SAARC J. Agri., 15(2): 103-112 (2017) *DOI: http://dx.doi.org/10.3329/sja.v15i2.35150*

INCREASING CROPPING INTENSITYAND PRODUCTIVITY THROUGH BORO-T.AUS-T.AMAN-MUSTARD CROPPING PATTERN IN BANGLADESH

M.A.H. Khan[1*], M.S. Zaman[1], M.K. Hasan[2] and A.S.M.M.R. Khan[2]

[1]On-Farm Research Division, Bangladesh Agricultural Research Institute, Mymensingh, Bangladesh
[2]On-Farm Research Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

ABSTRACT

The experiment was conducted at Multiplication Testing Site (MLT) Trishal of on-farm research division, Bangladesh Agricultural Research Institute, Mymensingh during 2015-16 and 2016-17 to study the comparative agro-economic performance of four crops pattern for increasing cropping intensity and productivity as compared with existing farmers' pattern. Four crops pattern (Boro-T.Aus-T.Aman-Mustard) and farmers' existing pattern (Boro-fallow-T.Aman- fallow) as control were tested. On an average, organic matter 3.94 t $ha^{-1}$and 2.60 t ha^{-1} were added to soil in four crops pattern and farmers existing pattern by incorporation of biomass of respective crops. Two years average results showed that the highest rice equivalent yield (20.63 t ha^{-1}) was obtained from four crops pattern. The highest average gross return and gross margin of the four crops pattern were obtained Tk.359570 and Tk. 170162 ha^{-1} which were 80 and 207 % higher over farmers' pattern. Farmers' practice gave the lower gross return (Tk. 199790 ha^{-1}). The mean marginal benefit cost ratio (MBCR) was found 2.23 which indicated the superiority of four crops pattern over the farmers' existing pattern. The marginal benefit cost ratio (MBCR) analysis also showed that inclusion of mustard and T.Aus rice in the existing pattern might be profitable and acceptable to the farmers. Nutrient uptake and balance showed that considerable amounts of N, P, K and S were removed by crops every year. However, the N, K and S balances were found negative in all cases but P balance was found positive. From the above result showed that four crops can be grown successfully one after another in sequence of the tested pattern.

Keywords: Cropping intensity, cropping pattern, land utilization index, rice equivalent yield

[*] Corresponding author e-mail: helim1367@gmail.com

Received: 21.05.2017 *Accepted: 09.09.2017*

INTRODUCTION

Bangladesh is a densely populated (1008 per sq. km.) country of the world with an area of 147570 sq. km with population growth rate 1.89 percent (BBS 2015). At present total cultivable land is 8.5 million hectares which is decreasing at the rate of about 0.87% per year due to construction of houses, roads and industrial infrastructure. There is very little scope of increasing cultivable land but there are some scope of increasing productivity and cropping intensity from existing level of 191 to 300 % or more by improving the present cropping patterns incorporating short duration crops like; mustard, mungbean, potato, T.Aus etc. in the rice based cropping patterns following the modern variety and technologies. Sustainable crop production in Bangladesh through improvement of cropping patterns in rice based cropping system is regarded as an important in national issues such as food security, poverty alleviation and creation of job opportunity. The main challenge of the new millennium is to increase yield of per unit area by at least 50 % through manipulating the limited land resource. In order to produce more food within a limited area, two most important options to be adopted are i) to increase the cropping intensity by producing three or more crops from the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices. It is reported that more than 60 % of the cultivable lands in Mymensingh region are used for cultivating two rice crops i.e. Boro and T.Aman. As a result, the vast area remains fallow for 75 days after T.Aman and 75 days after Boro harvest. So, there is a great scope of increasing cropping intensity as well as crop productivity. The areas of oilseed and pulse in rabi season are decreasing because of increasing cultivation of Boro rice. Recently with the development of short duration T.Aus and T.Aman rice and mustard varieties opportunities have been created to accommodate four crops in same piece of land in a year. Potential adoption of mustard and T.Aus in Boro- fallow-T.Aman cropping system would generate employment and additional income for the rural poor and producing more of these crops utilizing fallow and underutilized lands in the country. Considering the above issues, the present study was undertaken to evaluate the feasibility of increasing cropping intensity and productivity by growing four crops in a year in a same piece of land by incorporating mustard and T.Aus rice in the existing cropping system.

MATERIALS AND METHODS

The trial was conducted to increase cropping intensity and productivity by incorporating mustard and T.Aus rice in the existing cropping system (Boro-fallow-T.Aman-fallow) during 2015-16 and 2016-17. The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) of Mymensingh. The geographical position of the area is between $24^{o}45^{/}$ N latitude and $90^{o}24^{/}$ E longitude. The land was medium high and the soil of the study area was sandy loam in texture with well drainage system and almost neutral in reaction having pH range of 6.0 to 6.9. Maximum rainfall was received during the months of April to September. The

meteorological data of the experimental site revealed that the highest temperature (33.9^{o}C) in August and the lowest in December (10.1^{o}C). The relative humidity was the highest (84.5%) in August and the lowest (75.2 %) in March. The crop received (140.5mm) rain showers from October to March. Monthly mean maximum and minimum air temperature (31.9 and 19.3^{o}C), total rainfall (2018 mm) and relative humidity (82.7 %) were prevailing during the study period. The land type was medium high and the soil texture of the experimental plots was clay loam which belongs to Old Brahmaputra Floodplain soil (AEZ-9). Initial and final soil samples were collected and analyzed (Table 1). General soil types predominantly include Dark Grey Floodplain soils. Organic matter content was low, top soils were acidic to neutral and sub-soils were neutral in reaction. In general, fertility level including N, K and B was low.

Table 1. Initial and post harvest soil test values of farmers field at Trishal, Mymensingh

Sample	Land type	Rainfed/ Irrigated	pH	OM (%)	Total N (%)	K (meq/100 g)	P (Bray)	S	Zn	B
							($\mu g\ g^{-1}$)			
Initial	MHL	Irrigated	6.07	1.39	0.073 (VL)	0.070 (VL)	17.30 (Opt.)	24.42 (Opt.)	1.28 (M)	0.08 (VL)
Post harvest	MHL	Irrigated	6.08	1.28	0.068 (VL)	0.067 (VL)	22.67 (H)	22.94 (Opt)	1.25 (M)	0.11 (VL)

The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping pattern viz. four crops pattern and farmers' existing pattern were the treatments variables of the experiment. The unit plot size was 1000-1200 Sq. m. Boro rice was the first crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 35-40 days old seedlings of rice var. BRRI dhan28 at a spacing of 20 cm × 15 cm during 26 to 31 January, 2015 and 2016 in four crops pattern. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). Boro rice was harvested during 26 April to 06 May, 2015 and 2016 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.Aus and T.Aman rice was the second and third crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 25-30 days old seedlings of T.Aus rice var. BRRI dhan48 were transplanted with 20 cm × 15 cm during 9 to 13 May, 2015 and 2016 and T.Aman rice var. BRRI dhan57 were transplanted with 20 cm × 15 cm during 8 to 15 August, 2015 and 2016 in both years. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). T.Aus rice was harvested during

1 to 6 August, 2015 and 2016 and T.Aman rice was harvested during 22 to 31 October, 2015 and 2016 in two consecutive years. T.Aus rice plant was harvested at 30 cm and T.Aman rice plant was harvested at 15 cm from soil surface and remaining parts of the plants was incorporated in soil. Mustard was grown during *rabi* season and it was the fourth crop of the sequence. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to FRG, 2012. Mustard var. BARI sarisha-14 was seeded as broadcast method with seed rate of 7 kg ha^{-1}. The crop was sown during 3 to 10 November, 2015 and 2016 and harvested during 19 to 24 January, 2016 and 2017, respectively. Crop nutrient uptake was estimated following the standard value of FRG, 2012. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency 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 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.

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

Production efficiency

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).

$$\text{Production Efficiency (kg ha}^{-1}\text{ day}^{-1}) = \frac{\sum Y_i}{\sum d_i}$$

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:

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

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

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).

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

RESULTS AND DISCUSSION

Soil chemical analysis of four crop pattern revealed that on an average, pH of the soil increased slightly whereas organic matter a little bit decreased (0.11%) in four crops pattern (Table 1). There was no definite trend followed by the elements but total N, K and B maintained below critical level and P, S and Zn maintained above critical level. Organic matter added to soil through incorporation of non-economic plant parts helped to maintain the quality of soil (Table 2).

Table 2. Addition of organic matter from crop residues in soil of four crops pattern and farmers' pattern at Trishal, Mymensingh during 2015-16 and 2016-17

Crops	4-Crops pattern added residues (t ha^{-1})			Farmers' pattern added residues (t ha^{-1})		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Boro rice (30cm)	1.73	1.78	1.76	1.95	1.99	1.97
T.Aus rice (30cm)	1.55	1.59	1.57	-	-	-
T.Aman rice (15cm)	0.59	0.63	0.61	0.62	0.64	0.63
Mustard	-	-	-	-	-	-
Total	3.87	4.00	3.94	2.57	2.63	2.60

Grain yield and by-product yield

Results of four crops pattern (Boro-T.Aus-T.Aman-Mustard) and farmer's existing pattern (Boro-fallow-T.Aman-fallow) have been presented in tables 3-5. Grain yield of Boro rice was 5.96 t ha^{-1} in 1st year and 6.24 t ha^{-1} in 2nd year. Mean grain and straw yields of Boro rice were 6.10 and 6.17 t ha^{-1}. Grain yield of T.Aus rice was 4.88 and 5.24 t ha^{-1} in two consecutive years and mean grain and straw yields were 5.06 and 5.40 t ha^{-1} whereas T.Aman rice grain yields were 4.39 and 4.38 t ha^{-1} in 1st and 2nd year and mean grain and straw yields of T.Aman rice were 4.38 and 4.95 tha^{-1}. Seed yield of mustard were 1.52 and 1.46 t ha^{-1} and stover yields were 2.95 and 2.80 t ha^{-1} in two successive years, respectively. Mean seed yield of mustard was 1.49 t ha^{-1}. Mustard seed yield decreased 4% by 2nd year and it might be due to shorter duration (6 days) than 1st year. It was revealed that all the 4-crops under Boro-T.Aus-

T.Aman-Mustard cropping pattern gave higher grain and by-product yield (Table 3). T.Aman rice in 4-crops pattern produced 11% higher grain yield over farmers' practice due to change of variety with improved production technologies. Similar results were also obtained by (Nazrul et al., 2013; Khan et al., 2006). Farmers' pattern gave lower yield due to imbalance use of fertilizers and poor management practices. Four crops pattern produced higher by-product yield (19.40 t ha^{-1}) over farmers' practice (11.76 t ha^{-1}). Mean by-product yield of four crops pattern was 65 % higher over farmer's pattern due to change of variety with improved technologies and inclusion of two crops in the existing pattern.

Table 3. Agronomic parameters of four crops pattern and farmers' existing pattern at Trishal, Mymensingh during 2015-16 and 2016-17

Parameters	Years	Four Crops Pattern				Farmers' Pattern	
		Boro	T.Aus	T.Aman	Mustard	Boro	T.Aman
Variety	2015-16	BRRI dhan28	BRRI dhan48	BRRI dhan57	BARI Sarisha-14	BRRI dhan29	BRRI dhan32
	2016-17	BRRI dhan28	BRRI dhan48	BRRI dhan57	BARI Sarisha-14	BRRI dhan29	BRRI dhan32
Sowing/ planting time	2015-16	27-31 Jan.	09-13 May	08-12 Aug.	03-09 Nov.	09-13Jan.	10-15 Aug.
	2016-17	26-31Jan.	13-16 May	11-15 Aug.	05-10 Nov.	26-29 Jan.	09-13 Aug
Seedling age (days)	2015-16	35-40	25-30	25-30	-	40-45	30-35
	2016-17	35-40	25-30	25-30	-	35-40	30-35
Harvesting time	2015-16	26-28 April	01-06 Aug.	22-25 Oct.	22-24 Jan.	10-15May	15-20 Nov.
	2016-17	02-06 May	01-05 Aug.	28-31 Oct.	19-22 Jan.	26-29May	12-16 Nov.
Grain yield (t ha^{-1})	2015-16	5.96	4.88	4.39	1.52	6.87	3.92
	2016-17	6.24	5.25	4.37	1.46	6.98	3.94
Straw yield (t ha^{-1})	2015-16	5.94	5.15	5.10	2.95	6.99	4.27
	2016-17	6.39	5.64	4.80	2.80	7.49	4.77
Field duration (days)	2015-16	100	78	76	80	121	97
	2016-17	96	79	77	74	121	94
TAT (days)	2015-16	7	10	7	7	92	55
	2016-17	8	12	11	8	88	62

Field duration

Field duration of a cropping pattern comprises on the individual crop duration. Farmers' cropping pattern Boro-fallow-T.Aman-fallow has needed 218 and 215 days

field duration in 1st and 2nd year. The newly introduced two crops in the farmers existing pattern were mustard (var. BARI Sarisha-14) and T.Aus (var. BRRI dhan48). A short duration T.Aman rice var. BRRI dhan57 was also introduced to minimize the field duration of the crop. Total field duration of four crops pattern Boro-T.Aus - T.Aman-Mustard has needed 334 and 326 days (excluding seedling age of rice) to complete the cycle in 1st and 2nd year (Table 3). Thus, long turn around period of 147-150 days in the farmers existing pattern was utilized. Result indicated that mustard and T.Aus rice could be easily fitted in Rice-Rice cropping pattern with an average of 35 days turn around time in a year. Similar trend was also observed by Mondal et al. (2015) who reported that all the tested four crops pattern can be grown successfully one after another in sequence.

Rice equivalent yield

Total productivity of four crops pattern and farmers' pattern were evaluated in terms of rice equivalent yield (REY) and it was calculated from the yield of component crops. Mean rice equivalent yield (20.63 t ha^{-1} yr^{-1}) was found in four crops pattern and farmers' existing pattern produced (10.72 t ha^{-1} yr^{-1}) rice yield (Table 4). Inclusion of mustard in rabi season and T.Aus in kharif-1 season in existing cropping pattern increased total productivity by 92 % compared to farmers' practice. These results are in agreement with Mondal et al. (2015). They reported that total productivity increased by 67 % over farmers' practice.

Table 4. Rice equivalent yield, production efficiency and land utilization index of four crops pattern and farmers' existing pattern at Trishal, Mymensingh during 2015-16 and 2016-17

Items	Four crops pattern			Farmers' pattern		
	2015-16	2016-17	Average	2015-16	2016-17	Average
REY (t $ha^{-1}yr^{-1}$)	20.30	20.95	20.63	10.52	10.92	10.72
PE (kg $ha^{-1}day^{-1}$)	60.78	53.50	57.14	48.89	50.79	49.64
LUI (%)	92	89.32	90.66	58.00	58.90	58.45

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

Production efficiency

Mean maximum production efficiency (57) in terms of kg $ha^{-1}day^{-1}$ was obtained from four crops pattern and minimum (50 kg ha^{-1} day^{-1}) in farmers' practice (Table 4). The higher production efficiency in four crops pattern might be due to inclusion of high yielding mustard and T.Aus rice varieties and improved management practices. Similar trend were noted by Nazrul et al. (2013) and Khan et al. (2006).

Land utilization index (LUI)

Land utilization index is the effective use of land in a cropping year, which mostly depends on crop duration. Land utilization index (LUI) indicated that four crops pattern used the land for 91% period of the year, whereas farmers' pattern used the land for 58 % period of the year (Table 4). The higher land use efficiency in four crops pattern because this pattern occupied the field for longest duration (326-334 days) whereas the farmers' pattern occupied the field for 215-218 days of a year.

Cost and return analysis

From the economic point of view, Boro-T.Aus -T.Aman- Mustard rice cropping pattern showed its superiority over Boro-T.Aman (farmers' pattern) cropping pattern. Mean gross return of four crops pattern was found Tk. 359570 ha^{-1} and farmers' pattern was Tk.199790 ha^{-1} which was more than 80 % higher over farmers' pattern (Table 5). Two rice crop patterns (Farmers' pattern) gave the lower gross return Tk. 199790 ha^{-1}. Mean variable cost was higher in four crops pattern (Tk. 189408 ha^{-1}) might be due to inclusion of two component crops in the pattern. The mean gross margin was significantly higher in four crops pattern (Tk.170162 ha^{-1}) than farmers' pattern (Tk. 82117 ha^{-1}). Four crops pattern achieved higher gross margin mainly due to higher yield advantages of the component crops. The mean marginal benefit cost ratio (MBCR) was found 2.23 which indicated the superiority of the four crops pattern over the farmers' pattern. The marginal benefit cost ratio (MBCR) also showed that inclusion of mustard and T.Aus in the existing pattern might be profitable and acceptable to the farmers. These results are supported by Mondal et al. (2015). They reported that inclusion of T.Aus, potato, mustard and mungbean in the existing pattern were profitable and acceptable to the farmers and grown successfully one after another in sequence of one year cycle.

Table 5. Cost and return analysis of four crop based cropping pattern and farmers' cropping pattern at Mymensingh during 2015-16 and 2016-17

Parameters	Gross return (Tk. ha^{-1})			Total variable cost (Tk. ha^{-1})			MBCR		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
4-Crops pattern	358820	360320	359570	186381	192435	189408	2.32	2.13	2.23
Farmers' pattern	192460	207120	199790	114771	120575	117673	-	-	-

Price (Tk. kg^{-1}): Mustard-50.0, Boro rice-15.0, T.Aman-16.0, T.Aus rice-14.50, Stover-1.0 and Straw-2.0

Apparent soil nutrient balance

Total N, P, K and S uptake by different crops at the farmer's field are presented in table 6. The partial net balance of N was negative in both pattern and ranged from -74

to -223 kg ha^{-1}. Nitrogen replenishment through chemical fertilizer and organic matter addition either singly or incombination was not enough to balance N removal by crops since much of applied N was lost from the soil. The N balance thus, was negative (Table 6). The P balance was favourable as expected due to individual crop basis fertilization. Excess amount of P accumulated in the soil and positive effect of P was reflected in four crops pattern. In farmers pattern, P balance was also negative but the amount is very low (-2kg ha^{-1}). In case of K, it was evident that this element was removed in excess of the quantity added as fertilizer in both pattern. The partial net balance of K was negative and ranged from -79 to -128 kg ha^{-1}. This may lead to K depletion in the long run. There was negative balance of S in both pattern and it ranged from -3 to -15 kg ha^{-1}. This results are supported by Khan et al. (2006) and Ishaque et al. (1998).

Table 6. Effect of Boro-T.Aus-T.Aman-Mustard cropping pattern on the soil nutrient balance at Trishal, Mymensingh (Average of 2015-16 and 2016-17)

Pattern	Nutrient uptake (kg ha^{-1})				Nutrient added (inorg.+org.) (kg ha^{-1})				Apparent nutrient balance (kg ha^{-1})			
	N	P	K	S	N*	P	K	S	N	P	K	S
4-Crops	380	60	321	58	393	83	193	45	-223	23	-128	-15
FP	178	31	160	17	260	29	81	14	-74	-2	-79	-3

*40% of applied fertilizer/manure N was considered effective

CONCLUSION

Mustard and T.Aus rice could be easily fitted in the existing pattern with higher rice equivalent yield and higher benefit. Besides, cultivation of four crops, Boro (var. BRRI dhan28)-T.Aus (var. BRRI dhan48)-T.Aman (var. BRRI dhan57)-Mustard (var. BARI Sarisha-14) pattern in a year in the same piece of land could be created more employment opportunity as well as increased production of rice and mustard for the farmers at the same time cropping intensity and productivity could be increased.

ACKNOWLEDGEMENT

Authors are grateful to Ministry of Agriculture, Peoples Republic of Bangladesh for a research grant to OFRD, BARI for development of four crop based cropping patterns.

REFERENCES

BBS (Bangladesh Bureau of Statistics). (2015). Statistical Pocket Book Bangladesh, Statistics and Informatics Division, Ministry of Planning, Government People's Republic of Bangladesh, Dhaka, p. 92.

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

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

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

Ishaque, M., Panaullah, G.M., Bhuyian, N.I., and Saha, P.K. (1998). Integrated nutrient management with inorganic fertilizer and green/ organic manures for Boro-T.Amanrice cropping pattern. In proceedings "National Workshop on Integrated Nutrient Management for Crop Production and Soil Fertility" held on 24-25 March, 1998 at BARI, Gazipur, Bangladesh, p. 111-114.

Khan, M.A., Hossain, S.M.A., and Khan, M.A.H.K. (2006). A study on some selected jute based cropping patterns at Kishoregonj. *Bangladesh Journal of Agricultural Research*, 31 (1), 85-95.

Khan, M.A.H., Khurram, M.M.H., Chowdhury, D.A., Quayyum, M.A. and Islam, M.F. (2006). Integrated nutrient management in wheat-Jute-T.Amanrice cropping system. *Bangladesh Journal of Agricultural Research*, 31(2), 249-257.

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

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

Rahman, M.M., Khan, M.H., Mallick, R.N., and Hudgens, R.E. (1989). *Guidelines for Farming Systems Research Methodology.* Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215.

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

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