DOI: http://doi.org/10.5281/zenodo.6419408
U.S. ISSN 2694-4812

Development of Four Crop Based Cropping Pattern Mustard-Boro-T. Aus-T. Aman Against Fallow-Boro-Fallow-T. Aman Rice

Md. Nuruzzaman[1], Most. Mahbuba Khanum[2],* Md. Mahfuz Bazzaz[3], Sheikh Istiaque[4] and Md. Zahidul Islam[5]
[1]On-Farm Research Division, Agricultural Research Station, Bangladesh Agricultural Research Institute, Dinajpur-5200, Bangladesh
[2]Agronomy Division, Agricultural Research Station, Bangladesh Agricultural Research Institute, Dinajpur-5200, Bangladesh
[3]Principal Scientific Officer, Bangladesh Wheat and Maize Research Institute, Dinajpur-5200, Bangladesh
[4]On-Farm Research Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh
[5]Deputy Manager Sales, Nature Care Mfg Industry Ltd. Bangladesh
*Corresponding Author's Email: mahbuba.bari27@gmail.com
Received: 09 January 2022; Accepted: 10 March 2022

Abstract— A trial was conducted at multi-location testing (MLT) site Ranigonj, Dinajpur and Ghoraghat, Dinajpur under On-Farn Research Division (OFRD) during 2015-16 and 2016-17 to develop an economically sustainable and profitable cropping patterns, viz. Mustard (var. BARI Sarisha-14)-Boro (var. BRRI dhan28)- T. Aus (var. BRRI dhan48)-T. Aman (var. BRRI dhan62) against the farmers existing pattern Fallow- Boro (var. BRRI dhan28)- T. Aman (var. Swarna)-Fallow. The experiment was carried out in RCB design with six dispersed replications. Over both locations two years average results showed that the highest rice equivalent yield 20.82 tha-1 was obtained from four crops pattern. The highest average gross return and gross margin of the four crops pattern were obtained Tk. 333160 ha-1 and Tk.146463 ha-1 which was 93.70% and 122.58% higher over farmers existing pattern. The mean marginal benefit cost ratio (MBCR) was found 2.03 which indicated the superiority of four crops pattern over the farmers existing pattern. Both locations two years result showed that Grain yield of inclusion T. Aus rice and mustard yield were satisfactory that indicates the superiority of the alternate pattern over the farmer's practice. So, it could be grown one after another in a sequence in the farmers field of Dinajpur region in Bangladesh.

Keywords— Mustard, Rice, Four crops pattern, Cropping intensity and Challenges

I. INTRODUCTION

Bangladesh is the world's most densely populated country, with an annual population growth rate of about 1.37% (BBS, 2019). On the other hand, agricultural land is lost @ 0.73% each year owing to the development of houses, roads, and industrial infrastructure (BBS, 2019). Because decreasing agricultural land makes it impossible to meet the issue of providing food security by horizontal expansion, an increase in crop production might be achieved through vertical expansion by improving crop yield per unit area and minimizing production losses. In near future, the main challenge is to increase 50% yield per unit land by manipulating limited resources. The most essential choices for producing more food within a confined area are to increase cropping intensity and individual crop production efficiency by applying best management practices (Mondal et al., 2015) With the development of short-duration rice cultivars, an opportunity has arisen to grow mustard, potato, legumes, maize, jute, and other crops in the same piece of land as rice in an annual cycle (Azad et al., 2020). Rice based cropping system consisting of Boro-Fallow-T. Aman is a popular cropping pattern of Bangladesh (Parvin et al., 2017). Inclusion of Mustard and short duration T. Aus variety in this cropping pattern might boost cropping intensity in our country by up to 400% while also increasing farmer incomes. Climate change, population pressures, food insecurity, poverty, hunger, rapid land cover change, and environmental degradation are major challenges that the twenty-first century faces (Neamatollahi et al., 2017). Around 1 billion people go hungry every day around the world due to insufficient food supplies, and this number is expected to rise to 2 billion by 2050. This scenario reinforces the increasing momentum in agriculture production, with more than a 70% increase for developing Asian and African countries in the coming decades (Neamatollahi et al., 2017). In this regard, improved cropping pattern, better management practices are crucial to boost agriculture productivity.

oilseeds are the important group of crops are mostly grown in rabi (winter) season in Bangladesh. The area of oilseeds in rabi season is decreasing because of increasing cultivation of irrigated boro rice (Wahhab et al., 2002). Rapeseed-mustard can be increased by 20-25% only replacing traditional variety by high yielding short duration ones, like BARI Sarisha-14 and BARI Sarisha-15 in existing rice-based cropping system (OFRD, 2014).

Admittedly, potential adoption of mustard, T. Aus in Fallow-Boro-Fallow-T. Aman cropping system would increase crop, productivity, generate employment and bring additional income for the rural poor people by utilizing fallow and under-used lands of the country. However, the benefit of incorporation of extra crops in the rice-based cropping pattern will largely depend on the selection of suitable crop varieties and adoption of appropriate agronomic practices. In Dinajpur region 46%

land are fallow, so hither a huge scope increases cropping intensity by inclusion Mustard and T. Aus. Therefore, the present experiment was undertaken to study the economic feasibility of growing four crops in a year in the same piece of land by incorporating mustard and T. Aus rice in the existing two or three crops-based cropping patterns

II. Materials and Methods

A trial was conducted over two locations at MLT site Raniganj (latitude-250.687845 N, and longitude-880.661124 E) Sadar, Dinajpur and Kashiatola, Ghoraghat (latitude-250.305250 N and longitude-890.189643 E) Dinajpur during the two consecutive years 2015-16 and 2016-17, respectively. The improved cropping patterns Mustard-Boro-T.Aus-T.Aman rice was introduced against the existing cropping pattern Fallow-Boro-Fallow-T.Aman rice. The experiment was carried out in RCB design with six dispersed replications. Initial and final soil samples from experimental plots were collected and analyzed. The experimental soil was loamy with medium organic matter content (1.99%) and soil pH was 5.16 strongly acidic in nature. The status of N, P, K, S, Zn and B was low, low, low, optimum and low respectively at Ghoraghat and the soil of MLT site Raniganj was also loamy texture having 1.37% organic matter, pH 5.75, 0.07% total nitrogen (N), 0.11 meq 100 g-1 soil potassium (K), 9.45 µg/g phosphorus (P), 7.40 µg/g sulfur (S), 1.44 µg/g zinc (Zn) and 0.20 µg/g boron (B). There was no significant change in soil pH, organic matter, total N, P, K and Zn content were observed. Increasing tendency was observed in B in different treatments (Table 1) compared to initial soil. It might be due to the residual effect of applied fertilizer in different crops (Table 1). Relevant information about cropping patterns with crop and variety, date of sowing/transplanting, harvesting and yield of different crops is given in Table 2. The land area of three farmers for each cropping pattern in each site was 1200 m2. Variety of different crops in the patterns were selected considering their duration, yield performance and adaptability to changing climatic conditions. For early mustard, variety BARI Sarisha-14 was selected for the cropping pattern Mustard-Boro-T.Aus -T.Aman Rice for its rapid growth. Mustard was sowing 28 oct.-03 Nov. in both the years. After early Mustard, Boro rice was transplanted by 23-30 January and for this reason Mustard was harvested in 83 days after sowing in two consecutive years. In this pattern rice variety BRRI dhan28 for Boro rice, BRRI dhan48 for T.Aus rice, BRRI dhan62 for T. Aman rice and BARI Sarisha-14 were selected for its short duration and highly yield potentiality. Recommended fertilizer dose based on soil test value and agronomic practices were followed for each crop (FRG'12). All PKS used as basal during final land preparation and N used in 2 equal splits at 15-20 DAT and another one in 35-40 DAT for all rice crops, and for mustard PKSZnB and Half N used as basal dose and rest amount of N used was before flowering. All season's rice was transplanted at a spacing of 20cm×15cm. Mustard was seeded as broadcast method with seed rate of 7 kg ha-1. Recommended fertilizer packages (FRG'12) following the application methods were used for all the crops. Theovit (S containing fungicide as growth stimulating agent), Rovral-50wp (to control Alternaria leaf blight) and Melathion-57 EC (to control Aphid) were applied in Mustard. Furadan, Belt for stem borer and Confidor, Mipcin were applied in rice to control BPH and also Nativo was applied to control Sheath blight & Blast.

For making a sense of comparison between crop sequences, the yields of all crops were converted into rice equivalent yield on the basis of prevailing market price of individual crops. The economic indices like gross return, gross margin and marginal benefit cost ratio (MBCR) were also calculated on the basis of prevailing market price of the inputs and outputs. Crop cut was done from an area of 3m2 at three spots from each plot for yield samples in all cases. The data on yield and economics of all the crops were taken plot wise and stated in Table 3. The agronomic practices used for crop production under existing and improved cropping pattern presented in Table 2.

Agronomic performance viz. land use efficiency, production efficiency, rice equivalent yield and Marginal Benefit Cost Ratio of cropping patterns were calculated as follows:

Land use efficiency: Land use efficiency is worked out by taking total duration of individual crop in a sequence divided by 365 days (Lal et al., 2017; Tomer and Tiwari, 1990). It is calculated by following formula:

$$\text{Land use efficiency} = \frac{d_1 + d_2 + d_3 + d_4}{365} \times 100$$

Where d1, d2, d3 and d4 the duration of first, second, third and four crops of the pattern.

Production efficiency: Production efficiency values in terms of Kg ha-1day-1were calculated by total production in a cropping sequence divided by total duration of crops in that sequence (Tomer and Tiwari. 1990).

$$\text{Production efficiency} = \frac{Y_1 + Y_2 + Y_3 + Y_4}{d_1 + d_2 + d_3 + d_4} \text{ Kg ha}^{-1}\text{day}^{-1}$$

Where, Y1: Yield of first crop; and d1: Duration of first crop of the pattern; Y2: Yield of second crop and d2: Duration of second crop of the pattern; Y3: Yield of third crop, d3: Duration of third crop of the pattern and Y4: Yield of four crop d4: Duration of four crop of the pattern.

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.

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

For Marginal Benefit Cost Ratio, the following formula was used:

$$\text{MBCR} = \frac{\text{Gross Return } (GR_1) - \text{Gross Return } (GR_0)}{}$$

Variable cost (VC_1) - Variable cost (VC_0)

Where, GR1= Gross return of main crop (Tk. ha-1)

GR0= Gross return of component crop (Tk. ha-1)

VC1= Variable cost of main crop (Tk. ha-1)

VC0= Variable cost of component crop (Tk. ha-1)

III. Results and Discussion

Yield performance

Grain yields of short-duration T. Aman rice (BRRI dhan62) were outstanding, ranging from 4.03 to 4.08 t ha-1 in the improved cropping pattern at Ghoraghat and Raniganj, respectively and 4.21 to 4.31 t ha-1 in the existing pattern at Swarna/Ranjit (Table 3). Because of the long duration T.

Table 1. Soil physical and chemical properties of experimental field

Soil properties	pH	Organic matter (%)	Total N (%)	Available P (µg/g)	Exchangeable K (meq/100g soil)	Available S (µg/g)	Zn (µg/g)	B (µg/g)
Ghoraghat								
Initial	5.16	1.99	0.10	7.49	0.09	11.78	1.23	0.16
Final	5.40	1.95	0.12	6.94	0.10	10.67	1.22	0.17
Status	Strongly A	M	L	L	L	L	M	L
Raniganj								
Initial	5.75	1.37	0.07	9.45	0.11	7.40	1.44	0.20
Final	5.70	1.34	0.08	8.98	0.10	6.82	1.42	0.21
Status	Slightly A	L	VL	L	L	L	Opt.	L
Critical level		10:1	0.12	10.0	0.12	10.0	0.6	0.2

Strongly A=Strongly Acidic, Slightly A= Slightly Acidic, M=Medium, L=Low, VL=Very low, Opt.=Optimum

The agronomic practices used for crop production under existing and improved cropping pattern presented in Table 2.

Table 2. Crop management of improved and existing cropping pattern at Ghoraghat and Raniganj Dinajpur during 2015-16 and 2016-17.

Parameters	Existing cropping pattern (ECP)		Improved cropping pattern (ICP)			
Crop	Boro	T. Aman	Mustard	Boro	T. Aus	T. Aman
Variety	BRRI dhan28	Swarna/ Ranjit	BARI Sarisha-14	BRRI dhan28	BRRI dhan48	BRRI dhan62
Seedling age	40-45	40-45	-	35-40	20-25	20-25
Date of sowing/ Transplanting	23-30 January	20 July-2 August	25 Oct.-03 Nov.	24-30 January	08-13 May	01-07 August
Seed rate (kg ha^{-1})	50	50	7	50	50	50
Spacing	25 cm x 15 cm	25 cm x15 cm	Broadcast	20 cm x 15 cm	20 cm x 15 cm	20 cm x 15 cm
Fertilizer dose (N, P, K, S, Zn and B kg ha^{-1})	136-20-50-08-0-0	102-20-62-08-0-0	80.6-26-33.5-10-1.6-0.5	150-20-65-18-1.3-0	75-10-25-9-0.6-0	90-10-35-12-1-0
Irrigation (no)	12	-	1	14	2	-
Weeding (no.)	Herbicide	Herbicide	-	Herbicide	Herbicide	Herbicide
Date of harvesting (range)	30 April-07 May	28 Oct.-04 Nov.	17-23 Jan.	1-7 May	24-31 July	22-27 Oct.
Field duration (days)	100	102	83	97	84	80
Turnaround time (days)	80	83	5	5	5	6

Table 3. Productivity of existing and improved cropping patterns at MLT site Ghoraghat and Raniganj under Dinajpur district during 2015-16 and 2016-17

Productivity	Location	Years	ECP (Existing Cropping pattern		ICP (Improved cropping pattern)			
			Boro	T.Aman	Mustard	Boro	T.Aus	T.Aman
Grain yield (tha^{-1})	Ghoraghat	2015-16	5.74	4.25	1.43	5.50	5.38	4.16
		2016-17	5.90	4.33	1.48	5.81	5.26	3.90
		Mean	5.82	4.29	1.45	5.66	5.32	4.03
	Raniganj	2015-16	5.85	4.41	1.49	5.77	5.35	3.96
		2016-17	5.79	4.21	1.52	5.89	5.23	4.20
		Mean	5.82	4.31	1.51	5.83	5.29	4.08
	Mean of locations		5.82	4.3	1.48	5.74	5.30	4.05
By product yield (tha^{-1})	Ghoraghat	2015-16	6.12	4.34	3.05	5.38	5.25	4.12
		2016-17	6.25	4.25	3.15	5.46	5.23	4.34
		Mean	6.18	4.29	3.1	5.42	5.24	4.23
	Raniganj	2015-16	6.03	4.36	3.10	5.19	5.28	4.35
		2016-17	6.16	4.29	3.01	5.28	5.15	4.22
		Mean	6.09	4.32	3.05	5.23	5.21	4.28
	Mean of locations		6.14	4.31	3.07	5.32	5.22	4.25

Table 4. Rice equivalent yield, Production efficiency, land use efficiency of existing and improved cropping patterns during 2015-16 and 2016-17

Cropping patterns	Locations	Years	Rice equivalent yield ($t\ ha^{-1}$)	Production efficiency ($kg\ ha^{-1}$ day)	Land use efficiency (%)
ECP	Ghoraghat	2015-16	10.62	52.57	55.06
		2016-17	10.87	53.81	54.24
		Mean	10.75	53.19	54.65
	Raniganj	2015-16	10.88	53.86	54.52
		2016-17	10.63	52.62	55.34
		Mean	10.76	53.24	54.93
	Mean of locations		10.75	53.21	54.79
ICP	Ghoraghat	2015-16	20.61	59.91	94.24
		2016-17	20.71	60.20	93.15
		Mean	20.66	60.05	93.69
	Raniganj	2015-16	20.82	60.52	94.52
		2016-17	21.15	61.48	93.97
		Mean	20.98	61.00	94.24
	Mean of locations		20.82	60.52	93.96

Aman rice varieties Swarna/Ranjit, the average yield of Aman rice was greater in farmers practice (4.30) t ha-1 than improved (4.05) t ha-1 in both sites. Nazrul et al., (2013), Khan et al., (2006), Khan et al., (2005), and Hossain and Wahhab (1992) all came up with similar conclusions. Because to the short growing season, this rice might be harvested in October. At Ghoraghat, the mustard yield was 1.45 t ha-1, whereas at Raniganj, it was 1.51 t ha-1. Due to the early harvest of BARI Sarisha-14, boro rice was transplanted on schedule. The grain yield of boro rice (BRRI dhan28) was likewise greater and more or less equal in both locations (5.82 tha-1 to 5.74 tha-1). T. Aus rice BRRI dhan48 was likewise a short duration variety that was transplanted on time. The BRRI dhan48 grain yield was excellent ranging from 5.32 to 5.29 tha-1 in Ghoraghat and Raniganj respectively. T. Aus (BRRI dhan48) rice lasted exactly 84 days in the field. A similar outcome was also achieved (Khanum et al., 2020).

Table 5. Cost and return analysis of existing and improved cropping pattern at Ghoraghat and Raniganj under Dinajpur district during 2015-16 and 2016-17

Cropping patterns	Locations	Years	Gross return (Tk. ha^{-1})	Total cost of Cultivation (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
ECP	Ghoraghat	2015-16	169920	106033	63887	
		2016-17	173920	105550	68370	
		Mean	171920	105792	66129	
	Raniganj	2015-16	174080	106458	67622	
		2016-17	170080	106750	63330	
		Mean	172080	106604	65476	
	Mean of locations		172000	106198	65802	
ICP	Ghoraghat	2015-16	329760	185570	144190	1.97
		2016-17	331360	186788	144572	1.94
		Mean	330560	186179	144381	1.96
	Raniganj	2015-16	333120	187450	145670	2.14
		2016-17	338400	186980	151420	2.09
		Mean	335760	187215	148545	2.11
	Locations mean		333160	186697	146463	2.03

Unit price: Mustard = Tk. 50 kg^{-1}, BRRI dhan28 = Tk. 16.00 kg^{-1}, BRRI dhan62 = Tk. 16 kg^{-1} BRRI dhan48 = Tk. 17 kg^{-1} and Sharna/Ranjit = TK. 16 kg^{-1}, straw of rice and stover = Tk. 1 kg^{-1}, ECP=Existing cropping pattern, ICP=Improved cropping pattern

Rice equivalent yield

Due to the addition of a new crop and short-duration high-yielding varieties as well as enhanced management procedures, the modified cropping pattern provided greater rice equivalent yield than the farmer's traditional cropping system (Table 4). At Ghoraghat (20.66 t ha-1year-1) and Raniganj (20.98 t ha-1year-1) respectively, the improved pattern enhanced rice equivalent yield by 192.18% and 194.98%. Due to local variety and customary management approaches, lower rice equivalent yields of 10.75 tha-1year-1 were attained in the farmer's pattern at Ghoraghat and 10.76 tha-1year-1 at Raniganj. The preceding data show that other cropping patterns yielded higher yields than the present pattern (Nazrul et al., 2017; Khanum et al., 2020).

Crop duration

Farmers using the Fallow-Boro-Fallow-T.Aman cropping pattern needed 163 days in the field to complete the cycle, whereas those using the Mustard-Boro-T. Aus-T. Aman cropping pattern needed 344 days (excluding rice seedling age) (Table 2). BARI Sarisha-14 and T. Aus (BRRI dhan48) were two new crops added into the farmers' established pattern. The total field length of the four crops under the enhanced cropping pattern was 344 days, indicating that the farmer's current method had a turnaround period of 163 days. Mustard (BARI Sarisha-14) and T. Aus (BRRI dhan48) rice might be easily integrated into the present cropping pattern with a 21 days turnaround time every year according to the results.

Production efficiency

Improved pattern during specific years resulted in maximum production efficiency which also indicates data (Table 4). It's possible that the better cropping pattern's increased production efficiency is related to the use of new or modern varieties and management approaches. In contrast, the farmer's pattern showed the lowest production efficiency with crops being in the field for shorter periods of time and yields being lower resulting in reduced output per day. The enhanced pattern had a greater mean production efficiency (60.52 kg ha-1day-1) than the farmers' pattern (53.21 kg ha-1day-1). In the case of increased cropping sequences, Nazrul et al., 2013 and Khanum et al., 2020 saw similar patterns.

Land use efficiency

Land use efficiency refers to how effectively land is used throughout a cropping year which is mostly determined by crop length. Improved patterns utilized the land for 93.96% of the year whereas farmers patterns used the land for 54.79% of the year according to the average land use efficiency (Table 4). Due to the inclusion of Mustard and T. Aus as a supplementary crop during the fallow season, the enhanced pattern had a greater land use efficiency. Identical outcomes were also achieved (Khatun et al., 2019; Khanum et al., 2020).

Cost and return analysis

The improved pattern yielded a greater gross return of Tk. 330560 ha-1 at Ghoraghat and Tk. 335760 ha-1 at Raniganj, which was 192.18% and 194.98% higher than the farmers' current pattern respectively. The gross margin in the alternate pattern was much greater in both locations (Tk. 144381 ha-1 and Tk. 148545 ha-1) than in the farmer's pattern (Tk. 66129 ha-1 and Tk. 65476 ha-1). The alternate pattern's larger gross margin was mostly owing to increased yield advantages of component crops. The enhanced pattern has an MBCR of 1.96 at Ghoraghat and 2.11 at Raniganj, indicating that it outperforms the farmer's practice (Table 5). Others (Mondal et al., 2015 and Khanum et

al., 2020) concurred that in the near future, the four crops based farming pattern will be critical for guaranteeing the country's food and nutrition security. Rice equivalent yield, productivity, and profitability were higher than the farmer's current patterns, indicating that the alternate cropping pattern was agronomically practical and economically advantageous (OFRD, 2017).

Farmers' opinion

The BARI Sarisha-14, BRRI dhan28, BRRI dhan62 and BRRI dhan48 produce almost adequate yields and may be easily adapted into a four-crop cropping system. Following the harvest of T. Aman rice, a short-duration, high-yielding mustard variety (BARI Sarisha-14) may be easily cultivated, without interfering with or delaying the growing of the crop (Boro rice). BRRI dhan28 was chosen for Boro rice because of its popularity, middle length (94 days), and greater yield. BRRI dhan48 may easily be cultivated after Boro rice harvesting without interfering with T. Aman growing because it takes just 80 days to mature.

Challenges

The research was carried out at an area where four crops might be planted in the same year on the same land. The tight timeline for crop establishment, natural disasters (rain, cold, high temperature, excess or inadequate moisture in the soil, etc.) and seed availability of diverse crops are the key obstacles for introducing four crops in the same cropping pattern. However, if we overcome those limits, we can incorporate four crops into a cropping system. A number of studies on various cropping patterns are available in Bangladesh (Khan et al., 2005, and Nazrul et al., 2013) where a new crop might be added without making significant modifications to the current ones, resulting in a significant boost in total productivity and profitability for farmers.

IV. Conclusion

Results from the previous two years were compared, as well as variations in grain yields from different crops and market prices for inputs and outputs. Though the data from the previous two years are insufficient to make a conclusion for this sort of research. However, under an intensified cropping system, better gross return and gross margin, as well as higher productivity, demonstrated that the enhanced cropping pattern performs better than the farmer's practice. Mustard (BARI Sarisha-14)-Boro (BRRI dhan28)-T.Aus (BRRI dhan48)- T.Aman (BRRI dhan62) were found to be lucrative on both location, as well as an appropriate cropping pattern for cropping on medium high land of Dinajpur region in Bangladesh.

Acknowledgement

The authors are very thankful to On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI) for providing the fund to do this research work.

Conflicts of Interest: The authors declare no conflicts of interest.

References

[1] Azad, A.K., Miaruddin, M., Wahab, M.A., Seikh, M.H.R., Nug, B.L. and Rahman, M.H.H. (2020). Krishi Projukti Hatboi (Handbook on Agro-Technology), 9th edition, Gazipur-1701, Bangladesh

[2] BBS (Bangladesh Bureau of Statistics). (2015). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka, Bangladesh.

[3] BBS. (2019). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Dhaka. Bangladesh.

[4] Elahi, N.E., Khan, A.H., Siddique, M.R., Saha, A., Nasim, M., Mollah, M.I.U., Shahidullah, S.M. (1999). Existing cropping patterns of Bangladesh, potential technologies and strategies for improving systems productivity. In proceedings of the workshop of modern rice cultivation in Bangladesh held during 14-16 February 1999. P.107-170.

[5] FRG (Fertilizer Recommendation Guide). (2012). Nutrient uptake by various crops at definite yield level. Bangladesh Agricultural Research Council. Farmgate, New Airport Road, Dhaka-1215, p.7.

[6] Khan, M.A.H., Quayyum, M.A., Nazrul, M.I., Sultana N.& Mollah, M.R.A. (2005). On-Farm evaluation of production potential and economics mustard-rice based improved cropping system. Bangladesh J.Socio.Res.Dev.2(1),37-42.

[7] Khanum, M.M., Bazzaz, M.M., Nuruzzaman, M., Huda, M.S., Muzahid, M.A.A.A. (2020). Development Of Alternate Cropping Pattern Against Tomato-Fallow- T. Aman Rice In Medium High Land Of Dinajpur. Reviews In Food And Agriculture, 1(1): 18-21.

[8] Khatun, M.U.S., Ferdous, Z., Haque, Z., Alam, M.A.U., Hasan, M., Islam, M.K. (2019). Increasing cropping intensity of Fallow-Boro-T. Aman cropping pattern with inclusion of Mustard in Tista Mender Floodplain soil. Progressive Agriculture 30 (4): 360-370.

[9] Lal, B., Gautam, P., Panda, B.B., Raja, R., Singh, T., Tripathi, R. (2017). Crop and varietal diversification of rainfed rice-based cropping systems for higher productivity and profitability in Eastern India. PLoS ONE, 12 (4), Pp. 17-57.

[10] Mondal, R.I., Begum, F., Aziz, A and Sharif, S.H. (2015). Crop sequences for increasing cropping intensity and productivity. SARC Journal of Agriculture,13(1):135-147.

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

[12] Nazrul, M.I., Shaheb, M.R., Khan, M.A.H. & Khan, A.S.M.M.R. (2013). On-Farm Evaluation of production potential and economic returns of potato-rice based improved cropping system, Bangladesh Agronomy Journal,16(2),41-50.

[13] OFRD (On-Farm Research Division). (2014). Improvement of Mustard Boro-T.Aman cropping pattern. Annual Research Report, OFRD, BARI.

[14] OFRD (On-Farm Research Division). (2017). Performance of four crops based cropping patterns against farmers' existing pattern in different agro-ecological zones of Bangladesh. Paper presented in national workshop on "Increasing cropping intensity and productivity with 4 crops based pattern program" held at BARI, Joydebpur on 4 March, 2017.

[15] Parvin, N., Khatun, A., Quais, M. K. and Nasim, M. (2017). Cropping pattern, Intensity and Diversity in Dhaka Region. Bangladesh Rice J.21(2):123-141.

[16] Rahman, M.M., Rahman. M. A., Ahmed, M., Uddin, M.M. and Choudhury, A.K. (2015). Improvement from mustard-boro-T. Aman cropping pattern to mustard-boro-jute-T.Aman. Bangladesh Journal of Agricultural Research. 40(2): 259-270.

[17] Rasid, M.H., Rony, M.K.I. and Nasrin, S. (2012). Increasing productivity of rice-rice cropping system adopting short duration rice and mustard and relay cropping. In proceeding of the international conference on Environment, Agriculture and Food Sciences (ICEAFS`2012) held during 11-12 August, 2012 in Phuket (Thailand). p.13-16.

[18] Tomer, S.S., Tiwari, A.S. (1990). Production potential and economics of different crop sequences. Indian J. of Agron., 35 (1, 2), Pp. 30-35.

[19] Wahhab, M.A., Mondal, M.R.I., Akbar, M.A., Alam, M.S., Ahmed, M.U. and Begam, F. (2002). Status of oil crop production in Bangladesh. Oilseed Research Centre, BARI, Joydebpur, Gazipur-1701.

[20] World Bank. (2013). Bangladesh Poverty Assessment: Assessing a Decade of progress in Reducing Poverty, 2000-2010. Bangladesh Development Series..