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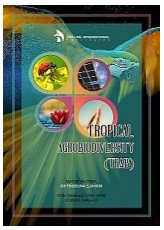

RESEARCH ARTICLE

INCREASING CROPPING INTENSITY AND PRODUCTIVITY THROUGH FOUR CROPS BASED CROPPING PATTERN IN DINAJPUR REGION OF BANGLADESH

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ABSTRACT

A four crops-based trial was conducted for the two consecutive years at MLT site Raniganj, Sadar, Dinajpur and Kashiatola, Ghoraghat, Dinajpur during 2015-16 and 2016-17 to develop a sustainable and economically profitable cropping pattern Potato-Boro-T. Aus-T. Aman against the farmers existing pattern Fallow-Boro-Fallow-T.Aman. The experiment was carried out in RCB design with six dispersed replications. Suitable and short duration high yield potential varieties of different crops Potato ((BARI Alu-7), Boro (BRRRI dhan28) T.Aus (BRRI dhan48) and T.Aman (BRRI dhan62) were selected for the experiment. Grain yield of rice and potato tuber yield was satisfactory. Inclusion of two crops (Potato and T. Aus rice) in the existing pattern attributed to the higher system productivity. The improved alternate cropping pattern produced the higher gross return and gross margin compared to the farmers existing pattern. The marginal benefit cost ratio (MBCR) over the existing pattern was 2.01 at Ghoraghat and 1.85 at Raniganj which indicated the superiority of the alternate pattern over the farmer's practice. Potato based cropping pattern could be most suitable and profitable pattern in these areas. From the two years observations in both the locations, four crops pattern could be recommended for higher system productivity and economic benefit along with for more employment opportunity.

KEYWORDS

Four crops pattern, Rice, Potato, Cropping intensity and Challenges

1. INTRODUCTION

Bangladesh is a densely populated country in the world with an area of 1,47,570 sq.km with population of about 165 million which is also increasing at a rate of 1.37% per year (BBS, 2015). In Bangladesh, total cultivable land is 7.9 million hectares, and it is shrinking day by day. On the other hand, the annual loss of agricultural land is about 0.73% due to construction of roads, houses industrial infrastructure and therefore, there is a very little scope of increase cultivable land, but cropping intensity may be increase from the existing level of 192% by incorporating short duration crop varieties of rice, potato, mustard, mungbean and maize in existing rice-based cropping pattern in Dinajpur region (BBS, 2015). The T. Aman-Fallow-Boro cropping pattern is the dominant cropping pattern of Bangladesh covering an area of 1.8 million hectares representing 22% of the total area (Elahi et al., 1999).

This cropping pattern needs intensification for increasing system productivity and to increase income of the Bangladesh farmers (Rasid et al., 2012). The existing situation is agriculture sector contributes 18% of the gross domestic product of the country and generates employment opportunity for 47 % people of the country (World Bank, 2013). Therefore, intensive and diversify use of the lands will help to increase production, ease market pressure on commodities, it's availability, farmer's income generation, employment opportunity and livelihood improvement. Although Bangladesh is almost self-sufficient in rice production, other foods such as wheat, pulses, oil crops, and so on are still in scarce supply. Recently, with the introduction of short-duration rice varieties, an opportunity has been created to accommodate mustard, potato, pulses, maize etc. following rice is same piece of land in a yearly sequence. Thus, development of short duration crop varieties by research organizations created and produces more yields of this crops on limited land.

The present experiment was thus carried out to assess the feasibility of increasing cropping intensity and productivity by growing four crops in a year on the same piece of land by incorporating short duration crop (Potato and T. Aus) varieties in the existing rice-based cropping system in the Dinajpur region. Increase of cropping intensity in rice-based cropping system is very important for food security, poverty alleviation and livelihood improvement. The main challenge of the new millennium is to increase 50% yield per unit land are through manipulating the limited land resource. In Dinajpur region 46% land are fallow, so here a huge scope increases cropping intensity by inclusion potato and T. Aus. In this view the present study undertaken here, the objectives are i). increasing cropping intensity by producing four crops over the same piece of land in a year and ii) increasing production efficiency of the individual crop by

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using optimum management practice.

2. 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 Potato-Boro-T.Aus-T.Aman rice was introduced against the existing cropping pattern 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 potato, variety BARI Alu-7 was selected for the cropping pattern Potato-Boro-T.Aus -T.Aman Rice for its rapid growth. Potato was planted 28 oct.-03 Nov. in both the years. After early potato Boro rice was transplanted by 23-30 January and for this reason potato was harvested in 80 days after planting 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 potato BARI Alu-7 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 potato cowdung, PKSZnB and Half N used as basal dose and rest amount of N used was after 35-40 days after planting during earthing up operation. All season's rice was transplanted at a spacing of 20cm×15cm. Whole potato tubers were sown at a spacing of 60cm×20cm. Recommended fertilizer packages (FRG'12) following the application methods were used for all the crops. Theovit (S containing fungicide as growth stimulating agent), Mancozeb (to control late blight) and Acimix (to control soil born pest) were applied in potato. Rajdhan and Confidor was applied in rice to control stem borer and 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.

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 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

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		Improved cropping pattern			
Crop	Boro	T. Aman	Potato	Boro	T. Aus	T. Aman
Variety	BRRI dhan28	Swarna/ Ranjit	BARI Alu-7	BRRI dhan28	BRRI dhan48	BRRI dhan62
Date of sowing /Transplanting	24-30 January	01-07 August	28 Oct.-03 Nov.	24-30 January	05-11 May	01-07 August
Seed rate (kg ha^{-1})	50	50	1500	50	50	50
Spacing	25cm×15 cm	25cm×15 cm	60cm×20 cm	20cm×15 cm	20cm×15cm	20cm×15cm
Fertilizer dose (N, P, K, S, Zn and B kg ha^{-1})	136-20-50-08-0-0	102-20-62-08-0-0	115-30-110-20-2-1	150-20-65-18-1.3-0	75-10-25-9-0.6-0	90-10-35-12-1-0
Irrigation (no.)	12	-	2	14	2	-
Weeding (no.)	Herbicide	Herbicide	1	Herbicide	Herbicide	Herbicide
Date of harvesting (range)	28 April-04 May	28 Oct.-04 Nov.	17-23 Jan.	28 April-04 May	24-30 July	20-27 Oct.
Field duration (days)	94	88	80	94	80	80
Turnaround time (days)	88	95	7	7	7	10

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 d_1, d_2, d_3 and d_4 the duration of first, second, third and four crops of the pattern.

Production efficiency: Production efficiency values in terms of Kg ha^{-1}day^{-1}were 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, Y_1: Yield of first crop; and d_1: Duration of first crop of the pattern; Y_2: Yield of second crop and d_2: Duration of second crop of the pattern; Y_3: Yield of third crop, d_3: Duration of third crop of the pattern and Y_4: Yield of four crop d_4: 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.

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

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

$$\text{MBCR} = \frac{\text{Gross Return } (GR_1) - \text{Gross Return } (GR_0)}{\text{Variable cost } (VC_1) - \text{Variable cost } (VC_0)}$$

Where, GR_1= Gross return of main crop (Tk. ha^{-1})
GR_0= Gross return of component crop (Tk. ha^{-1})
VC_1= Variable cost of main crop (Tk. ha^{-1})
VC_0= Variable cost of component crop (Tk. ha^{-1})

3. Results and Discussion

3.1 Yield performance

Grain yield of short duration T.Aman rice (BRRI dhan62) was satisfactory and ranged from 3.40 to 3.10 t ha^{-1} at Ghoraghat and Raniganj, respectively in the improved cropping pattern, while 4.05 to 3.57 t ha^{-1} (Swarna/Ranjit) in existing pattern (Table 3). Average yield of Aman rice was varied in both sites and higher yield was recorded in farmers practice (4.05 to3.57) t ha^{-1} over improved (3.40 to3.10) t ha^{-1} due to long duration T. Aman rice varieties Swarna/Ranjit. Similar results were also obtained (Nazrul et al., 2013; Khan et al., 2006; Khan et al., 2005; Hossain and Wahhab, 1992). It was possible to harvest this rice within October due to its short duration. The yield of potato was 23.01 t ha^{-1} at Ghoraghat and 24.88 t ha^{-1} at Raniganj. Boro rice transplanted timely due to early harvest of BARI Alu-7. The grain yield (5.74 tha^{-1} to 5.93 tha^{-1}) of boro rice (BRRI dhan28) was also higher and more or less similar in both the locations. T. Aus rice BRRI dhan48 also short duration varieties and was transplanted timely. The grain yield of BRRI dhan48 was highly satisfactory and ranged from 5.50 to 5.00 t ha^{-1} at Ghoraghat and Raniganj, respectively. The field duration of T. Aus (BRRI dhan48) rice was only 80 days. Similar result was also obtained (Khanum et al., 2020).

Table 3: Yield and economics of improved and existing cropping pattern at Ghoraghat and Raniganj, Dinajpur during 2015-16 and 2016-17

Parameters	Existing cropping pattern				Improved cropping pattern							
Crop	Boro		T. Aman		Potato		Boro		T. Aus		T. Aman	
Variety	BRRI dhan28		Swarna		BARI Alu-7		BRRI dhan28		BRRI dhan48		BRRI dhan62	
	Ghoraghat	Raniganj	Ghoraghat	Raniganj	Ghoraghat	Raniganj	Ghoraghat	Raniganj	Ghoraghat	Raniganj	Ghoraghat	Raniganj
Yield (t ha^{-1})	5.92	5.65	4.05	3.57	23.01	24.88	5.74	5.93	5.50	5.00	3.40	3.10
Straw (t ha^{-1})	6.18	6.10	5.28	5.20	-		5.83	6.20	6.20	5.89	5.08	5.00
Rice equivalent yield (tha^{-1} year^{-1})	6.31	6.03	4.38	3.90	14.38	12.44	6.10	6.32	5.89	5.37	3.93	3.61
Gross return (Tk. ha^{-1})	100960	96480	70080	62400	230080	199040	97600	101120	94240	85920	62880	57760
Total variable Cost (Tk. ha^{-1})	60563	60563	45470	45470	118847	118847	58241	58241	42476	42476	42476	42476
Gross margin (Tk. ha^{-1})	40337	35917	24610	16930	111233	80193	39359	42879	51764	43444	20404	15284

Unit price: Potato = Tk. 10 kg^{-1}, BRRI dhan28 = Tk. 16.00 kg^{-1}, BRRI dhan62 = Tk. 16 kg^{-1} BRRI dhan48 = Tk. 16 kg^{-1} and Sharna/Ranjit = TK. 16 kg^{-1}, Straw of rice = Tk. 1 kg^{-1}

3.2 Rice equivalent yield

Rice equivalent yield revealed that improved cropping pattern produced higher rice equivalent yield over farmer's traditional cropping system (Table 3) due to inclusion of a new crop and short duration high yielding varieties and improve management practices. The improved pattern increased 183.44% and 179.35% rice equivalent yield at Ghoraghat (30.30 t ha^{-1}year^{-1}) and Raniganj (27.74 t ha^{-1}year^{-1}), respectively. Lower rice equivalent yield 10.69 tha^{-1}year^{-1} at Ghoraghat and 9.93 tha^{-1}year^{-1} at Raniganj were obtained in the farmer's pattern due to local variety and traditional management practices. It is evident from the above findings that alternate cropping pattern gave higher yield compared to existing pattern (Nazrul et al., 2017; Khanum et al., 2020).

Crop duration: Farmers' cropping pattern Fallow-Boro-Fallow-T.Aman required 183 days field duration and improved cropping pattern Potato-Boro-T. Aus-T. Aman required 334 days (excluding seedling age of rice) to complete the cycle. The newly introduced crop in the farmers existing pattern were BARI Alu-7 and T. Aus (BRRI dhan48). Total field duration of the four crops under improved cropping pattern was 334 days indicated that turnaround period of 183 days in the farmer's existing pattern was utilized. Result indicated that potato (BARI Alu-7) and T. Aus (BRRI dhan48) rice could be easily fitted in the existing cropping pattern with 31 days turnaround time in a year.

3.3 Production efficiency

Maximum production efficiency was obtained from improved pattern during individual years and also means data (Table 4). The higher production efficiency of improved cropping pattern might be due to inclusion of a new or modern varieties and management practices. In conversely, the lowest production efficiency was observed in farmer's pattern where crop remain in the field for shorter time and yields were also lower, leading to lower production per day. Mean production efficiency (86.89 kg ha^{-1}day^{-1}) was higher in improved pattern and lower (56.24 kg ha^{-1}day^{-1}) in farmers' pattern. Similar trends were noted in case of increase cropping sequences (Nazrul et al., 2013; Khanum et al., 2020).

Table 4: Land use efficiency and production efficiency of farmers and improved cropping pattern at MLT site Ghoraghat and Raniganj in Dinajpur (Mean)

Year	Cropping pattern	Land use efficiency (%)	Production efficiency (Kg $ha^{-1}day^{-1)}$
2015-17	Existing cropping pattern	49.86	56.24
	Improved cropping pattern	91.51	86.89

3.4 Land use efficiency

Land use efficiency is the effective use of land in a cropping year, which mostly depend on crop duration. The average land use efficiency indicated that improved pattern used the land for 91.51% period of the year, whereas farmers pattern used the land for 49.86% period of the year (Table 4). The land use efficiency was higher in improved pattern due to cultivation of Potato and T. Aus as additional crop in fallow period. Similar results were also obtained (Khatun et al., 2019; Khanum et al., 2020).

Table 5: Profitability of improved cropping pattern over the existing pattern at Ghoraghat and Raniganj, Dinajpur during 2015-16 and 2016-17 (Mean)

Parameters	Existing cropping pattern		Improved cropping pattern	
	Ghoraghat	Raniganj	Ghoraghat	Raniganj
Pattern rice equivalent yield (t $ha^{-1}year^{-1}$)	10.69	9.93	30.30	27.74
Pattern gross return (Tk. ha^{-1})	171040	158880	484800	443840
Pattern variable Cost (Tk. ha^{-1})	106033	106033	262040	262040
Pattern gross margin (Tk. ha^{-1})	64947	52787	222760	181800
MBCR			2.01	1.85

Unit price: Potato = Tk. 10 kg^{-1}, BRRI dhan28 = Tk. 16.00 kg^{-1}, BRRI dhan62 = Tk. 16 kg^{-1} BRRI dhan48 = Tk. 16 kg^{-1} and Swarna/Ranjit = TK. 16 kg^{-1}, straw of rice = Tk. 1 kg^{-1}

3.5 Cost and return analysis

The higher gross return of Tk. 484800 ha^{-1} at Ghoraghat and Tk. 443840 ha^{-1} at Raniganj in improved pattern, which was 183.44% and 179.35% higher of that location, respectively compared to that of farmers existing pattern. The gross margin was substantially higher in the alternate pattern both the location (Tk. 222760 ha^{-1} and Tk. 181800 ha^{-1}) than that of the farmer's pattern (Tk. 64947 ha^{-1} and Tk. 52787 ha^{-1}). The higher gross margin of the alternate pattern was achieved mainly due to higher yield advantages of components crops. The MBCR of 2.01 at Ghoraghat and 1.85 at Raniganj indicates the superiority of the improved pattern over the farmer's practice. Others agreed that the four crops-based cropping pattern will be crucial for ensuring food and nutrition security of the country in the near future (Mondal et al., 2015 and Khanum et al., 2020). Alternate cropping pattern was agronomically feasible economically profitable then existing patterns, rice equivalent yield, productivity and profitability was higher than the farmer's existing patterns (OFRD, 2017).

3.6 Farmer's opinion

The yield performances of the BARI Alu-7, BRRI dhan62 and BRRI dhan48 are almost satisfactory and can easily be fitted in four crops cropping pattern. After harvest of T. Aman rice, short duration high yielding potato variety (BARI Alu-7) can easily be grown which doesn't hamper or delay the crop (Boro rice) cultivation. In Boro rice BRRI dhan28 is selected for its popularity, medium duration (94 days) and higher yield. After harvesting of Boro rice BRRI dhan48 can easily be grown without hampering T. Aman cultivation because it takes only 80 days to maturity.

3.7 Challenges

The study was conducted where there is a scope to introduce four crops in same land in a year. The main limitations for introducing four crops in a same cropping pattern are the tight schedule for crop establishment, natural calamities (rain, cold, high temperature, excess or inadequate moisture in the soil etc.) and seed availability of different crops. However, it is possible to introduce four crops in a cropping pattern if we overcome those limitations. A number of reports on different cropping patterns are available in Bangladesh 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 (Khan et al., 2005, and Nazrul et al., 2013). Besides, labor scarcity, unavailability of seed of selected crops, birds and other pest problem due to small area coverage under four crops pattern etc. are the key issues for establishment of four crops pattern.

4. Conclusion

Comparative two years results, variation of grain yields of different crops, market price of inputs and outputs were observed. Though the two years' results are inadequate to draw a conclusion for such type of study. However, higher gross return and gross margin, higher productivity under intensified cropping system indicated the superiors of the improved cropping pattern over farmer's practice. Potato (BARI Alu-7)-Boro (BRRI dhan28) -T.Aus (BRRI dhan48)- T.Aman (BRRI dhan62) was found profitable at both sides as well as suitable cropping pattern for cropping at medium high land of Dinajpur region.

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