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INCREASING CROPPING INTENSITY, PRODUCTIVITY AND DIVERSITY OF CROPS THROUGH RICE BASED CROPPING PATTERN IN TANGAIL

M. A. H. KHAN[1], Q. NAHER[2], M. A. HOSSAIN[2]
M. M. RAHMAN[3] AND T. TASMIMA[4]

Abstract

The experiment was conducted at Farming Systems Research and Development site under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during the period of 2019-20 and 2000-21 having eight rice-based cropping patterns viz., Mustard-Boro-T. Aman rice, Potato-Boro-T. Aman, Mustard-T. Aus-T. Aman, Lentil- Jute-T. Aman, Wheat-Jute-T. Aman, Wheat-Sesame-T. Aman, Garden pea-Boro-T. Aman and Fallow-Boro-T. Aman (as check). The treatments were replicated five times in randomized complete block design with a plot size of 8.0 m × 5.0 m. Result showed that the highest rice equivalent yield (31.77 t ha^{-1}) was obtained from Potato-Boro-T. Aman cropping pattern which was followed by Garden pea-Boro-T. Aman cropping pattern (26.42 t ha^{-1}). The lowest rice equivalent yield (11.37 t ha^{-1}) was obtained from Fallow-Boro-T. Aman cropping pattern. Highest gross return (Tk. 557514 ha^{-1} and gross margin (Tk.260964 ha^{-1}) and production efficiency (108.43 kg ha^{-1}day^{-1}) was recorded from Potato-Boro-T. Aman cropping pattern. Maximum land use efficiency (86%) was observed in Wheat-Jute-T. Aman cropping pattern. Highest benefit cost ratio was recorded from Mustard (var. BARI Sarisha-14)-Boro-T. Aman and Mustard (var. BARI Sarisha-18)-T. Aus-T. Aman pattern (2.16 and 2.13). On the other hand, highest by-product yield was obtained from Potato-Boro-T. Aman rice sequence. However, the higher sustainable yield index value was recorded in Potato-Boro-T. Aman rice (97.30%), which was closely followed by Garden pea-Boro-T. Aman (95.74%) and Mustard-Boro-T. Aman (93.3 %). The more labour (537man days ha^{-1}) intensive cropping pattern was Potato-Boro-T. Aman rice. However, the profitable and viable cropping patterns were found Mustard-Boro-T. Aman followed by Potato-Boro-T. Aman and Garden pea-Boro-T. Aman which need to be disseminated in the farmer's fields.

Keywords: Cropping intensity, Diversity, Productivity, Profitability, Sustainable index, and Land utilization index.

Introduction

Rice is the major staple food crop in Bangladesh. The harvested area covers 11.5 million hectares (because of 2-3 crops per year) or 80% of the cultivated area. Rice is grown in single, double, and triple crop patterns across Bangladesh in the Boro, Aus and Aman season. Cropping pattern is an important indicator of a farmer's

[1]Principal Scientific Officer, [3]Senior Scientific Officer, [4]Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Tangail, and [2]Principal Scientific Officer, On-Farm Research Division, BARI, Gazipur, Bangladesh.

decision-making ability and also influences the consumption pattern as well as health and nutritional status of the people. Sustainable crop production in Bangladesh through improvement of cropping intensity in rice-based cropping system is regarded as increasingly 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 50% yield per unit land area through manipulating the limited land resource. In order to produce more food within a limited area, the most important options: are i) to increase the cropping intensity by producing three or more crops over the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices (Salam *et al*., 2014). To meet the challenges of a globalizing market in agriculture as well as the growing and changing needs of the population, diversification is taking place either through area augmentation or by crop substitution.

Fallow-Boro-T. Aman, Mustard-Boro-T. Aman, Potato-Boro-T. Aman, Mustard-T. Aus-T. Aman, Lentil-Jute-T. Aman, Wheat-Jute-T. Aman, Wheat-Sesame-T. Aman, Garden pea-Boro-T. Aman are the major cropping patterns at Tangail region.

Potential adoption of these improved cropping patterns intensifying mustard, pulses, potato, wheat, jute, sesame and garden pea in Fallow-Boro-T. Aman cropping pattern would generate employment and additional income for the rural poor through producing more of these crops utilizing fallow and unused lands in the country. The farm level adoptions of improved oilseeds, pulses, potato, wheat, jute and garden pea in rice-based cropping patterns have already been created a wide range of socio-economic impacts that need to be evaluated properly. Considering the above issues, this study was undertaken with the objectives: i) to increase cropping intensity, productivity and diversity in rice-based cropping systems and ii) Increase farmer’s income, access to food and nutrition and create employment opportunity in agriculture.

Materials and Method

The study was conducted at Farming Systems Research and Development (FSRD) site Atia, Delduar under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during two consecutive years of 2019-20 and 2020-21. The geographical position of the area is between $24^{0}17'$ N latitude and $89^{0}90'$ E longitude. The meteorological data of the experimental site revealed that maximum rainfall was received during the months of April to September where peak in July (558 mm). The meteorological data in 2019-20, monthly mean maximum 31.3^{0}C and minimum 20.9^{0}C air temperature and annual total rainfall 2439 mm and in 2020-21, monthly mean maximum 30.6^{0}C and minimum 20.6^{0}C air temperature and annual total rainfall 2240 mm were prevailing in the study area (Appendix1). The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological

Zone (AEZ-9) of Tangail. The land type was medium high and general soil type predominantly includes Dark Grey Floodplain soils. Organic matter content is low (1.38 %), soils are slightly acidic (6.08) in reaction. General fertility level including N (0.099 %), P (6.96 µg g^{-1}), K (0.11 meq $100g^{-1}$ soil), S (9.12 µg g^{-1}) and B (0.18 µg g^{-1}) are low (Appendix 2).

The study consisted of eight rice-based cropping patterns, i.e., i. Mustard - Boro-T. Aman, ii. Potato-Boro-T. Aman, iii. Mustard -T. Aus-T. Aman, iv. Lentil-Jute-T. Aman, v. Wheat-Jute-T. Aman, vi. Wheat-Sesame-T. Aman and vii. Garden pea-Boro-T. Aman and viii. Fallow-Boro-T. Aman. The treatments were replicated (dispersed) five times in randomized complete block design with a plot size of 8.0 m × 5.0 m. Details of varieties of crops, fertilizer dose, sowing/transplanting and harvesting dates and duration of crops under different crop sequences are presented in Table 1. All crops were grown with recommended package of practices. Intercultural operations such as irrigation, weeding and pest control were done properly for normal growth and development of the crops.

Yield data were collected from 4m × 3m area of each plot. Grains and straw were sun dried and weighed adjusting at 10 % moisture content for T. Aman rice. Agronomic performance viz., field duration, rice equivalent yield (REY), production efficiency (PE) and land utilization index (LUI), sustainable yield index (SYI) and harvest index (HI) of cropping patterns were calculated as follows.

Rice equivalent yield (REY): For comparison between crop sequences, the yields of all crops were converted into rice equivalent on the basis of prevailing market prices of individual crop (Verma and Modgal, 1983). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by prevailing market price of that crop divided by market price of rice.

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

Production Efficiency (PE): 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).

$$\textbf{Production Efficiency} = \left(\frac{Y_1 + Y_2 + Y_3}{d_1 + d_2 + d_3}\right) \text{ kg ha}^{-1}\text{ day}^{-1}$$

Where, Y_1= Yield of 1st crop and d_1= Duration of 1st crop of the pattern, Y_2= Yield of 2nd crop and d_2= Duration of 2nd crop of the pattern and Y_3= Yield of 3rd crop and d_3= Duration of 3rd crop of the pattern

Land utilization index (LUI): It was worked-out by taking total duration (days) of crops in an individual cropping pattern divided by 365 (Rahman *et al.* 1989). It was calculated by the following formula:

Land utilization index (LUI) = $\frac{d_1 + d_2 + d_3}{365} \times 100$

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

Sustainable yield index (SYI) of different cropping patterns were worked out by the following formula suggested by Krishna and Reddy, 1997

$$\text{SYI (\%)} = \frac{A^{-}\text{-}Y^{-}}{Y_{\text{max.}}} \times 100$$

where, A^{-} = Mean of particular treatment, Y^{-} = Standard deviation of the treatment and $Y_{\text{max.}}$=Potential yield of treatment in different years

Harvest index (HI) was calculated as per following equation:

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

Final crop yields (main product and by-product yield) were recorded and converted into rice equivalent yield. Total gross returns, total production cost, gross margin and benefit cost ratio were calculated on the basis of prevailing market price of the crops. The number of labourers (man-days) required for growing each crop of the pattern were also accounted.

Table 1. Varieties, fertilizer dose, sowing and harvesting dates and duration of crops under different cropping patterns during the years of 2019-20 and 2020-21.

Crop	Variety	Fertilizer dose ($kg\ ha^{-1}$) N-P-K-S-Zn-B	Sowing/Transplanting dates		Harvesting Dates		Duration		Mean
			2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	
Mustard	BARI Sarisha-14	90-35-40-30-2-2	18.11.19	21.11.20	08.02.20	14.02.21	82	84	83
Mustard	BARI Sarisha-18	90-35-40-30-2-2	19.11.19	22.11.20	07.03.20	12.03.21	109	111	110
Garden pea	BARI Motorshuti-3	20-16-15-10-0-2	28.11.19	24.11.20	06.02.20	04.02.21	70	72	71
Potato	BARI Alu-41	160-45-130-15-5-2	25.11.19	21.11.20	21.02.20	19.02.21	89	91	90
Lentil	BARI Masur-8	20-40-25-0-0-2	04.12.19	29.11.20	22.03.20	18.03.21	108	110	109
Wheat	BARI Gom-32	90-30-55-22-4-1	22.11.19	20.11.20	12.03.20	10.03.21	112	110	111

Crop	Variety	Fertilizer dose (kg ha^{-1}) N-P-K-S-Zn-B	Sowing/Transplanting dates		Harvesting Dates		Duration		Mean
			2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	
Boro	BRRI dhan29	140-15-60-15-3-0	08-02-20	11.02.21	25.05.20	28.05.21	106	108	107
T. Aus rice	BRRI dhan48	60-20-32-10-3-0	04.05.19	07.05.20	06.08.19	11.08.20	94	96	95
T. Aman rice	BRRI dhan87	70-20-35-10-3-0	04.08.19	05.08.20	08.11.19	10.11.20	95	97	96
Sesame	BARI Til-4	55-28-22-10-2-2	14.04.19	16.04.20	26.07.19	29.07.20	103	105	104
Jute	BJRI Toshapat-8	90-10-30-184-0	14.04.19	18.04.20	25.07.19	05.08.20	102	109	106

Results and Discussion

Crop management of cropping patterns: The details of crop management under different improved cropping patterns are shown in Table 1. The newly introduced crops in the farmers existing pattern were mustard (var. BARI Sarisha-14 and BARI Sarisha-18), garden pea (var. BARI Motorshuti-3), potato (var. BARI Alu-41), lentil (var. BARI Masur-8), wheat (var. BARI Gom-32), T. Aus (var. BRRI dhan48), T. Aman (var. BRRI dhan87), sesame (var. BARI Til-4) and jute (var. BJRI Toshapat-8). Total field duration under different improved cropping patterns were ranged from 274-313 days with total turnaround period ranged from 91-52 days. Farmers' pattern: Fallow-Boro-T. Aman has needed average 203 days field duration in two consecutive years. Thus, long turnaround period of 162 days in the farmers' existing pattern was utilized. Result indicated that one additional crop could be easily fitted in Rice-Rice cropping pattern. Similar trend was also observed by Khan *et al.* (2018) who reported that all the tested patterns can be grown successfully one after another in sequence.

Crops and system Rice equivalent yield: The yields of main product, by-product and equivalent yield of different component crops of the cropping patterns are presented in Table 2. For T. Aman rice, the higher grain yield (5.50 t ha^{-1}) was obtained from Potato-Boro-T. Aman cropping pattern and lower grain yield (4.56 t ha^{-1}) from farmers' pattern. In Boro rice, the higher grain yield (7.20 t ha^{-1}) was obtained from Garden pea-Boro-T. Aman cropping pattern and lower grain yield (6.81 t ha^{-1}) from farmers' pattern. Mustard seed yield (1.51 & 1.91 t ha^{-1}), potato tuber yield (37.58 t ha^{-1}), lentil seed yield (1.75 t ha^{-1}), jute fibre yield (3.54 t ha^{-1}), wheat grain yield (4.30 t ha^{-1}), sesame grain yield (1.42 t ha^{-1}) and garden pea green pod yield (7.20 t ha^{-1}) were additional yield obtained from alternate cropping patterns. In farmers pattern these crops were not cultivated. In alternate cropping patterns, T. Aus rice produced grain yield of 4.75 t ha^{-1}. In farmers pattern T. Aus rice was not cultivated. Individual crop yield increased due to use of high yielding modern varieties, balanced fertilizers and optimum management practices. The results revealed that the highest rice equivalent yield (31.77 t ha^{-1}) was obtained from Potato-Boro- T. Aman followed by Garden pea – Boro – T. Aman (26.42 t ha^{-1}). The lowest rice equivalent yield (11.37 t ha^{-1}) was obtained from farmers pattern involving two rice crop patterns i.e., Fallow-Boro-T. Aman. The rice equivalent was higher 30.17 to 179.41% higher over farmers' pattern due to inclusion of a new crop and use modern technologies. The rice-based cropping pattern with potato incurred higher rice equivalent yield compared to other cropping patterns due to higher productivity of potato crop. Khan *et al*. (2018) in their study recorded the maximum rice equivalent yield (15.33 t ha^{-1}) in Wheat-Jute-Rice cropping pattern.

Land use efficiency of cropping patterns: Land use efficiency was highest (86 %) in Wheat-Jute-T. Aman rice cropping pattern because this pattern occupied 313 days in the field for longest period (Table 2). These results are in agreement with Khan *et al*. (2018) who reported that the highest land use efficiency of 70.69 % in improved Wheat-Mungbean-T. Aman rice cropping sequence followed by Lentil-Jute-T. Aman rice and Wheat-Sesame-T. Aman rice (85 %). The lowest (56 %) land use efficiency was recorded in Fallow-Boro-T. Aman rice cropping pattern because of two crops involved in this pattern. Khan *et al*. (2018) reported that the lowest land use efficiency of 61% in Jute-Fallow -Wheat cropping sequence where two crops are involved.

Production efficiency of cropping patterns: Maximum production efficiency (108.43 kg $ha^{-1}day^{-1}$) was obtained from Potato-Boro-T. Aman rice pattern might be due to the higher productivity of potato crop. The lowest production efficiency (54.40 kg $ha^{-1}day^{-1}$) was observed in Fallow-Boro-T. Aman rice cropping pattern involving two rice crop-based pattern

Sustainable yield index of cropping patterns: The highest sustainable yield index value was recorded in Potato-Boro-T. Aman rice (97.30%), which was closely followed by Garden pea-Boro-T. Aman rice (95.74%) (Table 2). It indicated that Potato-Boro-T. Aman rice and Mustard -Boro-T. Aman rice cropping patterns were more stable than other cropping patterns.

Harvest Index of cropping patterns: Improved cropping pattern Potato (var. BARI Alu-41) - Boro (var. BRRI dhan29) - T. Aman rice (var. BRRI dhan87) recorded the higher harvest index (77.46 %) followed by Garden pea (var. BARI Motorshuti-3)- Boro (var. BRRI dhan29) - T. Aman rice (var. BRRI dhan87) and Lentil (var. BARI Masur-8)-Jute (var. BJRI Toshapat-8)-T. Aman (var. BRRI dhan87) where as two rice crop-based cropping pattern Fallow-Boro (var. BRRI dhan29)-T. Aman (bar. BRRI dhan49) recorded the lower harvest index (50.69 %). The harvest index of improved cropping pattern had higher value due to inclusion of potato, garden pea, lentil and T. Aman varieties which contributed the higher economic and biological yield.

Table 2. Average yield, rice equivalent yield and agronomic indicators of rice-based cropping patterns during the years of 201920 and 2020-21

Cropping Pattern	Average Yield Grain/Tuber/ Fibre ($t\ ha^{-1}$)			Average By-Product Yield ($t\ ha^{-1}$)			REY ($t\ ha^{-1}$)	Total Field Duration (days)	Land Use Efficiency (%)	Production Efficiency ($kg\ ha^{-1}\ day^{-1}$)	Harvest Index (%)	Sustainable Yield Index (%)
	Crop I	Crop II	Crop III	Crop I	Crop II	Crop III						
Mustard-Boro-T. Aman	1.51	6.96	5.47	2.64	6.09	4.53	16.22	286	78	56.71	51.25	93.53
Potato-Boro-T. Aman	37.58	6.81	5.50	3.46	6.05	4.85	31.77	293	80	108.43	77.46	97.30
Mustard-T. Aus-T. Aman	1.91	4.75	5.32	3.45	4.15	4.34	19.62	301	83	65.18	50.08	85.66
Lentil-Jute-T. Aman	1.75	3.57	4.84	0.65	2.98	4.32	21.85	311	85	70.25	56.10	91.30
Wheat-Jute -T. Aman	4.20	3.50	4.90	3.00	2.90	4.25	20.44	313	86	65.30	46.59	91.88
Wheat-Sesame-T. Aman	4.40	1.42	4.72	3.50	1.42	4.45	14.80	311	85	47.59	52.99	89.40
Garden pea -Boro-T. Aman	7.20	7.48	4.55	1.47	6.05	4.94	26.42	274	75	75.44	60.68	95.74
Fallow- Boro-T. Aman	-	6.27	4.56	-	6.63	4.45	11.37	203	56	54.40	50.69	81.77

REY= Rice Equivalent Yield

Crops and System Profitability: Among the eight rice-based cropping patterns, the pattern with potato and garden pea resulted in higher gross return and gross margin than that of other crops. The gross return (Tk. 557514 ha^{-1}) was recorded maximum from Potato-Boro-T. Aman rice sequence, which was closely followed by Garden pea-Boro-T. Aman rice (Table 3). The production cost (Tk. 274150 ha^{-1} and Tk. 261700 ha^{-1}) was also higher in potato and garden pea might be due to use of costly inputs i.e., seeds, fertilizers, irrigation, labour as well as intensive management practices. The lowest production cost was found in Fallow-Boro-T. Aman rice cropping pattern. The maximum t gross margin (Tk. 283364 ha^{-1}) was also obtained from Potato-Boro-T. Aman cropping pattern followed by Garden pea-Boro-T. Aman cropping pattern (Tk 264490 ha^{-1}). The higher gross margin of these two patterns were achieved mainly due to higher yield advantages as well as higher price of the component crops. The lowest gross margin was recorded in Fallow-Boro-T. Aman rice cropping pattern due to less gross return for two rice cultivation. The gross margin was 154% higher in Potato-Boro-T. Aman rice pattern and 134 % higher in Garden pea-Boro-T. Aman rice cropping pattern than farmers' pattern Fallow-Boro-T. Aman due to inclusion of high value crops potato and garden pea. But higher benefit cost ratio of 2.16 and 2.13 were obtained from Mustard (var. BARI Sarisha-14)-Boro-T. Aman and Mustard (var. BARI Sarisha-18)-T. Aus-T. Aman cropping patterns. The benefit cost ratio of potato and garden pea containing patterns were lower compared to mustard containing cropping pattern might be due to costly inputs (seeds and fertilizer) and labour required for potato and garden pea cultivation. Hence, the benefit cost ratio (2.03 and 2.01) of potato and garden pea containing patterns were low despite of higher gross return and gross margin. These findings are supported by Sarker *et al.* (2014) who reported that among the six patterns, three crop based patterns produced higher economic benefit in terms of BCR. It was noted here that rice-based cropping pattern with potato and garden pea as a third crop generated more labour employment which was 39 and 34 % higher than that of Fallow-Boro-T. Aman rice cropping pattern (Table 3). This was mainly due to two intensive crops (Potato and Garden pea) contained in these patterns.

Table 3. Cost and return analysis of different rice-based cropping patterns during the years of 2019-20 and 2020-21 (average of 2 years).

Cropping Pattern	Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR	Labour Employment (man-days ha^{-1})
Mustard-Boro-T. Aman	364950	168945	196005	2.16	467
Potato-Boro-T. Aman	557514	274150	283364	2.03	537
Mustard-T. Aus-T. Aman	381950	178945	203005	2.13	457
Lentil-Jute-T. Aman	494910	236259	258651	2.09	480
Wheat-Jute -T. Aman	496250	236750	259500	2.10	477
Wheat-Sesame-T. Aman	328650	179226	149424	1.83	425
Garden pea Boro-T. Amar	526190	261700	264490	2.01	520
Fallow- Boro-T. Aman	248343	136659	111684	1.82	386

Conclusion

It can be concluded that rice-based cropping pattern containing mustard, garden pea and potato with improved cultivation practices would be the best cropping patterns in Tangail. Mustard, Garden pea and Potato based patterns are most profitable because of their higher gross margin and total monetary return. These patterns can generate more employment and may be suitable for the farmers who can afford higher investment. Thus, the rice-based cropping system including oilseed, tuber and pulses crops could be considered balanced and need oriented cropping patterns in the present agro-economic situation of AEZ-9.

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Appendix 1. Monthly air temperature, relative humidity and total rainfall in the experimental area of Tangail, during 2019-20 to 2020-21

Month	Temperature (°C)				Average RH (%)		Total rainfall (mm)	
	Avr. Max		Avr. Min					
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
July	33.99	33.38	27.36	25.74	80.61	82.74	540.50	576.10
August	33.44	34.13	26.85	26.68	82.68	79.00	356.50	200.10
September	33.54	33.07	25.99	25.71	81.69	82.90	270.50	254.30
October	31.45	31.99	22.80	23.10	80.68	82.00	75.80	163.60
November	29.84	29.92	17.89	19.22	76.83	82.00	46.00	19.50
December	25.63	24.31	13.29	13.51	78.35	85.30	22.80	10.00
January	26.31	23.15	11.57	11.87	74.71	83.58	00.00	44.30
February	28.09	26.26	14.73	13.29	71.71	74.25	73.60	01.00
March	31.26	31.51	19.10	18.47	67.52	66.80	99.70	44.60
April	33.18	33.13	22.37	21.48	74.70	74.77	281.20	273.30
May	34.79	32.93	24.36	23.09	77.13	79.00	360.30	350.40
June	34.13	33.57	25.32	25.45	80.8 0	82.73	312.40	303.40
Yearly average	31.30	30.61	20.97	20.63	77.28	79.59	2439.30	2240.60

Table 2. Initial soil test values of the experimental field at FSRD site Atia, Delduar, Tangail.

Sample	Rainfed/ Irrigated	pH	OM (%)	Total N (%)	K(meq/ 100 g soil)	P (Bray)	S	Zn	B
						($\mu g\ g^{-1}$)			
Initial	-	6.08	1.35	0.098	0.11	6.96	9.12	1.21	0.18
Critical level	-	-	-	0.12	0.12	7.00	10.00	0.60	0.20
Interpretation	Irrigated	SA	L	L	L	L	L	(M)	L