-economic plant parts helped to maintain the quality of soil (Table 6). These results are supported by Mondal *et al.* (2015) and Khan *et al.* (2018) who found that inclusion of mungbean in the existing farmer's cropping pattern improve the soil fertility status.

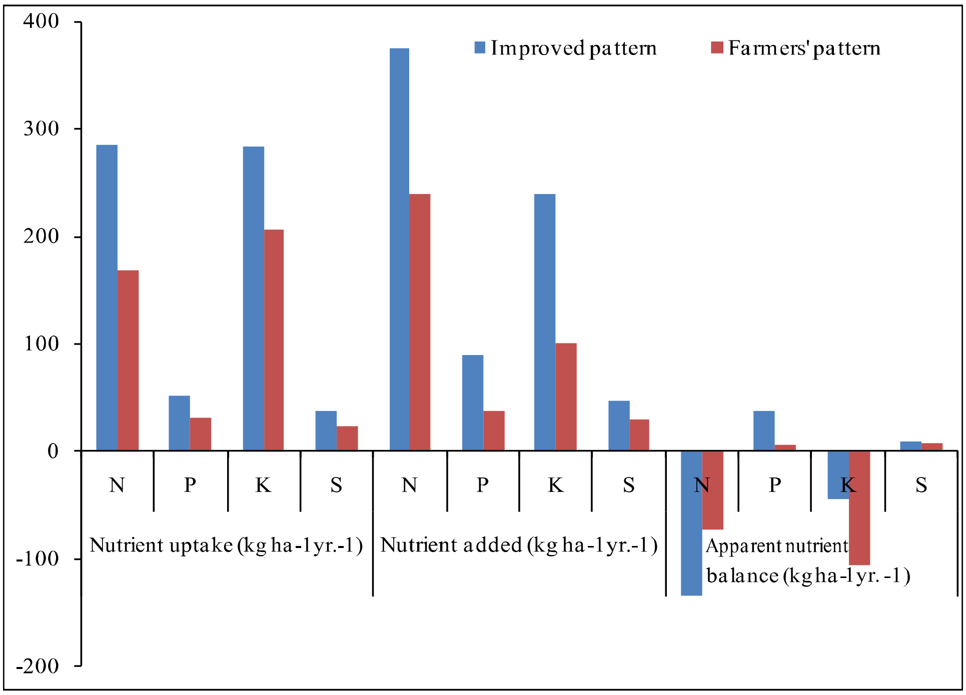

Fig 1. Effect of improved pattern and farmer's pattern on soil nutrient balance at Mymensingh .

Table 5. Mean initial and post harvest soil test values of farmers field at Mymensingh during 2017-18 and 2018-19

Sample	Rainfed/ Irrigated	pH	OM (%)	Total N (%)	K (meq/ 100g)	P (Bray)	S	Zn	B
						(μg g^{-1})			
Initial	Irrigated	5.97	1.35	0.094 (L)	0.14 (L)	17.23 (Opt.)	22.32 (M)	1.17 (M)	0.17 (L)
Post harvest	Irrigated	5.96	1.35	0.092 (L)	0.11 (L)	21.22 (H)	22.57 (Opt)	1.21 (M)	0.17 (L)
Critical level	-	-	-	0.12	0.12	7.00	10.00	0.60	0.20

Table 6. Addition of organic matter from crop residues in soil of improved and farmers' existing cropping pattern at Mymensingh during 2017-18 and 2018-19

Crops	Improved pattern added residues (t ha^{-1})			Farmers' pattern added residues (t ha^{-1})		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Potato	-	-	-	-	-	-
Boro rice (30cm)	1.27	1.23	1.25	1.29	1.26	1.27
T.Aman rice (15cm)	0.66	0.68	0.67	0.65	0.69	0.67
Total	**1.93**	**1.91**	**1.92**	**1.94**	**1.95**	**1.94**

Conclusion

It was revealed that Potato (BARI Alu-25)-B*oro* rice (BRRI dhan28)-*T*.A*man* rice (BRRI dhan49) cropping pattern gave higher benefit as compared to traditional cropping pattern Fallow-Boro (BRRI dhan29)-T.Aman rice (BRRI dhan49) in respect of productivity and economic return. Short duration potato variety like BARI Alu-25 could be fitted easily in the existing pattern without deteriorating soil nutrient system. Due to growing three crops in a year in the same piece of land more employment opportunity for male and female laboures could be created and at the same time cropping intensity and productivity could be increased.

References

BBS. (Bangladesh Bureau of Statistics) 2017. Statistical Year Book of Bangladesh, Statistics Division, Ministry of Planning, Dhaka Bangladesh.

CIMMYT (International Maize and Wheat Improvement Centre) 1988. Agronomic Data to Farmer Recommendation: An Economic Training Manual. International Maize and Wheat Improvement Centre, Mexico, D. F. 79p.

DAE (Department of Agriculture Extension, Mymensingh). 2018. Paper presented in the regional research extension review and program planning workshop at Regional Agricultural Research Station, BARI, Jamalpur.

FAOSTAT (Food and Agriculture Organization Corporate Statistical Database) 2014. FAO, Rome, Italy.

FRG 2012. Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215. p. 274.

Islam, M. F. and Haq, M. F. 1999. Integrated nutrient management with inorganic fertilizer and green manure in some dominant cropping patterns. Pp.55-72 in 'Proceedings of the national workshop on integrated nutrient management for crop production and soil fertility', ed. By M. F. Islam, D. A. Choudhury, G. M. Panaullah, M. u. Miah, J. Rijpma and M. F. Haque. Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Kamrozzaman, M. M., M. A. H. Khan, S. Ahmed, and A. F. M. Ruhul Quddus. 2015.On-farm evaluation of production potential and economics of Wheat-Jute-T. Aman rice based cropping system; *J. Bangladesh Agril. Univ*. **13**(1): 93–100.

Khan, M. A. H., N. Sultana, N. Akter, M. S. Zaman and A. K. Choudhury. 2018. Increasing cropping intensity and productivity through mungbean inclusion in wheat-fallow-T.A*man* rice cropping pattern. *Bangladesh J. Agril. Res*. 4**3** (2): 333-343.

Kumari, B. A. P., S. Thiruchelvam, H. M. H. Dissanayake and T. Lasantha. 2010. Crop diversification and income inequality in irrigation systems: The case of Minipe. *Tropical Agril. Res.* **21**: 308-320.

Malavia, D. D., M. P. Singh, M. M. Vyas, J. C. Patal and K. K. Kalaria. 1986. Production potential and economic feasibility of different crop sequences. *Indian J. Agron.* **31** (1): 75-78.

Mondal, R. I., F. Begum, A. Aziz and S. H. Sharif. 2015. Crop sequences for increasing cropping intensity and productivity. *SAARC J. Agri.* **13** (1): 135-147.

Nazrul, M. I., M. K. Hasan and M. R. I. Mondal. 2017. Production potential and economics of mungbean in rice based cropping pattern in Sylhet region under AEZ-20. *Bangladesh J. Agril. Res.* **42** (3): 413-424.

Neamatollahi, E., J. Vafabakhshi, M. R. Jahansuz and F. Sharifzadeh. 2017. Agricultural optimal Cropping pattern determination based on fuzzy system. *Fuzzy information and Engineering,* 9:479–491. https://doi.org/10.1016/j.fiae.2017.12.004

Osama, S., M. Elkholy and R. M. Kansoh. 2017. Optimization of the cropping pattern in Egypt. *Alexandria Engineering Journal*, 56: 557–566. https://doi.org/10.1016/j.aej.2017.04.015

Rahman, A. 2010. Promoting financial inclusion for poverty reduction with inclusive growth. Bazlur Rahman Memorial Lecture, Presented at the golden Jubilee of war of liberation: what type of Bangladesh we would like to see? Organized by Bangladesh Economic Association, Bangladesh, Dhaka.

Rahman, M. M., Khan, M. H., Mallick, R.N. and R. E. Hudgens, 1989. *Guidelines for Farming Systems Research Methodology.* Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215.

Rao, J. V. and R. B. L. Bhardwaj. 1980. Influence of residual fertility on green gram in intensive cropping system. *Indian J. Agron.***25**: 97-101.

Sarker, M. A. Z., M. A. Alam, A. Hossain and M. A. Mannaf. 2014. Agro-Economic performance of crop diversification in Rice based cropping systems of Northwest Bangladesh. *Agriculture, Forestry and Fisheries*. **3**(4):264--270.

Sarker, U. K., S. Monira and M. R. Uddin. 2020. On-farm evaluation and system productivity of Wheat-Jute- T.Aman rice cropping pattern in Char area of *Bangladesh. Agril. Sci*. **2** (1): 39-46.

Soni, P. N. and R. Kaur. 1984. Studies on production potential of different cropping systems. *Indian J. Agron*. **29** (3): 367-378.

Sultana, S., M. S. Zaman, M. Yasmin, and S. Akhter, 2014. Development of *Mastard-Boro-T.Aman rice* cropping pattern against fallow-boro-t aman rice cropping pattern. *Bangladesh J. Agriculturist.* **7**(1): 95-99.

Tomer, S. S. and A. S. Tiwari, 1990. Production potential and economics of different crop sequences. *Indian J. Agron*. **35** (1&2): 30-35.

Verma, S.P., and S. C. Modgal, 1983. Production potential and economics of fertilizer application as resources constraints in maize, wheat crop sequence. *Himachal J. Agric. Res*. **9** (2):89-92.

Appendix I. Monthly maximum, minimum and mean air temperature (°C) and monthly total rainfall (mm) of Mymensingh during September 2017 to August 2019

Month/ Year	2017-18			2018-19			Monthly total rainfall (mm)	
	Max.	Mini.	Mean	Max.	Mini.	Mean	2017-18	2018-19
September	32.7	26.1	29.4	31.8	26.0	28.9	433.8	143.9
October	32.4	24.2	28.3	30.9	22.5	26.7	214.5	95.1
November	32.1	16.4	24.3	29.3	17.4	23.4	25.1	36.2
December	28.7	11.2	19.9	26.0	13.5	19.7	33.7	17.7
January	26.3	112.2	19.2	26.3	12.2	19.3	00.0	00.0
February	27.0	15.6	21.3	27.0	15.6	21.3	00.0	33.0
March	29.8	18.6	24.2	29.8	18.6	24.2	33.0	58.6
April	31.7	22.3	27.0	31.7	22.3	27.0	268.1	66.8
May	32.6	24.2	28.4	32.6	24.2	28.4	487.7	331.8
June	32.2	26.1	29.2	32.2	26.1	29.2	301.4	421.3
July	32.6	26.7	29.7	32.6	26.7	29.7	305.9	315.2
August	32.8	27.2	30.0	32.8	27.2	30.0	214.7	245.5
Annual	30.9	20.9	25.9	30.3	21.03	25.7	2317.9	1765.1