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System productivity with inclusion of short duration mustard in T*. Aman*-fallow-Boro cropping pattern at Jashore district in Bangladesh

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ABSTRACT

A field experiment was conducted at Naldangha under Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jashore in two consecutive years, 2021-22 and 2022-23, to introduce BARI Sarisha-14 in the fallow period as well as to study comparative agronomic performance and economic return of two cropping sequences, viz. improved cropping pattern, i.e. Transplant aman (BRRI Dhan-75) –Mustard (BARI Sarisha-14) - Boro rice (BRRI Dhan-63) and existing cropping pattern, i.e Transplant aman rice Swarna)– Fallow - Boro rice (BRRI Dhan-28). The experiment was laid out in a randomized complete block design (RCBD) with ten dispersed replications. Two years mean data showed that the improved management practices for the pattern provided significantly higher yield in improved pattern. Higher rice equivalent yield (REY) of the cropping pattern (mean value 20.68 t/ha) was recorded with the improved pattern over existing pattern (mean value 12.08 t/ha). REY increased 8.60 t/ha by inclusion of mustard with improved production technologies for the component crops. Similar results were also found in the production efficiency (62.10 kg/ha/day) was obtained from improved cropping pattern, 92.88% mean land utilization index (LUI) in both years and the gross return of the improved pattern was BDT. 721350/ha which was 70.68% higher than farmers' pattern of BDTK. 422625/ha. The gross margin (493950) and MBCR (2.18) were higher in improved cropping pattern in both years than the existing pattern (231465) and (1.21) due to addition of mustard BARI Sarisha-14. This study it was concluded that improved cropping pattern was more profitable than the existing farmers' pattern.

Key words: increasing, oilseed crops, productivity, land use efficiency, cropping intensity

INTRODUCTION

The total land area of Bangladesh is about 14.84 million hectares of which 3.74 million hectares (25% of the total) is not available for agriculture due to use for urban areas, industrial buildings, rural homesteads, roads and other infrastructure. The net area of Bangladesh for crop cultivation declined to 7.84 million hectares in 2011 from 8.85 million hectares in 1985 (BBS, 2012). Bangladesh also suffers regularly from several natural calamities (Haq *et al*., 2012; Islam *et al*., 2017; Rahman *et al.,* 2018), which may worsen in the future due to climate change (Hossain *et al*., 2016; Rokonuzzaman *et al*., 2018; Rahman *et al*., 2019). Thus, Bangladesh needs to produce more food on less land to assure future food security for millions of people every year. Horizontal expansion is very limited, but increase in crop production could be possible with vertical expansion through increasing cropping intensity and by increasing Land Use Efficiency. To achieve this, the two techniques that need to be adopted more frequently are an increase in the cropping intensity by producing two or more crops on the same land all-year round, and an increase in the productivity of individual crops, particularly their ability to utilize basic or limiting resources such as water and nutrients (Ladha *et al*., 2016). The present cropping intensity of the country is 192%. The urgent need is to produce more food to feed the teeming populations. Food requirement is

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estimated to be doubled in the next 25 years. Under such situation; it is very important improving the existing cropping pattern. There are some scopes of increasing cropping intensity from existing level of 192 to 300% or more by improving the existing cropping patterns by incorporating short duration crops like; mustard, potato, mungbean and transplant aus rice in the rice based cropping systems following the modern variety and technologies. Sustainable crop production in Bangladesh through improvement of cropping patterns in rice based cropping system is regarded as an important in national issues such as food security, poverty alleviation and creation of job opportunity. The main challenge of the new millennium is to increase yield of per unit area by at least 50 % through manipulating the limited land resource. In order to produce more food within a limited area, two most important options to be adopted are i) to increase the cropping intensity by producing three or more crops from the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices.

The major cropping pattern of agriculture in Bangladesh mostly consists of rice based cereal crops (Haque, 1998). More than 60% of the total cropped areas covered by Boro-Fallow-T. aman rice cropping pattern in Bangladesh. As a result, the vast area remains fallow for 75 days after T.Aman harvest. So, there is a great scope of increasing cropping intensity as well as crop productivity. The areas of oilseed and pulse in rabi season are decreasing because of increasing cultivation of Boro rice. In self-sufficiency of rice, the dominant cropping pattern T. Aman (wet season rice)- Fallow-Boro (dry season rice) plays an important role which covers about 1.8 million hectare (about 22% of the total land) of land (Elahi *et al.,* 1999). Bangladesh Rice Research Institute (BRRI) has recommended the T. Aman- Mustard-Boro cropping pattern for the irrigated ecosystem (BARC, 2001; Khan *et al.,* 2004, Anwar *et al.,* 2012) with the inclusion of 70-75 days local mustard variety (Tori 7) in the transition period between T. Aman and Boro rice. But the farmers harvest poor yield from local var. Tori7 that can be increased manifold by introducing high yielding varieties (Alam and Rahman, 2006; Basak *et al.,* 2007). Recently, Bangladesh Agricultural Research Institute (BARI) has developed high yielding yellow seeded mustard (*Brassica campestris*) varieties, BARI Sarisha- 14 and BARI Sarisha-15 whose yield potential is higher than Tori-7 and can easily be cultivated during fallow period. Most areas of Bangladesh at present under two crops based cropping pattern, but there prerequisite to increase crop number to meet up the demand. A number of reports on different cropping pattern are available in Bangladesh and abroad (Khan *et al*., 2005, Anwar *et al*., 2012, Nazrul *et al*., 2013, Khatun *et al*., 2016 and Anwar *et al*., 2017, Ahmed *et al*., 2017) where an additional crop could be introduced without much changes or replacing the existing ones for considerable increase of the overall productivity as well as profitability of the farmers. Keeping these views in mind, the present study was designed to evaluate the feasibility of increasing cropping intensity and productivity by growing three crops in a year in a same piece of land by introduce BARI Sarisha-14 in the fallow period.

MATERIALS AND METHODS

The experiment was laid out in a randomized complete block design with ten dispersed replications. The trial was conducted by incorporating BARI Sarisha-14 in the existing cropping pattern T. Aman-fallow-Boro at the farmers' field condition in Naldangha, Jashore (Latitude: 23.163401 N, Longitude: 89.218166 E) during two consecutive years 2021-22 and 2022-23. Two cropping pattern viz. three crops pattern and farmers' existing pattern were the treatments variables of the experiment. There were two treatments viz., T_1 = Existing cropping pattern T. Aman rice – Fallow - Boro rice, T_2 = Improved cropping pattern T. Aman rice – Mustard-Boro rice. Small unreplicated trials on farmers' fields, known as "dispersed experiments", were established under local farm conditions (Ferdous *et al.,* 2016; Ferdous *et al*., 2017). The land was divided into two equal plots. The unit plot size was 1340 Sq. m. where one plot was maintained either improved pattern, whereas the other plot was maintained existing pattern. T. Aman rice was the first crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 25-30 days old seedlings of T. Aman rice var. BRRIdhan 75 were transplanted with 20 cm × 15 cm during 25 July-05 Aug, 2021 and 2022 in both years. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). T. Aman rice was harvested during 22 to 23 October, 2021 and 2022 in two consecutive years. T. Aman rice plant was harvested at 15 cm from soil surface and remaining parts of the plants was incorporated in soil. Mustard was grown during rabi season and it was the second crop of the sequence. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to FRG (2012). Mustard var. BARI sarisha-14 was seeded as broadcast method with seed rate of 7 kg ha-1. The crop was sown during 05 November, 2021 and 2022 and harvested during 24 to 25 January, 2022 and 2023, respectively. Boro rice was the third crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 35-40 days old seedlings of rice var. BRRI dhan28 and BRRIdhan 63 at a spacing of 20 cm × 15 cm during 26 to 31 January, 2022 and 2023 in three cropping pattern. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). Boro rice was harvested during 26 April to 02 May, 2022 and 2023 in two consecutive years. Rice plant was harvested at 30 cm height from soil surface and remaining parts of the plants was incorporated in soil. Crop nutrient uptake was estimated following the standard value of FRG (2012). The area mostly falls under medium-high land and high land areas of the Agro Ecological Zone (AEZ) 11 (High Ganges River Floodplain). Organic matter content is low in higher parts, but moderate in lower parts. The general fertility level is low including N, P, S and B although CEC medium and K- bearing minerals are medium to high but the Zn status is low to medium (FRG, 2012). The area receives an annual rainfall of around 1035 mm with relatively early onset and late cessation and the mean annual high temperature is 32.1ºC (89.78ºF), annual low temperature is 22.95ºC (73.31ºF). The maximum land is under double-cropping followed by triple- and mono-cropping (Anwar *et al*., 2017). The initial soil status of the experimental sites was presented in Table 1.

Table 1. Initial status of soils of the experimental plots at Naldangha, Jashore

Soil characteristics				Naldangha, Jashore				
Land type and soil texture				Medium-high land and high land area and loamy soil				
Soil depth	pH	Organic Matter (%)	Total N (%)	Available nutrients				
				K (meq/100g soil)	P (µg/g soil)	S (µg/g soil)	Zn (µg/g soil)	B (µg/g soil)
0-15cm	7.7 Slightly alkalaine	1.71 low	0.09 Low	009 High	14.99 Low	16.05 Optimum	1.85 Medium	0.26 Low
15-30cm	7.8 Slightly alkalaine	0.82 Very low	0.04 Very low	0.04 Medium	7.62 Very low	18.38 Optimum	0.83 low	0.14 Very low

After physiological maturity, yield for each crop was determined as plot-wise and converted into yield on an area basis (kg/ha). Data on yield was statistically analyzed using statistics 10. Marginal benefit-cost analysis was done to estimate the economic feasibility of T. Aman rice, Mustard and Boro rice crop. The production costs of these crops included the cost of field preparation, seed, planting, irrigation, fertilizers, crop protection measures and harvesting. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated. The details of crop management practices followed for each crop is provided in Table 2.

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) (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.

$$\text{Rice equivalent yield (t/ha/yr)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{Market price of rice}}$$

Table 2. Crop management practices in farmer's existing and improved cropping pattern at Naldangha, Jashore

Observation	Existing cropping pattern			Improved cropping pattern		
Crop	T. Aman rice	Fallow	Boro rice	T. Aman rice	Mustard	Boro rice
Variety	Swarna	-	BRRIdhan 28	BRRIdhan 75	BARI Sarisha-14	BRRIdhan 63
Spacing	20 cm × 15 cm		20 cm × 15 cm	20 cm × 15 cm	Broadcast	20 cm × 15 cm
Unit plot size	1340 m2			1340 m2		
Fertilizer dose (Urea-TSP-MoP-Gyps.-Zn-B Kg/ha)	102-62-20-08-0-0	-	200-75-92-60-7.5-0	150-90-112.5-90-10-0	262-150-105-160-10+15	225-112-150-90-10-0
Date of sowing	01 July	-	20 Dec	01 July	05 Nov	20 Dec
Date of transplanting	29July-15 Aug	-	01-05 Feb	25July-05 Aug	-	01 Feb
Seedling age (days)	25-30	-	35-40	25-30	-	35-40
Harvesting date	15-30 Nov	-	26 April	22 to 31 October	19 to 24 January	02 May
Total crop duration (days)	113	-	130	113	80	140

Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated.

Production efficiency

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

$$\text{Production Efficiency (kg/ha/ day} = \frac{\sum \text{Yi}}{\sum \text{Di}}$$

Where, Yi= Yield (kg) of ith crop, di = Duration (day) of ith crop of the pattern and i = 1, 2, 3, 4

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:

$$\text{Land Utilization Index (\%)} = \frac{\text{d1} + \text{d2} + \text{d3}}{365} \times 100$$

Where, d1, d2 and d3 are the duration of 1st, 2nd and 3rd crop of the pattern, respectively. The gross income was estimated using the prevailing average market prices for the yield of these crops in Bangladesh. Net income was calculated by subtracting total expenditure from the gross income which was computed by dividing the gross income with total expenditure (Mahmood *et al*., 2016). 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) were computed according to CIMMYT (1988).

$$\text{Marginal Benefit Cost Ratio (MBCR)} = \frac{\text{d1} + \text{Gross return (E)} - \text{Gross return (F)d2} + \text{d3}}{\text{TVC (E)} - \text{TVC (F)}} = \frac{MVC}{MVP}$$

RESULTS AND DISCUSSION

Yield of the cropping patterns:

Results of the study have been presented in Table 3. It was revealed that the entire component crops of T. Aman rice – Mustard - Boro rice cropping pattern under improved practices (IP) gave higher yield as well as by-product yield in two consecutive years at the locations Naldangha, Jashore. The yield of improved pattern was higher due to inclusion of mustard with improved production technologies for the component crops. Similar results were also obtained by Anwar *et al*., 2017, Khatun *et al*. (2016), Kamrozzaman *et al*. (2015) and Nazrul *et al*. (2013). BARI Sarisha 14 is a short duration high yielding mustard variety which can easily be grown during the fallow period (Mondal *et al*., 2015). Inclusion of mustard with improved variety in T. Aman rice - Mustard-Boro rice cropping pattern practice increased the total yield over the farmers existing cropping pattern practice.

Grain yields of T. Aman rice in case of improved cropping pattern grain yields were 5.95 and straw yields 7.65 t/ha. and 5.99 t ha-1 and straw yields 7.65 t/ha. in 1st and 2nd year and mean grain and straw yields of T. Aman rice were 5.97 and 7.65 t/ha two consecutive years respectively. Seed yield of mustard were 1.75 and 1.8 t/ha and stover yields were 3.42 and 3.53 t/ha in two consecutive years respectively. Mean seed yield of mustard was 1.775 t/ha. Mustard seed yield increased 2.86% by 2nd year and it might be due to longer duration (2 days) than 1st year. It was revealed that all the 3-crops under T*.* Aman-Mustard - Boro cropping pattern gave higher grain and by-product yield. Grain yield of Boro rice were 7.10 t/ha and straw yields 6.94 t/ha. in first year and 7.20 t/ha and straw yields 6.95 t/ha. in second year. Mean grain and straw yields of Boro rice were 7.15 t/ha and 6.94 t/ha two consecutive years, respectively. T. Aman rice in three crops pattern produced 42.48% higher grain yield over farmers' practice due to change of variety with improved production technologies. Similar results were also obtained by (Nazrul *et al.,* 2013). Farmers' pattern gave lower yield due to imbalance use of fertilizers Urea, TSP, MoP, Gypsum and poor management practices. Three crops pattern produced higher by-product yield (18.07 t/ha) over farmers' practice (13.07 t/ha). Mean by-product yield of three crops pattern was 38.26% higher over farmer's pattern due to change of variety with improved technologies and inclusion of one crop in the existing pattern.

Table 3. Productivity of farmer's existing and improved cropping pattern at Naldangha, Jashore

Year	Cropping pattern	Crop	Variety	Field duration (days)	Total field duration (days)	Grain or seed yield (t/ha)	Straw or stover yield (t/ha)
2021-22	Existing cropping pattern	T.aman	Swarna	112		4.23±0.17	7.05±0.21
		Fallow	-	-	241	-	-
		Boro	BRRI dhan 28	129		5.7±0.21	6.05±0.24
	Improved cropping pattern	T.aman	BRRI dhan 75	113		5.95±0.15	7.65±0.29
		Mustard	BARI Sarisha-14	79		1.75±0.22	3.42±0.18
		Boro	BRRI dhan 63	139	331	7.10±0.11	6.94±0.29
2022-23	Existing cropping pattern	T.aman	Swarna	113		4.15±0.21	6.38±0.23
		Fallow	-	-	244	-	-
		Boro	BRRI dhan 28	131		5.59±0.15	6.65±0.18
	Improved cropping pattern	T.aman	BRRI dhan 75	114		5.99±0.16	7.653±0.12
		Mustard	BARI Sarisha-14	81		1.8±0.24	3.53±0.19
		Boro	BRRI dhan 63	140	335	7.20±0.23	6.95±0.27

Rice equivalent yield

Total productivity of a cropping system was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. Higher rice equivalent yield (REY) of cropping system (mean value 20.68 t/ha) was recorded with the improved pattern, T. Aman-Mustard-Boro over farmer's existing cropping pattern (mean value 12.08 t/ha.), T. Aman-Fallow -Boro at Naldangha, Jashore (Table 4). REY increased 8.7 tha-1 by inclusion of mustard with improved production technologies for the component crops. Inclusion of mustard in rabi season in existing cropping pattern increased total productivity by 72.35 % compared to farmers' practice. These results are in agreement with Mondal *et al.* (2015). They reported that total productivity increased by 67 % over farmers' practice. It is noted that inclusion of additional crop during the fallow period produced higher rice equivalent yield than farmer's practice, T. Aman-Fallow -Boro. Similar results were also obtained by Khatun *et al*. (2016); Kamrozzaman *et al*. (2015), Anowar *et al*. (2012), Nazrul *et al*. (2013).

Field duration

The field duration of a cropping pattern comprises on the individual crop duration. The farmer's cropping pattern of Boro-fallow-T. Aman was needed 241 and 244 days of field duration in the 1st and 2nd year. The newly introduced one crop in the farmer's existing pattern was mustard var. BARI Sarisha-14. A short duration T. Aman rice var. BRRIdhan 75 was also introduced to minimize the field duration of the crop. Total field duration of three crops pattern T. Aman-Mustard - Boro was needed 331 and 335 days including seedling age of rice to complete the cycle in the 1st and 2nd year (Table 3). Thus, long turn around period of 121 days in the farmer's existing pattern was utilized. Result indicated that mustard could be easily fitted in T. Aman rice- Mustard – Boro rice cropping pattern with an average of 32 days turnaround time in a year. Similar trend was also observed by Mondal *et al.* (2015) that the entire tested four crops pattern can be grown successfully one after another in sequence.

Production efficiency

Mean maximum production efficiency (62.10) in terms of kg ha-1 day-1 was obtained from improved cropping pattern T. Aman- Mustard -Boro and minimum (49.71 kg ha-1 day-1) in farmers' practice, T. Aman-Fallow -Boro (Table 4). The higher production efficiency in improved cropping pattern (three) T. Aman- Mustard -Boro might be due to inclusion of high yielding mustard varieties and improved management practices. Similar trend were noted by Nazrul *et al*. (2013).

Land utilization index

Land utilization index is the effective use of land in a cropping year, which mostly depends on crop duration. Mean land utilization index (LUI) indicated that improved cropping pattern used the land for 92.88% period of the year, whereas existing cropping pattern used the land for 66.58% period of the year (Table 4). The improved cropping pattern leads to higher land use efficiency due to longer period field occupied by the crops (333 days), whereas the farmers practice occupied the field for 243 days of the year. Similar results were also obtained by Khatun *et al*., (2016).

Table 4. Rice equivalent yield, production efficiency and land utilization index of farmers' existing and improved cropping pattern at Naldangha, Jashore during 2021-22 and 2022-23.

Items	Farmers' existing cropping pattern			Improved cropping pattern		
	2021-22	2022-23	Average	2021-22	2022-23	Average
REY (t/ha)	12.18	11.97	12.08	20.54	20.82	20.68
PE (kg/ha day-1)	50.12	49.26	49.71	61.68	62.52	62.10
LUI (%)	68.49	68.49	68.49	92.60	93.15	92.88

REY= Rice Equivalent Yield, PE= Production Efficiency and LUI= Land Utilization Index

Table 5. Cost and return analysis of farmer's existing and improved cropping pattern at Naldangha, Jashore during 2021-22 and 2022-23

Parameters	Gross return (Tk./ha)			Total variable cost (Tk./ha)			Gross magin (Tk./ha)			MBCR		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
Farmer's existing cropping pattern	426300	418950	422625	191654	190665	191160	234496	228415	231465	1.22	1.20	1.21
Improved cropping pattern	718900	723800	721350	221080	233720	227400	497820	490080	493950	2.25	2.10	2.18

Price: Mustard=BDT. 90/kg, Rice=BDT. 35/kg, Rice straw= BDT. 6/kg and Mustard stover = BDT. 5/kg Price (Tk./kg): Urea-22, TSP-22, MP-15, Gypsum-30, Zinc Sulphate-200, Boric acid-160, REY: rice equivalent yield, GM: gross margin, MBCR: Marginal Benefit cost Ratio.

Cost and return analysis

Economic analysis was done based on prevailing market price during the crop Season. Improved cropping pattern showed its superiority over farmers' pattern during two consecutive years at both the locations. Results of the study have been presented in Table 5. From the economic point of view, improved cropping pattern (T. Aman- Mustard- Boro rice) showed its superiority over farmers' existing cropping pattern (T. Aman- Boro rice). Mean gross return of improved cropping pattern (T. Aman- Mustard- Boro rice) was found Tk. 721350/ha and farmers' pattern was Tk. 422625/ha which was more than 70.68% higher over farmers' existing pattern. Two rice crop patterns (Farmers' existing pattern) gave the lower gross return Tk. 422625/ha. Mean variable cost was higher in improved cropping pattern (Tk. 227400/ha) that might be due to inclusion of new component crops (mustard) in the pattern. The mean gross margin was significantly higher in improved cropping pattern (Tk. 493950/ha) than farmer's existing cropping pattern (Tk. 231465/ha). Three cropping pattern achieved higher gross margin mainly due to higher yield advantages of the new component crops. The mean marginal benefit cost ratio (MBCR) was found 2.18 which indicated the superiority of the improved cropping pattern over the farmer's existing cropping pattern (1.21). The marginal benefit cost ratio (MBCR) also showed that inclusion of mustard in the existing pattern that might be profitable and acceptable to the farmers. Inclusion of new crop (mustard) as well as improvement of management practices in the improved cropping pattern increased the economic return. These results are supported by Mondal *et al.* (2015) and Khatun *et al*. (2016). They reported that inclusion of T. Aus, potato, mustard and mungbean in the existing pattern were profitable and acceptable to the farmers and grown successfully one after another in sequence of one year cycle.

Conclusion

From the above results showed that improved cropping pattern was more profitable as compared to existing pattern. Considering higher rice-equivalent yield, net monetary return and more sustainability of the improved cropping pattern (T. Aman rice – Mustard - Boro rice) with additional crop and improved technologies that might be suggested for medium-high land and high land areas of the High Ganges River Floodplain Agro Ecological Zone (AEZ) 11 of Bangladesh.

REFERENCES

Ahmed, N.U., Ferdous, Z., Mahmud, N.U., Hossain, A. & Zaman, M.A.U. (2017). Effect of split application of nitrogen fertilizer on the yield and quality of potato (*Solanum tuberosum*). *International Journal of Natural and Social Sciences*, 4(2), 60–66.

Alam, M.M. & Rahman, M.M. (2006). Effect of row spacing on seed yield of five varieties of Rapeseed. *Bangladesh Journal of Crop Science*, 17(1), 63- 168.

Anwar, M.M., Ferdous, M.Z. & Islam, M. (2012). Determination of nutrient management for potato mungbean-T. Aman based cropping pattern. Bangladesh Journal of Progressive Science & Technology, 10 (2), 173-176.

Anwar, M., Ferdous, Z., Sarker, M.A., Hasan, A.K., Akhter, M.B., Zaman, M.A.U., Haque, Z. & Ullah, H. (2017). Employment generation, increasing productivity and improving food security through farming systems technologies in the Monga regions of Bangladesh. *Annual Research and Review in Biology,* 16 (6), 1–15.

BARC (Bangladesh Agricultural Research Council) (2001). A compendium: Packages of Technologies. A handbook for Farming Systems Development. M. F. Haque, M. A. Razzaque and Abu AkteruzzAman (editors). FSR and D program. Bangladesh Agricultural Research Council, P.12.

Basak, N.C., Pandit, J.C., Khurram, M.H. (2007). On-farm evaluation of three mustard varieties under different fertilizer packages. *Bangladesh Journal of Science and Industrial Research*, 42(3), 335-340.

BRRI (Bangladesh Rice Research Institute) (2013). Modern Rice Cultivation, 17th edition, Bangladesh Rice Research Institute, Joydebpur, Gazipur-1701.

BBS (Bangladesh Bureau of Statistics) (2012). *Yearbook of Agricultural Statistics of Bangladesh.* Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka.

Bhuiyan, N.I., Paul, D.N.R. & Jabber, M.A. (2004). Feeding the extra millions by 2025: challenges for rice research and extension in Bangladesh. *In*: M. M. Haque, A. R. Gomosta & M. R. Mondal. *Proc. Of the workshop on Modern Rice Cultivation in Bangladesh*, 29-31, Bangladesh Rice Research Institute, Gazipur- 1701, Pp.1-24.

CIMMYT (International Maize and Wheat Improvement Centre) (1988). Agronomic data to farmer recommendation: An economic training manual. International Maize and Wheat Improvement Centre, Mexico, p.79.

Dobermann, A., Nelson, R., Beever, D., Bergvinson, D., Crowley, E., Denning, G., Giller, K., d'Arros Hughes, J., Jahn, M. & Zhang, F. (2013). Solutions for sustainable agriculture and food systems, *technical report for the post-development agenda. Sustainable Development Solutions Network*, New York, pp. 1–99.

FRG (Fertilizer Recommendation Guide) (2012). Nutrient uptake by various crops at definite yield level. Bangladesh Agricultural Research Council, Dhaka-1215, p.7.

Ferdous, Z., Ullah, H., Datta, A., Anwar, M. & Ali, A. (2018). Yield and profitability of tomato as influenced by integrated application of synthetic fertilizer and Biogas Slurry. *International Journal of Vegetable Science,* 16, 12-21.

Ferdous, Z., Anwar, M., Haque, Z., Islam, M.K., Khatun, M.U.S. & Alam, M.A. (2017). Sustainable food security through cropping system analysis using different farming technologies at northern region of Bangladesh. *Progressive Agriculture*, 28 (3), 204-215.

Ferdous, Z., Datta, A., Anal, A.K., Anwar, M. & Khan, M.R. (2016). Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh. *NJAS - Wageningen Journal of Life Science*, 78, 103–110.

Haq, M.Z., Robbani, M., Ali, M., Hasan, M.M., Hasan, M. M., Uddin, M.J., Begum, M. & Karim, M. R. (2012). Damage and management of cyclone Sidr-affected homestead tree plantations: a case study from Patuakhali. *Bangladesh. Natural Hazards*, 64 (2), 1305–1322.

Hossain, M.S., Hossain, A., Sarkar, M.A.R., Jahiruddin, M., Teixeira da S. & Hossain, M., (2016). Productivity and soil fertility of the rice wheat system in the high Ganges River floodplain of Bangladesh is influenced by the inclusion of legumes and manure. *Agriculture, Ecosystem and Environment*, 218, 40–52.

Islam, M.A., Hasan, A. & Farukh, M.A. (2017). Application of GIS in general soil mapping of Bangladesh. *Journal of Geographic Information System*, 9, 604-621.

Islam, M.A., Parvin, S. & Farukh, M.A. (2017). Impacts of riverbank erosion hazards in the Brahmaputra flood plain areas of Mymensingh in Bangladesh. *Progressive Agriculture*, 28 (2), 73-83.

Kamrozzaman, M.M., Khan, M.A.H., Ahmed, S. & Quddus, A.F.M.R. (2015). On-farm evaluation of production potential and economics of Wheat- Jute-T. Aman rice-based cropping system. *Journal Bangladesh Agricultural University*, 13(1), 93–100.

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 of mustard-rice based improved cropping system. *Journal of Social Research Development*, 2(1), 37-42.

Khan, A.H., Rashid, H., Khatun, A., Quddus, M.A. & Gomosta, A.R. (2004). Rice Farming System: improved rice-based cropping systems for different ecosystems. *The National Farming Systems Technology Inventory Workshop*, CERDI, Gazipur.

Khatun, M.U.S., Alam, M.A.U., Hossain, M.A., Islam, M.K., Anwar, M.M. & Haque, M.E. (2016). Evaluation of production potential and economics of Radish-Potato/Maize- T. *Aman* cropping pattern in Rangpur region. *Journal of Science, Technology and Environment Informatics*, 4(02), 293-300.

Ladha, J.K., Rao, A.N., Raman, A.K., Padre, A.T., Dobermann, A., Gathala, M., Kumar, V., Saharawat, Y., Sharma, S., Piepho, H.P., Alam, M.M., Liak, R., Rajendran, R., Reddy, C.K., Parsad, R., Sharma, P.C., Singh, S.S., Saha, A. & Noor, S. (2016). Agronomic improvements can make future cereal systems in South Asia far more productive and result in a lower environmental footprint. *Global Change Biology*, 22, 1054–1074.

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), 17-57.

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

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.

Rahman, M.A., Yeasmin, M., Islam, M.A. & Farukh, M.A. (2019). An empirical study on predicting the wind speed after landfall of tropical cyclones over Bay of Bengal. *International Journal of Scientific Research in Science and Technology*, 5(4), 75-84.

Rahman, M.M., Yasmine, F., Rahman, M.A., Ferdous, Z. & Kar, P.S. (2011). Performance of poultry bioslurry as a source of organic manure on potato production. *Journal of Agroforestry and Environment,* 5, 81– 84.

Rahman, M.M., Hiya, H.J., Auyon, S.T. & Islam, M.A. (2018). Exploring the status of disaster risk reduction focusing coping strategies in Rangpur division of Bangladesh. *Progressive Agriculture,* 29 (3), 195-204.

Rokonuzzaman, M., Rahman, M.A., Yeasmin, M. & Islam, M.A. (2018). Relationship between precipitation and rice production in Rangpur district. *Progressive Agriculture*, 29(1), 10-21.

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

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