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AGRO-ECONOMIC PRODUCTIVITY OF RICE- RABI CROP-RICE SYSTEMS IN NORTHWESTERN DROUGHT-PRONE AREAS OF BANGLADESH

M.M. Rahman*

Department of Agronomy, Bangladesh Agricultural University, Mymensingh

ABSTRACT

Productivity and economics of different rabi crop-based systems were evaluated at farmers' field in Durgapur upazilla of Rajshahi district, Bangladesh to select the best *rabi* crop(s) for fitting in the T. *Aman* rice - rabi crop – *DDS Aus* rice pattern. Nine rabi crops namely, (1) Mustard, (2) Potato, (3) Lentil, (4) Field pea, (5) Radish, (6) Cabbage, (7) French bean, (8) Carrot and (9) Tomato were cultivated during the rabi season in between the two rice crops to form nine cropping patterns. The experiment used Randomized Complete Block Design (RCBD) with three replications. *Aman* rice variety BRRI dhan57 was transplanted on 12 July 2017 and harvested on 28 October 2017, while, *Aus* rice variety BRRI dhan28 was sown in the dry cultivated land on 16 March 2018 and harvested on 24 June 2018 while rabi crops were sown/transplanted on 28 November 2017. Proper agronomic management practices were adopted for all the crops in the patterns. Data on yield and related attributes of DDS *Aus* rice were recorded at harvest. In addition, the yield of *Aman* rice and all the *rabi* crops were recorded. In addition, rice equivalent yield of each *rabi* crop, system yield (total yield of all the crops in the sequence), cost of production, gross return and benefit cost ratios (BCR) of all the patterns were recorded. Results revealed that yield of dry direct seeded *Aus* rice cv. BRRI dhan28 did not differ significantly due to different *rabi* crops grown under the respective patterns. The system yield was the highest in T. *Aman* rice –tomato – DDS *Aus* rice pattern (19.62 t ha^{-1}) and the lowest with T. *Aman* rice -mustard – *Aus* rice pattern (14.63 t ha^{-1}). Since the market price of a rabi crop changes from year to year, the net profit of a pattern depends on the yield of a crop grown in *rabi* season. Therefore, any of the nine *rabi* crops under the trial can be successfully cultivated in between the two rice crops under *Aman* rice – rabi crop –*Aus* rice patterns. However, the present study concludes that any of the nine *rabi* crops can be grown in between the two rice crops but carrot, French bean, mustard, field pea, and tomato could be the most profitable ones for the T. *Aman* rice – *rabi* crops –DDS *Aus* rice patterns.

* Corresponding Author: rahmanag63@gmail.com

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INTRODUCTION

The cropping patterns of Bangladesh are predominantly rice based. Rice is the staple food and the main element of food security in Bangladesh. About 77.07% cropped area of Bangladesh is used for rice production, with the annual production of 37.36 million tons from 11.68 million ha of land (AIS, 2020). The rice production in the country has been increased by 3.4 folds over the last four decades. In Bangladesh, more than 55.0 million tons of rice will be required by the year 2050 when population of Bangladesh will be 233.3 million (Basak et al., 2009). The possibility of expanding the area under rice in the near future is limited. Therefore, this extra rice production should to come from the productivity gain.

Rice is mostly cultivated by transplanting of seedling in the puddled soil. Usually, irrigation is not required in *Aman* season because it coincides with rainy season (June – October). On the other hand, *Boro* rice requires full irrigation water (1400 mm) mainly supplied from underground source as the rainfall is scanty during this season (January – May). For irrigation a huge amount of water is lifted from the ground which leads to decline of the water table and causes serious environmental hazards. In practice, *Boro* rice uses about 70% of the total water used in agriculture (Rahman, 2018). At present the water scarcity from both surface and ground sources are looming and under this situation, *Boro* rice cultivation cannot be sustained. Realizing the fact, the government is discouraging cultivation of *Boro* rice and encouraging cultivation of *Aus* or late season *Boro* rice in the northwestern drought-prone region of Bangladesh. This practice saves substantial amount of irrigation water as it does not require irrigation during the whole crop period rather it requires water for land preparation, crop establishment and also during the early growth stage of the crop. Generally, no irrigation is required during the later stages as this period coincides with rainfall. The harvest of *rabi* crops depends on their life duration and generally extends from late January to late February. Thus, adoption of late season *Boro* rice or *Aus* rice instead of the regularly cultivated *Boro* rice will allow farmers to grow a *rabi* crop during the fallow period between *Aman* rice and *Boro/Aus* rice (Rahman, 2019).

T. *Aman* rice – Fallow – T. *Boro* rice is the major cropping pattern in Bangladesh. Recently, many farmers cultivate mustard, potato and other short duration *rabi* crops during the *rabi* season in between the two rice crops. The area under T. *Aman* rice – Mustard –T. *Boro* rice pattern and T. *Aman* rice – Mustard –T. *Boro*rice pattern is increasing. Under these patterns, *Boro* rice is transplanted during February and even in March. Thus, the second rice crop is mainly cultivated in late *Boro/Aus* season. The late *Boro/Aus* rice still requires huge amount of irrigation for the puddling, crop establishment and vegetative stages. This irrigation water use can be cut

substantially if the crop is grown under dry direct seeded system instead of the conventional puddle transplanted system. The dry direct seeded (DDS) rice system is an alternative approach which reduces irrigation requirement by more than 50% compared with in the puddle transplanted method of rice cultivation (Rahman, 2019). Thus, the replacement of transplanting method with dry direct seeding method in *Boro/Aus* rice season could contribute to the saving of huge irrigation water. The adoption of T. *Aman* rice – Rabi crops – DDS *Boro/Aus* rice pattern instead of T. *Aman* rice – Fallow – T. *Boro/Aus* rice pattern will allow cultivation of many rabi crops in the fallow lands during rabi season before late *Boro/Aus* cultivation. This would help in increasing cropping intensity, crop diversity and farm income. Such an intensification and diversification of cropping systems may allow improving the productivity and sustainability of agricultural production. The present study has been undertaken with a view to evaluate the agro-economic productivity of various T. *Aman* Rice – *Rabi* crops – DDS *Aus* rice patterns.

MATERIALS AND METHODS

Site and soil

The experiment was conducted at farmers' field in Khitrokashipur village of Durgapur upazilla in Rajshahi district. The field is located at 24°75′ N latitude, 90°50′ E longitude and at an altitude of 18 m. The area falls under High Barind Tract agro-ecological zone (AEZ-26) having Non–calcareous dark grey floodplain soil. The land was a medium high with moderate drainage facilities. The soil was silt loam having pH value of 6.5. The particle density and bulk density values of soil were 2.60 and 1.35 g cc^{-1}, respectively. Soil contained 1.78% organic matter, 0.14% total N, 1.98 µ g^{-1} available P, 0.10 meq $100g^{-1}$ exchangeable K and 4.56µg g^{-1} available S. The experimental area falls under the sub-tropical climate characterized by its heavy rainfall during *Kharif* season (April to September) and scanty rainfall during *Rabi* season (October to March).

Experimental Treatments and Design

Nine rabi crops were included in the trial in between transplanted *Aman* rice cv. BRRI dhan57 and dry direct seeded (DDS) *Aus* rice cv. BRRI dhan28 to form nine cropping patterns. The rabi crops included were: (1) Mustard, (2) Potato, (3) Lentil, (4) Field pea, (5) Radish, (6) Cabbage, (7) French bean, (8) Carrot and (9) Tomato. Therefore, the cropping patterns tested were: (1) *Aman* rice – Mustard – DDS *Aus* rice, (2) *Aman* rice – Potato – DDS *Aus* rice, (3) *Aman* rice – Lentil – DDS *Aus* rice, (4) *Aman* rice – Field pea – DDS *Aus* rice, (5) *Aman* rice – Radish – DDS *Aus* rice, (6) *Aman* rice – Cabbage – DDS *Aus* rice, (7) *Aman* rice – French bean – DDS *Aus* rice, (8) *Aman* rice – Carrot – DDS *Aus* rice and (9) *Aman* rice – Tomato – DDS *Aus* rice. The experiment used a RCB design with three replications. The unit plot size was 4.0 m x 2.5 m.

Crop management

Aman rice variety BRRI dhan57 was cultivated by transplanting of 25 day old seedlings at 25 cm × 15 cm allocating 3-4 seedlings hill^{-1} on 10 July 2017. The crop was harvested at maturity on 27 October 2017 and the yield was recorded from randomly selected five spots of 10 x10 m^2 area of the rice fields. The rabi crops were sown/transplanted on 28 November 2017 maintaining their recommended spacings and after harvest of the rabi crops, *Aus* rice cv. BRRI dhan28 was sown on 16 March 2018by hand at 25 cm × 15 cm spacing allocating 3-4 seeds hill^{-1}. The land was fertilized as per nutrient recommendation for each crop stated in the Fertilizer Recommendation Guide-2018 (BARC, 2018) in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate (Table 1). All the agronomic managements were done as and when needed following the standard protocol. The dry direct seeded rice was harvested on 24 June 2018.

Table 1. Nutrient recommendation (kg ha^{-1}) for different crops under the trial (BARC, 2018)

Crop	N	P	K	S	Zn
Mustard	90	27	32	10	1.0
Potato	135	30	90	10	2.0
Lentil	18	24	30	18	2.0
Field pea	24	48	30	9	1.2
Radish	125	40	90	20	2.0
Cabbage	180	66	50	16	1,5
French bean	92	96	75	25	1.2
Carrot	120	35	80	20	1.0
Tomato	135	45	50	10	1.0
Aman rice (cv. BRRI dhan57)	90	10	30	8	1.0
Aus rice (cv. BRRI dhan28)	75	10	25	6	0.6

Data recording

Data on yield and related attributes of *Aus* rice were recorded. The yield of *rabi* crops and the rice equivalent yield of each *rabi* crop was also recorded. Data on economic parameters of different cropping patterns such as (i) System yield (yield of all the crops in a pattern), (ii) Cost of production, (iii) Gross return and (iv)Benefit cost ratio (BCR) were also recorded.

Rice equivalent yield (REY) was calculated to compare system performance by converting the yield of each *rabi* crop into equivalent *Boro* rice yield on a price basis, using the formula:

$$REY \text{ (of crop x)} = Y_x \times (P_x / P_r)$$

Where, Y_x = yield of crop x (tons harvest product ha^{-1}), P_x = price of cropx, and P_r = price of rice.

Net return or profit was calculated by subtracting production cost from the gross value of the produce, including by-product value or gross return. Prices used for harvest products were average prices observed during the experimental period. The benefit: cost ratio (BCR) was calculated by dividing the net return by the production cost for individual crops and for various systems.

Data analysis

Data on yield and related parameters of dry direct seeded rice were subjected to statistical analysis using analysis of variance technique and mean comparison was done using STATISTIX 10 computer software.

RESULTS AND DISCUSSION

Yield performance of *Boro* rice

Grain yield of dry direct seeded (DDS) *Aus* rice cv. BRRI dhan28 did not differ significantly due to the preceding rabi crops grown under nine T. *Aman* rice – *rabi* crop – DDS *Aus* rice cropping pattern. The grain yield ranged between 5.45t $ha^{-1}$and 6.29 t ha^{-1} (Table 3). The straw yield of DDS *Aus* rice did not also differ significantly due to preceding *rabi* crops in the patterns. Plant height, total tiller $hill^{-1}$, effective tiller $hill^{-1}$, non-effective tillers $hill^{-1}$and number of grains $panicle^{-1}$ of DDS *Aus* rice differed significantly due to the preceding *rabi* crops in the pattern (Table 2).

On the other hand, sterile spikelet $panicle^{-1}$and thousand grain weight of DDS *Aus* rice did not differ significantly due to different T. *Aman* rice – *rabi* crop – DDS *Aus* rice cropping pattern (Table 3). The tallest plants of DDS *Boro* rice (113 cm) were found in T. *Aman* rice – Tomato – DDS *Aus* rice pattern which was statistically similar with T. *Aman* rice - French bean – DDS *Aus* rice pattern. The highest numbers of total and effective tiller $hill^{-1}$ were found with patterns having French bean and Tomato and the lowest with lentil and Cabbage. The highest number of non-effective tiller (2.67) was found in *Aman* rice – mustard- DDS *Aus* rice pattern and the lowest number (0.42) was noted in *Aman* rice –tomato- DDS *Aus* rice pattern. The highest number of grains $panicle^{-1}$ of DDS *Aus* rice was found in Aman rice – carrot- DDS *Aus* rice pattern which was closely followed by *Aman* rice –tomato - DDS Boro pattern and Aman rice –lentil- DDS *Aus* rice pattern while the lowest was found in Aman rice –French bean - DDS *Aus* rice pattern (Table 3).

Table 2. Effect of different T. *Aman* rice – *rabi* crops – DDS *Aus* rice cropping pattern on plant height and tiller density of dry direct seeded *Aus* rice cv. BRRI dhan28

Cropping pattern	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)
Pattern 1	106.7cd	17.33abc	14.67abc	2.66a
Pattern 2	107.0cd	16.50abc	15.50abc	1.08cd
Pattern 3	108.2bcd	14.17c	13.42c	0.75cd
Pattern 4	107.2cd	14.83bc	13.58bc	1.25cd
Pattern 5	109.0bc	15.58abc	14.66abc	0.92cd
Pattern 6	108.6bc	13.92c	13.17c	0.75cd
Pattern 7	111.3ab	19.17a	16.83a	2.33ab
Pattern 8	105.0d	16.50abc	16.08ab	0.42d
Pattern 9	113.0a	18.25ab	16.75a	1.50bc
Level of sign.	**	*	*	**
LSD	3.49	4.66	2.63	0.98

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letter differ significantly; *= Significant at 5% level of probability;

= Significant at 1% level of probability; *= Significant at 0.01% level of probability; ns= non significance

[Patterns: (1). *Aman* rice – Mustard – DDS *Aus* rice, (2). *Aman* rice – Potato – DDS *Aus* rice, (3). *Aman* rice – Lentil – DDS *Aus* rice, (4). *Aman* rice – Field pea – DDS *Aus* rice, (5). *Aman* rice – Radish – DDS *Aus* rice, (6). *Aman* rice – Cabbage – DDS *Aus* rice, (7). *Aman* rice – French bean – DDS *Aus* rice, (8). *Aman* rice – Carrot – DDS *Aus* rice and (9). *Aman* rice – Tomato. – DDS *Aus* rice]

The present study showed that the yield of DDS *Aus* rice (the second rice crop in the pattern) did not vary much due to inclusion of different rabi crops in different T. *Aman* rice – rabi crops – DDS *Aus* rice patterns due to change of the rabi crops. Rajon (2019) conducted a similar experiment at Mymensingh and found that the DDS *Boro* rice yield did not differ due to different rabi crops grown in T. Aman rice – rabi crops – DDS *Boro* rice patterns. On the other hand, Singh and Beniwal (1983) reported yield decline of rice after mustard/rapeseed while Biswas and Mitra (1987) found rice yield increased after potato. Mustard is a nutrient exhaustive crop which might have contributed to the reduced yield of the succeeding rice crop while potato contributed to nutrient building up that attributed to increased yield of the succeeding rice crop. Biswas (2015) reported that organic matter increased considerably after jute and potato, irrespective of cropping systems. This might be due to greater rhizo-

deposition and leaf shedding of jute throughout its growth period and due to the incorporation of potato haulm at harvest, both contributing to an increase in organic carbon.

Table 3. Effect of different T. *Aman* rice – rabi crops – DDS *Aus* rice cropping pattern on yield and related attributes of dry direct seeded *Aus* rice cv. BRRI dhan28

Rabi crops	Grains panicle^{-1} (no.)	Sterile spikelet panicle^{-1}(no.)	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Pattern 1	84.00bc	20.67	21.41	5.63	6.19
Pattern 2	84.20bc	23.13	21.28	6.30	6.34
Pattern 3	87.77ab	24.67	21.46	5.46	5.88
Pattern 4	81.63bc	21.30	21.12	5.74	6.09
Pattern 5	75.50bc	20.67	21.01	5.45	5.78
Pattern 6	74.53c	20.83	20.74	5.48	5.63
Pattern 7	76.43bc	22.27	21.07	5.76	5.91
Pattern 8	97.77a	21.79	21.49	6.01	6.07
Pattern 9	87.83ab	19.97	21.28	6.12	6.02
Level of sign.	*	ns	ns	ns	ns
LSD	12.75	7.35	0.71	1.06	0.69

[Patterns: (1). *Aman* rice – Mustard – DDS *Aus* rice, (2). *Aman* rice – Potato – DDS *Aus* rice, (3). *Aman* rice – Lentil – DDS *Aus* rice, (4). *Aman* rice – Field pea – DDS *Aus* rice, (5). *Aman* rice – Radish – DDS *Aus* rice, (6). *Aman* rice – Cabbage – DDS *Aus* rice, (7). *Aman* rice – French bean – DDS *Aus* rice, (8). *Aman* rice – Carrot – DDS *Aus* rice and (9). *Aman* rice – Tomato. – DDS *Aus* rice]

Agro-economic productivity

Nine rabi crops such as mustard, potato, lentil, field pea, radish, cabbage, French bean, carrot and tomato were included in the T. *Aman* rice – rabi crop – DDS *Aus* rice pattern to form nine cropping patterns (Table 4). The rice equivalent yield (REY) of different rabi crops were calculated based on their market price. It was found that the REY was the highest (7.50 t ha^{-1}) for potato and lowest (3.83 t ha^{-1}) for radish. Further, the system yield for each pattern was calculated by adding the yield of *Aman* rice, REY and DDS *Aus* rice yield. The highest system yield was found in T. *Aman* rice – Potato – DDS *Aus* rice pattern (18.30 t ha^{-1}) and the lowest with T. *Aman* rice – Radish – DDS *Boro* rice pattern (13.78 t ha^{-1}). The gross cost of production for the crops under each pattern was calculated and the highest cost was noticed in T. *Aman* rice – Potato – DDS *Aus* rice pattern (BDT 279150.00) while the lowest in T. Aman

rice – Carrot – DDS *Aus* rice pattern (BDT 165300.00). The benefit cost ratio (BCR) was the highest in T. *Aman* rice – Carrot – DDS *Aus* rice pattern (1.99) and the *lowest (1.06) in T. Aman rice – Radish – DDS Aus* rice pattern (Table 4).

Table 4. System productivity and benefit cost ratio (BCR) of different T. *Aman* rice – rabi crop – DDS *Aus* rice cropping patterns

Rabi crops	Rabi crop yield (t ha^{-1})	REY of the rabi crop (t ha^{-1})	DDS Boro rice yield (t ha^{-1})	System yield (t ha^{-1})	System cost (BDT)	BCR of the pattern
Pattern 1	1.80	4.50	5.63	14.63	174000	1.68
Pattern 2	15.00	7.50	6.30	18.30	279150	1.31
Pattern 3	1.20	5.10	5.46	15.06	183600	1.64
Pattern 4	1.45	3.98	5.74	14.22	172100	1.65
Pattern 5	17.0	3.83	5.45	13.78	260000	1.06
Pattern 6	17.0	5.10	5.48	15.08	262700	1.15
Pattern 7	1.50	5.25	5.76	15.51	175600	1.77
Pattern 8	18.0	6.00	6.01	16.51	165300	1.99
Pattern 9	18.0	6.12	6.12	16.74	218300	1.53

Yield of T. Aman rice = 4.50 t ha^{-1}, REY = yield of the rabi crop converted to the yield of Aus rice. [{Price of crops (BDT/kg): mustard=50, potato=10, lentil=85, field pea= 55, radish = 4.5, cabbage = 8.50, French bean = 70, carrot = 8, Aman rice = 22, and Aus rice= 20}. The cost of production (BDT/ha) for Aman rice = 48625 and Aus rice = 61075]

[Patterns : (1). *Aman* rice – Mustard – DDS *Aus* rice, (2). *Aman* rice – Potato – DDS *Aus* rice, (3). *Aman* rice – Lentil – DDS *Aus* rice, (4). *Aman* rice – Field pea – DDS *Aus* rice, (5). *Aman* rice – Radish – DDS *Aus* rice, (6). *Aman* rice – Cabbage – DDS *Aus* rice, (7). *Aman* rice – French bean – DDS *Aus* rice, (8). *Aman* rice – Carrot – DDS *Aus* rice and (9). *Aman* rice – Tomato. – DDS *Aus* rice]

In an experiment at Mymensingh, Rajon (2019) reported the highest REY with Cabbage and the lowest with Garden pea. On the other hand, Rahman (2018) found the highest REY with mustard and lowest with Cabbage in Mymensingh site, while the highest REY was found with potato and lowest with Mustard at Rajshahi site. Rahman (2018) also reported that the highest system yield was recorded with T. *Aman* rice – Potato – DDS *Aus* rice pattern while the lowest was recorded with T. *Aman* rice – Mustard – DDS *Aus* rice in Mymensingh. In Rajshahi, the highest system yield was recorded in T. *Aman* rice – Carrot – DDS *Boro* rice and the lowest with T. *Aman* rice – Cabbage – DDS *Boro* rice. Thus, it was apparent from the study that REY and SY are the two good indicators of economic productivity of a pattern may be subjected to abrupt change mainly due to the flexibility of the market price of the product. Since the price is variable with time and space dimension the profit depends on the demand of the crop for a geographic location although the yield of the

crops remained unchanged. Due to introduction of high-yielding short duration rice in the 1970s and increasing irrigated area, *Boro* rice replaced most pulses and rabi crops in this area. Crop intensification and/or diversification has now further increased with inclusion of short duration rapeseed and potato in between *Aman* rice and *Aus* rice, resulting in higher production per unit area per unit time, higher nutrient removal, and varying changes in soil fertility as compared with rice-rice (R-R) and rice-wheat (R-W) systems (Biswas, 2015). However, it is evident from the present experiment that a number of rabi crops can be grown in between the two rice crops which could surely help increase the farm production and farmers' income. The system yield is the highest with T. *Aman* rice – Potato– DDS *Aus* rice pattern but the production cost was also the highest (279150 BDT) inthis pattern. Due to increased production cost the BCR (1.31) of this pattern also T. *Aman* rice – Potato– DDS *Aus* rice pattern. The cost of production was the highest for potato which was closely followed by cabbage, carrot and tomato that contributed to the lowering the BCR of these pattern. Biswas (2015) reported that cropping pattern containing potato had the highest levels of yield, net return and benefit to cost ratio. However, in the present study the highest benefit cost ratio was found with T. *Aman* rice – Carrot – DDS *Aus* rice pattern which was closelyfollowed by T. *Aman* rice – French bean – DDS *Aus* rice pattern, T. *Aman* rice – Mustard – DDS *Aus* rice pattern, T. *Aman* rice – Field pea – DDS *Aus* rice pattern and T. *Aman* rice – Lentil – DDS *Aus* rice pattern.

CONCLUSION

Farmers of the experimental area generally follow T. *Aman* rice – Fallow – T. *Boro* rice patterns. The conventional practice is less productive and highly irrigation water intensive. The present study showed that the cultivation of any rabi crop in between the two rice crops do not have any adverse effect on the yield and productivity of the succeeding dry direct seeded *Aus* rice. It is also evident that any rabi crops such as potato, tomato, carrot, field pea, french bean, mustard and lentil can be easily grown in between the two rice crops. Nevertheless, the present study concludes that any of the nine rabi crops can be grown in between the two rice crops, however carrot, French bean, mustard, field pea, and tomato could be the most profitable for the T. *Aman* rice – rabi crops –*Aus* rice patterns.

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