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INCLUSION OF SHORT DURATION MUSTARD INCREASES PRODUCTIVITY AND PROFITABILITY OF RICE BASED CROPPING PATTERN IN NORTH-EASTERN BANGLADESH

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Abstract

An on-farm trial was conducted at the farmers' field of Netrokona, a north-eastern district of Bangladesh during 2023-24 and 2024-25 to develop an improved cropping pattern *T. Aman* (var. BRRI dhan71)- mustard (var. BARI Sarisha-14)-*Boro* rice (var. BRRI dhan92) against farmers existing pattern *T. Aman* (var. BRRI dhan49)-Fallow-*Boro* rice (var. BRRI dhan29) for increasing the system productivity and profitability. The experiment was laid out in a randomized complete block design with five dispersed replications. Two cropping patterns *viz.,* improved (*T. Aman*- Mustard-*Boro*) and farmers' existing one (*T. Aman*-Fallow-*Boro*) were the treatment variables of the experiment. The unit plot size was 1000-1200 m^2. The result of the study revealed that three crops could be grown successfully in sequence in the tested site. Mean rice equivalent yield of improved cropping pattern was 16.45 t ha^{-1} which was 32.88 % higher than the existing cropping pattern (12.38 t ha^{-1}). Besides, land utilization index, harvest index and profitability of improved pattern was higher than farmers' existing one. The mean gross return (Tk. 4,97,330 ha^{-1}) and gross margin (Tk. 2,48,673 ha^{-1}) were higher in improved pattern compared to farmers' pattern. The marginal benefit cost ratio (2.30) was also indicated the superiority of the improved pattern over the farmers' existing cropping pattern. Based on the findings, it is concluded that the improved cropping pattern, *T. Aman* (var. BRRI dhan71)-mustard (BARI Sarisha-14)-*Boro* rice (BRRI dhan92) could profitably be grown in the north-eastern part of Bangladesh.

Keywords: Cropping pattern, Mustard, Short duration, Productivity, Profitability, Netrokona

Introduction

Agricultural land is decreased by 0.73% each year due to infrastructural development of the country (BBS, 2024). The situation created a threat to food security in Bangladesh, which needs to address properly. With the advent of short-duration high yielding transplanted *T. Aman* rice varieties, opportunity has been created to include new crop in the cropping pattern, eg. mustard. It has been

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reported that mustard yield could be increased by 20-25% replacing traditional variety with high yielding short duration one, like BARI Sarisha-14 in the existing rice-based cropping system (OFRD, 2014).

Bangladesh is almost self-sufficient in rice production but other food production such as oil crops, pulses, wheat and vegetables etc. are still insufficient to a large extent. Mustard is one of the *rabi* crops in Bangladesh, while *T. Aman* rice is predominantly cultivated in monsoon season. Most of the *T. Aman* rice area is covered with long duration *T. Aman* varieties which cause a delay in mustard crop sowing, resulted reduce the yield. November 01 to 15 is the best time for mustard sowing, which can avoid drought and diseases at terminal growth stage of the crop. After harvest of *T. Aman* and before transplanting of *Boro* rice the land remains mostly fallow for around 80-86 days. Mustard (BARI Sarisha-14) is a high value cash crop which brings higher economic return. In Fallow-*Boro*-*T. Aman* rice cropping patterns mustard may be introduced as an alternative of farmers' pattern. Farmers' practices 'Fallow-*Boro*-*T. Aman'* cropping pattern is greatly influenced by the distribution pattern of annual rainfall.

There are 10 major cropping patterns in Netrakona district, among which Fallow-*Boro*- *T. Aman* rice covered 63 % of the net cropped area (DAE, 2024). Bangladesh Agricultural Research Institute (BARI) has developed short duration (75-80 days) high yielding mustard variety, namely BARI Sarisha-14 which has 30-40 % higher yield potential than the traditional variety of Tori-7. Inclusion of this new mustard variety after harvest of short duration *T. Aman* rice (115-120 days) can create an opportunity to fit in the Mustard-*Boro*-*T. Aman* rice cropping sequence. Therefore, the present study was conducted to evaluate the productivity and profitability of the new pattern 'Mustard-*Boro*-T.*Aman* rice' against the farmers' existing pattern in north-eastern Bangladesh.

Materials and Methods

The trial was conducted at the farmers' field of Netrokona MLT site under On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Mymensingh during 2022-23 and 2023-24 to increase cropping intensity, productivity and profitability of the farmers by inclusion of mustard (var. BARI Sarisha-14), *Boro* (var. BRRI dhan92) and T. *Aman* (var. BRRI dhan71) in the existing cropping system 'Fallow-*Boro* (var. BRRI dhan29)-T.*Aman* (var. BRRI dhan49)'. The experimental site belongs to Old Brahmaputra Flood plain Agro-ecological Zone (AEZ-9) of Netrokona. The approximate geographic coordinates for experimental site under Netrokona Sadar are at 24.88^0N latitude and 90.73^0E longitude with the altitude of 15 m above sea level. The land was medium high and the soil of the study area was clay loam to clay in texture with well drainage system. General soil types predominantly include Dark Grey Floodplain soil. The soil is

generally acidic having pH range of 4.3 to 5.8. Organic matter content is low to medium. Soils are mainly deficient in N, P, K, S, Zn and B. Maximum rainfall was received during the months of April to September. The highest temperature (33.9ºC) was in August and the lowest was in December (10.1ºC). The relative humidity was the highest (84.5%) in August and the lowest (75.2 %) in March. Monthly mean maximum and minimum air temperature (31.9 and 19.3ºC), total rainfall (2018 mm) and relative humidity (82.7 %) were prevailing during the study period.

The experiment was laid out in a randomized complete block design with five dispersed replications. Two cropping patterns *viz.*, improved (*T. Aman*- Mustard-*Boro*) and farmers' existing one (*T.Aman*-Fallow-*Boro*) were the treatment variables of the experiment. The unit plot size was 800-1000 m^2. T. *Aman* rice was the first crop of the sequence. Seedlings of *T. Aman* rice var. BRRI dhan71 with 30 to 35 days old were transplanted with 20 cm × 15 cm spacing during 25 to 28 July 2023 and 22 to 27 July 2024 in two consecutive years. *T. Aman* rice was harvested during 20 to 27 October, 2023 and 20 to28 October, 2024 in two successive years. Mustard was grown during *rabi* season and it was the second crop of the sequence. Fertilizer management was followed by Ahmmed *et al*. (2018) and intercultural operations like weeding, irrigation and pest management were done to support the normal growth and development of the crops. Mustard var. BARI Sarisha-14 was seeded as broadcast method @ 6 kg ha^{-1}. The crop was sown during 11 to 15 November, 2023 and 14 to19 November 2024 and harvested during 25 to 31 January, 2024 and 01 to 08 February 2025, respectively. Boro rice was the third crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 30 to 35 days old seedlings of *Boro* rice var. BRRI dhan92 at a spacing of 20 cm × 15 cm during 20 to 25 February 2024 and 18 to 22 February 2025. *Boro* rice was harvested during 12 to 20 Jun. 2024 and 12 to 18 Jun. 2025 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. T. *Aman* rice plant was harvested at 15 cm from soil surface and remaining parts of the plants was incorporated in soil.

Data on the yield of various crops in sequences were recorded and converted to ton per hectare. The data of farmer's practice was recorded from adjacent farmers' plots. Agronomic performance like field duration, rice equivalent yield (REY), productivity and land utilization index of cropping patterns were calculated.

Rice Equivalent Yield (REY): For comparison between crop sequences, the yield of every crop was converted into rice equivalent yield 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.

$$\textbf{Rice Equivalent Yield (t ha}^{-1}\textbf{)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

Productivity: Production efficiency value in terms of $kgha^{-1}day^{-1}$ was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

$$\textbf{Production efficiency } (kgha^{-1}day^{-1}) = \frac{\sum Y_i}{\sum d_i}$$

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, 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:

$$\textbf{Land Utilization Index (\%)} = \frac{d_1 + d_2 + d_3 + d_4}{365} \times 100$$

Where d_1, d_2, d_3 and d_4 the duration of 1^{st}, 2^{nd} 3^{rd} and 4^{th} crop of the pattern

Harvest index (HI) was calculated as per following equation (Rahman *et al*., 1989).

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

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).

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

Results and Discussion

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, field duration and turnaround time etc. of improved and existing cropping pattern are shown in Table 1. Field duration of cropping pattern comprises on the individual crop duration. Farmers' cropping pattern *T. Aman*-Fallow-*Boro* has needed 219 and 215 days field duration in 1^{st} and 2^{nd} year. The newly introduced two crops in the farmers

Table 1. Agronomic parameters of farmers' existing cropping pattern and improved cropping pattern at MLT site Netrakona, during 2023-24 and 2024-25

Parameters	Years	Farmers' Pattern (FP)			Alternate Pattern (AP)		
Crop	2023-24	T. Aman	Fallow	Boro	T. Aman	Mustard	Boro
	2024-25	T. Aman	Fallow	Boro	T. Aman	Mustard	Boro
Variety	2023-24	BRRI dhan49	Fallow	BRRI dhan29	BRRI dhan71	BARI Sarisha-14	BRRI dhan92
	2024-25	BRRI dhan49	Fallow	BRRI dhan29	BRRI dhan71	BARI Sarisha-14	BRRI dhan92
Sowing/	2023-24	15-19 Jul.23	Fallow	15-19 Jan.24	25-28 Jul.23	11-15 Nov. 23	20-25 Feb.24
planting time	2024-25	12-16 Jul.24	Fallow	10-15Jan.25	22-27 Jul.24	14-19 Nov. 24	18-22 Feb.25
Seedling age	2023-24	30-40	Fallow	40-45	30-35	-	30-40
(days)	2024-25	30-40	Fallow	40-45	30-35	-	30-40
Spacing (cm)	2023-24	20 × 15	Fallow	20 × 15	20 × 15	Broadcast	20 × 15
	2024-25	20 × 15	Fallow	20 × 15	20 × 15	Broadcast	20 × 15
Fert. dose	2023-24	74-12-40-10-3-0	Fallow	140-15-30-0-3-0	70-15-35-10-4-0	90-35-42-26-2-2	140-15-60-15-3-0
(NPKSZnB kg ha^{-1})	2024-25	74-12-40-10-3-0	Fallow	140-15-30-0-3-0	70-15-35-10-4-0	90-35-42-26-2-2	140-15-60-15-3-0
Harvesting time	2023-24	24-28 Oct.23	Fallow	12-16 May.24	20-27 Oct. 23	25-31Jan.24	12-20 Jun.24
	2024-25	23-27 Oct.24	Fallow	12-15 May 25	20-28 Oct.24	01-08 Feb.25	12-18 Jun.25
Field duration	2023-24	101	Fallow	118	89	76	114
(days)	2024-25	103	Fallow	122	92	79	115
TAT (days)	2023-24	60	Fallow	86	40	21	25
	2024-25	61	Fallow	79	39	24	16

existing pattern were mustard (BARI Sarisha-14) and *Boro* rice (BRRI dhan92). A short duration *T. Aman* rice variety BRRI dhan71 was also introduced to minimize the field duration of the crop. Total field duration of alternate cropping pattern *T. Aman*-Mustard-*Boro* rice has needed 279 and 286 days excluding seedling age of *T.Aman* and *Boro* rice to complete the cycle in 1st and 2nd year, respectively (Table 1). Thus, long turnaround time of 140-146 days in the farmers' existing pattern was utilized. Result indicated that mustard *T. Aman* and *Boro* rice could be easily fitted in Rice-Rice cropping pattern with average 23 days turnaround time in a year. The result is statistically similar with Khan *et al*. (2024) and Khatun *et al*. (2019). They reported that mustard could be easily fitted in the existing cropping pattern, *T. Aman*-Fallow-*Boro* rice.

Grain/Seed and by-product yield: Grain/Seed and by-product yield of the study have been presented in Table 2. It was revealed that the alternate cropping pattern, *T. Aman*- Mustard-*Boro* rice gave higher yield as well as by-product yield in two consecutive years. The yield of alternate pattern was higher due to inclusion of mustard with improved production technologies for the component crops. Similar results were also obtained by Nazrul *et al*. (2013), Anwar *et al*., (2017) and Khatun *et al*., (2019). Mustard var. BARI Sarisha-14 is a short duration high yielding mustard variety which can easily be grown during the fallow period (Mondal *et al*., 2015). *T. Aman* rice grain yields were 4.88 and 4.80 t ha^{-1} in 1st and 2nd years, respectively. Two years average grain and straw yields of T. *Aman* rice (var. BRRI dhan71) were 4.84 and 5.79 t ha^{-1} in alternate cropping pattern showed 4.08 and 26 % higher than the existing pattern, *T. Aman* rice (var. BRRI dhan49) due to change of variety with improved production technologies. Seed yield of BARI Sarisha-14 was 1.76 and 1.60 tha^{-1} and stover yields were 2.18 and 2.10 tha^{-1} in two successive years. Two years average result showed that seed and stover yield of BARI Sarisha-14 in alternate cropping pattern was 1.68 and 2.14 t ha^{-1}. Grain yield of *Boro* rice (var. BRRI dhan92) was 7.13 t ha^{-1} in 1st year and 7.21 t ha^{-1} in 2nd year whereas mean grain and straw yields of *Boro* rice were 7.17 and 6.98 t ha^{-1} respectively, which was 16 and 8.39 % higher than the existing pattern, *Boro* rice var. BRRI dhan29 with improved production technologies. Farmers' pattern gave lower yield probably due to imbalance use of fertilizers and poor management practices. It was revealed that the entire component crops of *T. Aman*-Mustard-*Boro* rice cropping pattern under improved practices gave higher yield as well as by-product yield in two consecutive years. Inclusion of mustard var. BARI Sarisha-14, rice var. BRRI dhan71 and BRRI dhan92 with improved production technologies increased the total yield over the farmers existing practice. Similar results were also obtained by Khatun *et al*. (2019), Kamrozzaman *et al*. (2015), Nazrul *et al*. (2013). Their findings also showed that inclusion of additional crop during the fallow period produced higher total yield than farmer's practice.

Table 2. Seed/grain yield and by-product yield of farmers' cropping patterns and alternate cropping pattern at MLT site Netrakona during 2023-24 and 2024-25

Parameters	Years	Farmers' cropping pattern (FP)			Alternate cropping pattern (AP)		
		T. Aman	Fallow	*Boro*	*T. Aman*	Mustard	Boro
Grain/Seed yield (t ha^{-1})	2023-24	4.80	-	6.22	4.88	1.76	7. 13
	2024-25	4.70	-	6.32	4.80	1.60	7.21
	Average	4.65	-	6.17	4.84	1.68	7.17
By-Product yield (t ha^{-1})	2023-24	5.60	-	6.72	5.79	2.18	6.89
	2024-25	5.40	-	6.75	5.25	2.10	7.07
	Average	5.50	-	6.74	5.52	2.14	6.98

Rice Equivalent Yield (REY): Total productivity of a cropping system was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. The mean higher rice equivalent yield (16.45 t ha^{-1}) was recorded with the alternate cropping system with the increase of 32.88 % due to inclusion of BARI Sarisha-14 and recent high yielding varieties of rice with improved production technologies for the component crops. The lower rice equivalent yield (12.38 t ha^{-1}) was obtained in the farmer's pattern presumably due to inclusion of only two crops *Boro and T. Aman* rice with traditional management practices. REY increased 4.07 t ha^{-1} by inclusion of mustard and rice varieties with improved production technologies for the component crops. It is evident from the above findings that alternate cropping pattern gave higher yield compared to the existing farmers' pattern. Similar results were also obtained by Khatun *et al*. (2019), Kamrozzaman *et al*. (2015), and Nazrul *et al*. (2013). Their findings also stated that inclusion of mustard crop during the fallow period produced higher REY than farmer's practice.

Production Efficiency (PE): Mean maximum production efficiency (49.65) in terms of kg ha^{-1} day^{-1} was obtained from farmer's existing cropping pattern which was 2.43 % higher over improved cropping pattern (Table 3). Production efficiency of improved cropping pattern was found 49.35 and 47.59 kg ha^{-1}day^{-1} in two consecutive years while in the existing cropping pattern it was found 50.32 and 48.98 kg ha^{-1}day^{-1}, respectively (Table 3). The lower production efficiency in alternate cropping pattern was probably due to the inclusion of mustard variety, that took 61 days longer than the farmer's existing pattern. The results indicate that the crops remained in the field for longer time leading to lower production per day. Similar results were obtained by Khan *et al*. (2024). They reported that longer field duration leading lower production per day in Mustard-*Boro*-*T.Aman* cropping pattern.

Land utilization index (LUI): Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The average land utilization index indicated that alternate cropping pattern used the land for 77.40 % period of the year whereas farmer's pattern used the land for 60.82% period of the year (Table 3). Land utilization index was about 27.26 % higher in alternate cropping pattern than farmer's practice due to alternate pattern occupied the land for longer duration (283 days) and farmer's pattern (222 days) in a year. This higher land use efficiency in alternate cropping pattern is due to cultivation of three component crops in the pattern. Similar results were also obtained by Khatun *et al*. (2016).

Harvest Index: Improved cropping pattern *T.Aman* (var. BARI dhan71) –Mustard (var. BARI Sarisha-14)-*Boro* rice (var. BRRI dhan92) recorded the higher harvest index (48.33 %) than the farmers' existing cropping pattern, *T. Aman* rice (var. BRRI dhan49)-Fallow-*Boro* (var. BRRI dhan29) . The harvest index of alternate cropping pattern had higher value due to inclusion mustard and *Boro* rice varieties which contributed the higher economic and biological yield.

Table 3. Rice equivalent yield, production efficiency, land utilization index and harvest index of farmers' practice and improved pattern at MLT site Netrakona during 2023-24 and 2024-25.

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency ($kgha^{-1}day^{-1}$)	Land utilization index (%)	Harvest Index (%)
2023-24	FP	12.61	50.32	60.00	47.22
	AP	16.65	49.35	76.44	48.10
2024-25	FP	12.15	48.98	61.64	47.90
	AP	16.24	47.59	78.36	48.56
Mean	FP	12.38	49.65	60.82	47.56
	AP	16.45	48.47	77.40	48.33

Note: FP= Farmers' Pattern and AP= Alternate Pattern

Profitability Analysis: The cost and return analysis were done on the basis of prevailing market price during the crop season as shown in Table 4. The study revealed that means gross return of the alternate and farmers' pattern was Tk.4,97,330 and Tk. 3,37,490 ha^{-1}, respectively. The mean gross return of alternate cropping pattern was about 47 % higher than the farmers' existing pattern and it might be due to inclusion of high yielding mustard, *Boro* and *T. Aman* rice varieties. The mean total variable cost of the alternate and the farmers' existing cropping pattern was Tk. 2,48,657 and Tk. 1,79,045 ha^{-1}, respectively. It is noted that higher cost was involved in farmers' pattern due to addition of one crop. But about 57 % higher gross margin (Tk. 2,48,673 ha^{-1}) was calculated in alternate pattern over farmer's existing cropping pattern (Tk. 1,58,445 ha^{-1}). The mean

MBCR was found 2.30 which also indicated the superiority of alternate cropping pattern over the farmer's existing cropping pattern. Inclusion of new crops as well as improvement of agronomic management practices in the alternate cropping pattern increased the monetary benefit. This result is supported by Monim and Ahammad (2023). They also reported that inclusion of mustard in *T. Aman*-Fallow-*Boro* rice cropping pattern is profitable and acceptable to the farmers.

Table 4. Cost and return analysis of farmers' and improved cropping pattern cropping pattern at MLT site Netrakona during 2023-24 and 2024-25

Year	Pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk.ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
2022-23	FP	3,44,780	1,79,140	1,65,640	2.26
	AP	5,02,930	2,49,120	2,53,810	
2023-24	FP	3,30,200	1,78,950	1,51,250	2.33
	AP	4,91,730	2,48,194	2,43,536	
Mean	FP	3,37,490	1,79,045	1,58,445	2.30
	AP	4,97,330	2,48,657	2,48,673	

Note: Unit price (Tk. kg^{-1}): Mustard =70/-, Boro rice =25/-, T. Aman rice = 30/-, stover=2/-, and Rice straw=4/-

Farmers' opinion: Farmer's expressed their satisfaction for getting higher yield and economic return from the *T. Aman*-Mustard-*Boro* rice cropping pattern. They would like to follow the alternate pattern for efficient use of fallow land for getting more income as compared to *T. Aman* -Fallow-*Boro* rice cropping pattern. They are also happy with yield potentiality of BARI developed mustard variety.

Conclusion

The total crop productivity in terms of REY, production efficiency and profitability of alternate cropping pattern, *T.Aman* (var. BRRI dhan71) Mustard (var. BARI Sarisha-14) –*Boro* rice (var. BRRI dhan92) were much higher than that of the existing cropping pattern, *T. Aman* (var. BRRI dhan49) - Fallow- *Boro* rice (var. BRRI dhan29). Thus, the alternate cropping pattern could be piloting for large scale production in the high and medium high land of the north-eastern part of Bangladesh with the collaboration of DAE and BARI.

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References

Ahmmed, S., M. Jahir Uddin, S. Razia, R. A. Begum, J. C. Biswas, A. S. M. M. Rahman, M. M. Ali, K. M. S. Islam, M. M. Hossain, M. N. Gani, G. M. A. Hossain and M. A. Satter. 2018. Fertilizer Recommendation Guide-2018. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215. P. 223.

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

BBS, 2024. Y*earbook of agricultural statistics of Bangladesh*. Dhaka: Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

CIMMYT. 1988. International Maize and Wheat Improvement Centre. From Agronomic Data to Farmer Recommendations: An Economic Training Manual. International Maize and Wheat Improvement Centre, Mexico, D. F. pp.1-79.

DAE. 2024. Department of Agriculture Extension). Paper presented in the regional research extension review and program planning workshop at Bangladesh Agricultural Research Institute, Gazipur-1701.

Gadge, S. S. 2003. Influence of changes in cropping pattern on farmers' economic status. *Indian Journal of Extension Education.* **39**: (1&2): 99-101.

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

Khan, M. A. H., M. M. Rahman, T. Tasmima and F. Begum. 2024. Increasing cropping intensity and profitability through improved cropping pattern against farmers' existing cropping pattern at Madhupur Tangail. *Bangladesh Journal of Agronomy* **26** (2):49-55.

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

Khatun, M.U.S., M.A.U. Alam, M. A. Hossain, M. K. Islam, M. M Anwar and M. E. Haque. 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**(2):293-300.

Khatun, M.U.S., Z. Haque, M.A.U. Alam, M. Hasan and M. K. Islam. 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.

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

Monim, M. A. and K. U. Ahammad. 2023. Increasing oil seed productivity through inclusion of mustard in T.Aman-Fallow- Boro rice cropping pattern in Jashore. *Bangladesh Journal of Agricultural Research* **48** (1):125-136.

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 Journal of Agricultural Research* **42**(3):413-424.

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

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

Rahman, M. M., M. H. Khan, R. N. Mallick and R. E Hudgens. 1989. Guidelines for Farming Systems Research Methodology. Bangladesh Agricultural Research Council, Framgate, Dhaka. P. 42.

Tomer, S. S and A. S. Tiwari. 1990. Production potential and economics of different crop sequences. *Indian Journal of Agronomy* **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 Journal of Agriculture Research* **9**(2): 89-92.