Hindawi
International Journal of Agronomy
Volume 2018, Article ID 7149835, 6 pages
https://doi.org/10.1155/2018/7149835

Research Article

Transforming Triple Cropping System to Four Crops Pattern: An Approach of Enhancing System Productivity through Intensifying Land Use System in Bangladesh

Md. Aminul Islam,[1] Md. Jahedul Islam,[2] M. Akkas Ali,[3] A. S. M. Mahbubur Rahman Khan,[3] Md. Faruque Hossain,[3] and Md. Moniruzzaman[4]

[1]*On-Farm Research Division, BARI, Masterpara, Gaibandha, Bangladesh*
[2]*Regional Wheat Research Center, BARI, Shyampur, Rajshahi, Bangladesh*
[3]*On-Farm Research Division, BARI, Joydebpur, Gazipur, Bangladesh*
[4]*On-Farm Research Division, BARI, Pabna, Bangladesh*

Correspondence should be addressed to Md. Aminul Islam; amin.agron@gmail.com

Received 17 December 2017; Accepted 23 April 2018; Published 21 May 2018

Academic Editor: David Clay

Changing three crops pattern to four crops can play a potential role for achieving countries food security. With this view to increase crop productivity, production efficiency, land use efficiency, and economic return through intensifying cropping intensity as well as crop diversity by transforming three crops pattern to four crops, the experiment was conducted in High Ganges River Floodplain Soils under the Agro-Ecological Zone (AEZ) 11 at Pali, Durgapur, under the Multilocation Testing Site, Puthia, Rajshahi, for two consecutive years 2014-15 and 2015-16. Four crops pattern mustard-onion/maize-T. *Aman* rice was tested at on-farm condition over the existing three crops pattern mustard-onion-T. *Aman* rice. Maize was introduced here as a relay crop with onion to fit it in the four crops pattern. The experiment was laid out in RCB design with six dispersed replications. Two-year crop cycles were completed, and data regarding component crops yield were considered for assessing the performance of the two cropping patterns for making a sense of comparing productivity. Although there was no significant difference in component crops yield between four crops and three crops pattern, as an additional crop, maize tremendously increased the system productivity and economic return of the four crops pattern. Higher rice equivalent yield 28.96 $t \cdot ha^{-1}$ in 2013-14 and 30.95 $t \cdot ha^{-1}$ in 2014-15 was recorded from the four crops pattern with a mean rice equivalent yield (REY) 29.95 $t \cdot ha^{-1}$ over the existing pattern with a mean value 21.76 $t \cdot ha^{-1}$. However, four crops pattern resulted in higher cultivation cost due to growing maize as an additional crop; nevertheless, it gave the higher gross return, marginal return, marginal benefit cost ratio, and production efficiency. The four crops pattern resulted averagely 37.63% higher production (REY) compared to the existing three crops pattern. Production as well as land use efficiency were increased by 9.33% and 19.18%, respectively, from the intensified alternate pattern.

1. Introduction

Trend of available agricultural land over the time is decreasing with an amount to 1.33 lac ha in 1976 (91.83% of total land area) that is decreased to 1.27 ha in 2000 with yearly loss of 23,391 ha. The area is further dropped to 1.21 lac ha in 2010 with yearly loss of 56,537 ha. A sum of 1.13 lac ha land has been lost during the past 34 years from 1976 to 2010. Rate of cropland shifting to nonagricultural land (housing, industry, etc.) is alarming as it is associated with the food security of the country. Total cropland was estimated to be 9,761,450 ha, 9,439,541 ha, and 8,751,937 ha in 1976, 2000, and 2010 with an average decrease of 0.14% during 1976 to 2000 and 0.73% during 2000–2010, respectively. Hasan et al. reported the rate of change over the 34 years is 0.30% which is still declining [1].

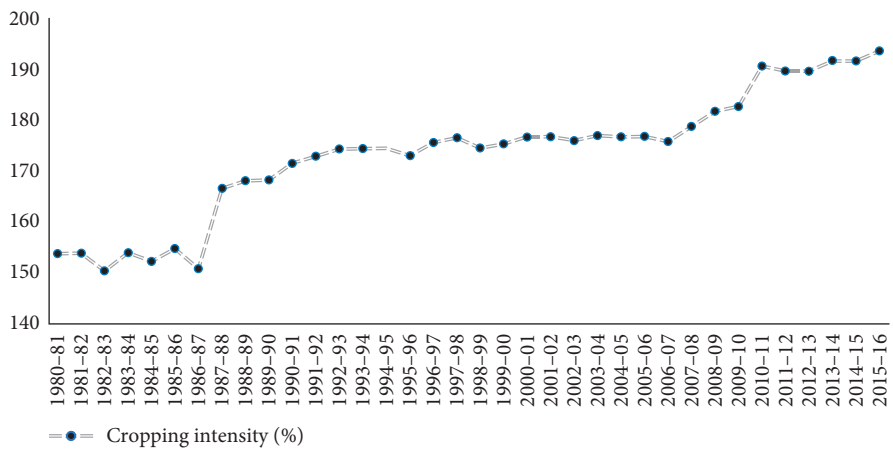

Figure 1: Trend of cropping intensity (%) in Bangladesh since 1980-81 to 2015-16 (BBS).

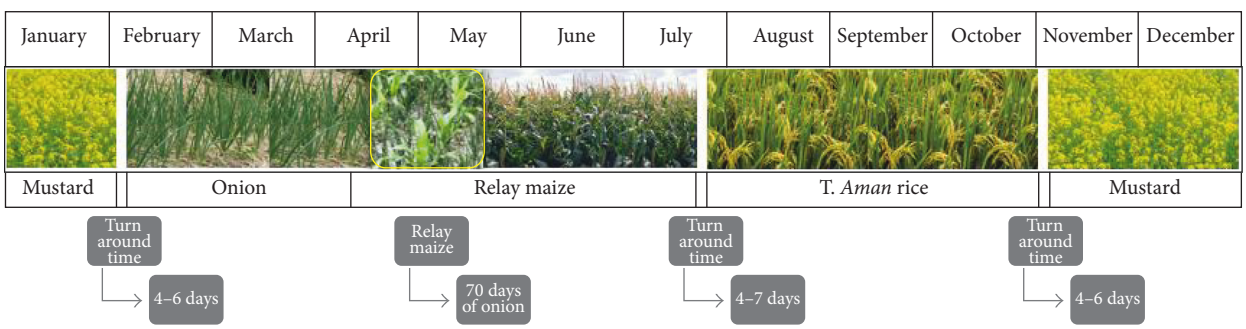

Figure 2: Calendar year of four crops pattern.

As per Bangladesh Bureau of Statistics (BBS) [2], around 3795 and 1688 thousand ha of land remain under double and triple cropped area, respectively, which means that 48.41% and 21.53% of the country's net cropped area has avenues partly or a major portion to be brought under quadruple cropping system. The area of cropland is decreasing, that is why there is no option of horizontal expansion but intensifying land use system through multiple cropping or by growing more and more crops on the same piece of land in a calendar year. However, the agriculture is heading towards a new paradigm to address the country's food security a concerned issue of Bangladesh. Alauddin and Tisdell [3] investigated that food production has been increased to 3.67 folds over the period of time, from an estimated amount of 1.01 m ton in 1971 during the independence of Bangladesh to 3.71 m ton in 2016 as recorded in BBS [2]. Cultivation of modern crop varieties, improvising cultural operations, and crop protection measures as well as increasing crop intensity (Figure 1) collectively contributed to such achievement.

Mustard-onion-T. *Aman* rice is a popular cropping pattern in Durgapur Upazilla of Rajshahi district under High Ganges River Floodplain. Upazila agricultural office of DAE claims that there are 2000 hectare of land in the upazila in which the pattern mustard-onion-T. *Aman* rice is being practiced during 2012 cropping year. Mustard is usually grown in Rabi season. Sowing is started in the last week of October to 1st or 2nd week of November, and the crop is harvested in the end of January to mid-February followed by cultivation of onion planted at 2nd week to end of February. After harvest of onion in April, farmers go for T. *Aman* rice cultivation in the end of July to 2nd or 3rd week of August. Thus, after harvest of onion, the land remains fallow from last week of April to July until T. *Aman* rice being transplanted. Some commercial maize hybrids grown in *Kharif* season mature in 95 to 105 days. Therefore, there is a chance of developing four crops pattern as maize can easily be grown as relay crop with onion in between the fallow period as shown in Figure 2. Tanveer et al. [4] reviewed the benefits of relay cropping that enhanced sustainable system productivity through efficient use of available resources like microclimate, nutrients dynamics [5–8]. Inclusion of fourth crop in the sequence will increase system productivity as well as improve farmer's economic condition. Keeping that in the point of view, the study was undertaken to increase diversification and intensification of existing Mustard-onion-T. *Aman* rice cropping pattern in terms of productivity, production efficiency, land use efficiency, and economic return.

2. Materials and Methods

2.1. Site Selection. The experiment was conducted at the farmers' field of Pali, Durgapur, under the Multilocation Testing Site (MLT), Shibpur, Puthia, Rajshahi, during 2014-15 to 2015-16 to assess the performance of alternate four crops pattern against existing three crops pattern (mustard-onion-T.

Table 1: Details of cultural practices adopted for different crops in field experiments.

Crop	Cultivar	Seed rate ($kg \cdot ha^{-1}$)	Spacing (cm^2)	Date of sowing	Date of harvesting	Rate of fertilizer application ($kg \cdot ha^{-1}$)					
						N	P	K	S	Zn	B
Mustard	BARI Sarisha-14	07	30 cm solid row	01–05 Nov	01–05 Feb	78	15	42	10	2	1.5
Onion	BARI Piaz-2	08	15 × 10	05–10 Feb	10–15 May	93	29	85	19	2	—
Maize	NK-40	21	60 × 20	10–15 Apr	15–20 Jul	250	53	100	40	—	—
T. *Aman* rice	BRRI dhan33	30	20 × 15	20–25 Jul	25–31 Oct	62	6	19	7	2	—

Aman rice) in High Ganges River Floodplain soils. Geographically, the experimental field is located at 20°024.49/N latitude and 88°47.20/E longitude with the elevation of 20 m above the sea level. The land was selected based on the discussion with local farmers, DAE personnel, and available secondary information.

2.2. Information Related to AEZ-11. There is an overall pattern of olive-brown silt loams and silty clay loams on the upper parts of floodplain ridges and dark grey, mottled brown, mainly clay soils on ridge sites and in basins. Most ridge soils are calcareous throughout. General soil types predominantly include calcareous dark grey floodplain soils and calcareous brown floodplain soils. Organic matter content in brown ridge soils is low and higher in dark grey soils. Soils are slightly alkaline in reaction. General fertility level is low.

2.3. Nutrient Status. The experimental soil was slightly alkaline (8.4) having low organic matter (1.78%). The soil contained 0.08% total N (very low), 25.85 ppm available P (optimum), 0.16 me% exchangeable K (low), 15.85 ppm available S (medium), 0.50 ppm available B (high), and 0.20 ppm available Zn (very low). The rates of the fertilizers for different crops were calculated using soil test values based (STB) on high yield goal as per Fertilizer Recommendation Guide' 2012 [9].

2.4. Experimental Procedure. The experiment was designed with two cropping patterns following randomized complete block design with six dispersed replications. The unit plot size was 8 m × 4 m. The treatments were C_1: mustard-onion/maize-T. *Aman* rice and C_2: mustard-onion-T. *Aman* rice. The sources of nutrients were urea for N, TSP for P, M_OP for K, gypsum for S, zinc sulphate for Zn, and Boric acid for B. The details of the varieties used and cultural operations adopted in different crop sequences are given in Table 1. For mustard, half of urea and all other inorganic fertilizers were applied according to individual plot and mixed with soil at the time of final land preparation. The rest of urea was top dressed before flowering just one day after first irrigation. In case of onion, half of urea and all other inorganic fertilizers were applied to individual plot and mixed with soil at the time of final land preparation. The rest of urea was top dressed 30 days after planting. Maize was planted 70 days after planting of onion. For maize, half of urea and all other inorganic fertilizers were applied according to individual plot after harvesting of onion at 6-leaf stage of maize as side dressing followed by earthing up. The rest urea was top dressed at 10-leaf stage. In case of T. *Aman* rice, all the fertilizers except urea were applied as basal. Urea was applied as top dress in three equal splits at 15, 30, and 45 days after transplanting. All the crops were harvested at maturity from an area of central 5.0 m^2. Data on yield of component crops in sequences were recorded and converted to ton per hectare. Total system productivity was calculated as summation of individual crop yield of each cropping cycle. The productivity of different crop sequences was compared by calculating their economic rice equivalent yield (REY) using formula given by Ahlawat and Sharma [10], where

$$\text{REY} = \frac{\text{Yield of each crop } \left(t \cdot ha^{-1}\right) \times \text{economic value of respective crop } \left(Tk \cdot t^{-1}\right)}{\text{Price of rice grain } \left(Tk \cdot t^{-1}\right)}. \quad (1)$$

2.4.1. Land Use Efficiency. Land use efficiency (LUE) was estimated by the total duration of crops in the sequence divided by 365 days and expressed in % as outlined by Jamwal [11]:

$$\text{LUE} = \frac{\sum \text{Dc}}{365} \times 100, \quad (2)$$

where Dc = duration of crops in the sequence.

2.4.2. Production Efficiency. Production efficiency (PE) was calculated by taking total economic yield of the sequence on wheat equivalent basis divided duration of crops using per formula by Jamwal [11].

$$\text{PE} = \frac{\text{REY}}{\sum \text{Dc}}, \quad (3)$$

where REY = rice equivalent yield in a sequence and Dc = duration of crops in that sequence.

2.4.3. Marginal Benefit Cost Ratio (MBCR). The economic analysis was done following the method suggested by CIMMYT [12]. The MBCR can be computed as the marginal

Table 2: Productivity of component crops (mustard and onion) in different cropping patterns.

Cropping pattern	Cropping year 2013-14		Cropping year 2014-15	
	Seed yield of mustard ($t \cdot ha^{-1}$)	Bulb yield of onion ($t \cdot ha^{-1}$)	Seed yield of mustard ($t \cdot ha^{-1}$)	Bulb yield of onion ($t \cdot ha^{-1}$)
Mustard-onion/maize-T. *Aman* rice	1.56	14.60	1.61	15.68
Mustard-onion-T. *Aman* rice	1.48	14.82	1.55	15.10
Level of significance	NS	NS	NS	NS
SE (±)	0.35	0.51	0.26	0.57
CV (%)	4.23	5.47	5.21	4.37

Table 3: Productivity of component crops (maize and T. *Aman* rice) in different cropping patterns.

Cropping pattern	Cropping year 2013-14				Cropping year 2014-15			
	Yield of maize ($t \cdot ha^{-1}$)		Yield of T. *Aman* rice ($t \cdot ha^{-1}$)		Yield of maize ($t \cdot ha^{-1}$)		Yield of T. *Aman* rice ($t \cdot ha^{-1}$)	
	Grain	Stover	Grain	Straw	Grain	Stover	Grain	Straw
Mustard-onion/maize-T. *Aman* rice	7.65	8.43	4.54	5.88	8.39	9.13	4.77	6.06
Mustard-onion-T. *Aman* rice	—	—	4.44	5.46	—	—	4.48	5.75
Level of significance	—	—	NS	NS	—	—	NS	NS
SE (±)	—	—	0.36	1.23	—	—	0.19	0.16
CV (%)	—	—	4.59	5.74	—	—	10.32	8.50

value product (MVP) over the marginal value cost (MVC). It can be computed as

$$\text{MBCR} = \frac{\text{MVP (over control)}}{\text{MVP (over control)}}. \quad (4)$$

All the data were statistically analyzed following the F-test and the mean comparisons were made by DMRT at 5% level as per the outline by Gomez and Gomez [13].

3. Results and Discussion

3.1. Yield of Mustard. Mustard was the first crop in both the cropping patterns. There was no significant difference of mustard yield in between the cropping patterns. However, numerically higher yield (1.56 $t \cdot ha^{-1}$ in 2013-14 and 1.61 $t \cdot ha^{-1}$ in 2014-15) was observed in the improved pattern followed the existing one (Table 2).

3.2. Yield of Onion. Onion was the second crop in both the sequences and planted in the late *Rabi* season (February). There was no significant difference between the cropping patterns on the bulb yield of onion. However, from the 1st year observation, numerically higher bulb yield was recorded in the existing cropping pattern (mustard-onion-T. *Aman* rice) than four crops pattern. The 2nd year trend was contrary to the first year result though the difference was statistically nonsignificant (Table 2).

3.3. Yield of Maize. Maize was the included crop in the improved pattern and grown as a relay crop with onion in *Kharif-I* season (April), whereas, in the existing pattern, this period remained fallow. From the two years' observation, it was clear that maize can effectively be grown as relay with onion to fit it in the four crops pattern by saving time. Inclusion of maize in the fallow period characteristically increased the system's equivalent yield. Generally, farmers use excess amount of fertilizers for preceding crop onion. Therefore, maize can be grown with a minimum support regarding input cost. However, maize produced 7.65 ton grain and 8.43 ton stover ha^{-1} in 2013-14 and 8.39 ton grain and 9.13 ton stover ha^{-1} in 2014-15 which contributed to a higher REY of 29.95 $t \cdot ha^{-1}$ in four crop-based pattern (Tables 3–5). Correia et al. [14] observed 209.57% higher yield from maize as intercropped/relayed with mucuna.

Table 4: System productivity (REY*) of component crops in different cropping patterns.

Cropping pattern	System REY ($t \cdot ha^{-1}$)	
	2013-14	2014-15
Mustard-onion/maize-T. *Aman* rice	28.96	30.95
Mustard-onion-T. *Aman* rice	21.51	22.01
Level of significance	0.05	0.05
SE (±)	2.65	2.96
CV (%)	6.21	8.62

*Rice equivalent yield.

3.4. Yield of T. Aman Rice. T. *Aman* rice is the common crop in the *Kharif-II* (July–October) season in both cropping patterns. Grain yield of T. *Aman* rice is a complex character depending on a large number of environmental, morphological, and physiological characters. Grain yields also depend upon their yield components. However, there was no significant difference on grain yield of rice in between the cropping patterns but numerically higher (2.25% in 2013-14 and 6.47% in 2014-15) grain yield observed in the imposed pattern might be due to the residual effect of fertilizers applied to the preceding maize crop (Table 3). Jabbar et al. [15] observed the positive impact on residual soil fertility when crops are grown as inter/relay cropping system.

Table 5: Field crop duration, production efficiency, and land use efficiency as influenced by cropping patterns.

Cropping pattern	Mean REY ($t \cdot ha^{-1}$)	Field duration of crop sequence (day)	Production efficiency ($kg^{-1} \cdot ha^{-1} \cdot day^{-1}$)	Land use efficiency (%)
Mustard-onion/maize-T. *Aman* rice	29.95	340	88.10	93.15
Mustard-onion-T. *Aman* rice	21.76	270	80.58	73.97

Table 6: Profitability of the four crops pattern over the existing pattern.

Cropping pattern	Gross return ($Tk. \cdot ha^{-1}$)	Cultivation cost (TVC) ($Tk. \cdot ha^{-1}$)	Marginal value (MVP) ($Tk. \cdot ha^{-1}$)	Marginal cost (MVC) ($Tk. \cdot ha^{-1}$)	MBCR*
Mustard-onion/maize-T. *Aman* rice	539180	285542	147540	46894	3.14
Mustard-onion-T. *Aman* rice	391640	238648	—	—	—

*Marginal benefit cost ratio; input: urea: 16 $Tk \cdot kg^{-1}$, TSP: 22 $Tk \cdot kg^{-1}$, MoP: 15 $Tk \cdot kg^{-1}$, gypsum: 6 $Tk \cdot kg^{-1}$, zinc sulphate: 120 $Tk \cdot kg^{-1}$, boric acid: 150 $Tk \cdot kg^{-1}$, furadan: 150 $Tk \cdot kg^{-1}$, mustard seed: 100 $Tk \cdot kg^{-1}$, tillage cost: 10000 $Tk \cdot ha^{-1}$, irrigation (1 time): 1000 $Tk \cdot ha^{-1}$, and labour: 200 $Tk \cdot day^{-1}$ (8 hours); output: rice grain: 18 $Tk \cdot kg^{-1}$, mustard seed: 50 $Tk \cdot kg^{-1}$, onion bulb: 15 $Tk \cdot kg^{-1}$, maize grain: 16 $Tk \cdot kg^{-1}$, maize stover: 1 $Tk \cdot kg^{-1}$, and rice straw: 2 $Tk \cdot kg^{-1}$.

3.5. System Productivity. System productivity was considered as rice equivalent yield (REY). The system REY significantly differed between the cropping patterns. However, data are presented in Table 2. In general, the pattern involving four crops produced significantly greater REY than that having three crops pattern. However, mustard-onion/maize-T. *Aman* rice showed higher productivity in terms of REY (28.96 $t \cdot ha^{-1}$ in 2013-14 and 30.95 $t \cdot ha^{-1}$ in 2014-15) with a mean REY 29.95 $t \cdot ha^{-1}$ (Table 5) than mustard-onion-T. *Aman* rice cropping pattern (21.76 $t \cdot ha^{-1}$). Total productivity increased by 37.63% in the maize-included four crops pattern. Mondal et al. [16] also claimed of having 49 to 67% higher productivity from the intensified land use system. Total field duration of crops by cropping pattern is presented in Table 5. Total field duration was the higher in mustard-onion/maize-T. *Aman* rice cropping pattern (340 days) due to additional maize crop cultivation and found lower (270 days) in the existing mustard-onion-T. *Aman* rice cropping pattern because of not cultivating maize in *kharif* season.

3.6. Production Efficiency (PE). The cropping patterns showed variation on production efficiency (PE) (Table 5). The pattern having four crops generated the higher PE (88.10 $kg^{-1} \cdot ha^{-1} \cdot day^{-1}$). This is due to the higher productivity of this sequence in which the contribution of maize is quite obvious. However, the mustard-onion-T. *Aman* rice gave the 9.33% lower PE (80.58 $kg^{-1} \cdot ha^{-1} \cdot day^{-1}$) in the sequences. Higher PE associated with improved cropping pattern coupled with modern management practices were noted by Nazrul et al. [17], Khan et al. [18, 19], and Krrishna and Reddy [20]. Though not studied here, inter/relay crops could increase system production by suppressing the weed growth [21].

3.7. Land Use Efficiency (LUE). Land use efficiency (LUE) varied according to the cropping patterns (Table 5). In general, patterns intensified by four crops resulted in 19.18% higher LUE than the triple cropping system. The higher LUE (93.15%) was recorded in mustard-onion/maize-T. *Aman* rice whereas the lower LUE (73.97%) was recorded in mustard-onion-T. *Aman* rice cropping pattern. The results are in agreement with Kamrozzaman et al. [22].

3.8. Economic Performance. Based on two years' observation, economic performance of the patterns is presented in Table 6. Cropping pattern attributed a remarkable impact on variable cost, marginal return, and marginal benefit cost ratio (MBCR). The annual gross return, cultivation cost, marginal return, and marginal cost were considered for assessing the suitability of the cropping pattern. In general, inclusion of the fourth crop (maize) markedly enhanced both the return and cultivation cost. Though maize accounted for 19.64% higher cultivation cost, consequently it contributed to 37.63% higher return in the four crops pattern. The mustard-onion/maize-T. *Aman* rice had a maximum gross return (Tk. 539180 ha^{-1}) along with a higher cultivation cost (Tk. 285542 ha^{-1}), which also contributed to higher marginal return (Tk. 147540 ha^{-1}) and MBCR (3.14) than mustard-onion/maize-T. *Aman* rice-based three crops pattern.

4. Conclusion

Relaying maize with onion is a simple but an effective time space saving technology for shifting the thee crops pattern to four crops (mustard-onion/maize-T. *Aman* rice) one. Considering systems REY, LUE, PE, and economic performances of the two-year crop cycle, it is revealed that four crops pattern is the best option for greater productivity and profitability over the triple cropping system.

Disclosure

The authors do certify that the statements made by them are true and correct to the best of their knowledge and belief. They understand that any false statements or any unfair means may provide grounds for the withdrawal or cancellation of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of the article.

Acknowledgments

The authors are thankful to the On-Farm Research Division, Bangladesh Agricultural Research Institute, Gazipur, for providing financial help and logistic support, respectively.

References

[1] M. N. Hasan, M. S. Hossain, M. A. Bari, and M. R. Islam, *Agricultural Land Availability in Bangladesh*, SRDI, Dhaka, Bangladesh, 2013.

[2] BBS (Bangladesh Bureau of Statistics), *Yearbook of Agricultural Statistics*, Statistics and Informatics Division (SID) Ministry of Planning, Dhaka, Bangladesh, 2016.

[3] M. Alauddin and C. Tisdell, "Trends and projections for Bangladeshi food production: an alternative viewpoint," *Food Policy*, vol. 12, no. 4, pp. 318–331, 1987.

[4] M. Tanveer, S. A. Anjum, S. Hussain, A. Cerdà, and U. Ashraf, "Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production," *Environmental Science and Pollution Research*, vol. 24, no. 8, pp. 6973–6988, 2017.

[5] H. Knörzer, H. Grözinger, S. Graeff-Hönninger, K. Hartung, H. P. Piepho, and W. Claupein, "Integrating a simple shading algorithm into CERES-wheat and CERES-maize with particular regard to a changing microclimate within a relay-intercropping system," *Field Crops Research*, vol. 121, no. 2, pp. 274–285, 2011.

[6] A. C. Gaudin, K. Janovicek, R. C. Martin, and W. Deen, "Approaches to optimizing nitrogen fertilization in a winter wheat–red clover (*Trifolium pratense* L.) relay cropping system," *Field Crops Research*, vol. 155, pp. 192–201, 2014.

[7] C. Amossé, M. H. Jeuffroy, B. Mary, and C. David, "Contribution of relay intercropping with legume cover crops on nitrogen dynamics in organic grain systems," *Nutrient Cycling in Agroecosystems*, vol. 98, no. 1, pp. 1–14, 2014.

[8] J. S. Schepers, D. D. Francis, and J. F. Shanahan, "Relay cropping for improved air and water quality," *Journal of Biosciences*, vol. 60, pp. 186–189, 2005.

[9] BARC (Bangladesh Agricultural Research Council), *Fertilizer Recommendation Guide*, BARC, Farmgate, Dhaka, Bangladesh, 2005.

[10] I. P. S. Ahlawat and R. P. Sharma, *Agronomid Terminology*, Indian Society of Agronomy, New Delhi, India, 3rd edition, 1993.

[11] J. S. Jamwal, "Productivity and economics of different maize (*Zea mays*) based crop sequences under dryland conditions," *Indian Journal of Agronomy*, vol. 46, no. 4, pp. 601–604, 2001.

[12] CIMMYT, *From Agronomic Data to Farmer Recommendations: An Economic Training Manual*, International Maize and Wheat Improvement Center, El Batan, MEX, Mexico, 1988.

[13] K. A. Gomez and A. A. Gomez, *Statistical Procedures for Agricultural Research, An International Rice Research Institute Book*, John Wiley and Sons, New York, NY, USA, 2nd edition, 1984.

[14] M. V. Correia, L. C. R. Pereira, L. D. Almeida et al., "Maize-mucuna (*Mucuna pruriens* (L.) DC) relay intercropping in the lowland tropics of Timor-Leste," *Field Crops Research*, vol. 156, pp. 272–280, 2014.

[15] A. Jabbar, R. Ahmad, I. H. Bhatti, T. Aziz, M. Nadeem, and R. A. Wasi-u-Din, "Residual soil fertility as influenced by diverse rice-based inter/relay cropping systems," *International Journal of Agriculture and Biology*, vol. 13, pp. 477–483, 2011.

[16] R. I. Mondal, F. Begum, A. Aziz, and S. H. Sharif, "Crop sequences for increasing cropping intensity and productivity," *SAARC Journal of Agriculture*, vol. 13, no. 1, pp. 135–147, 2015.

[17] M. I. Nazrul, M. R. Shaheb, M. A. H. Khan, and A. S. M. M. R. Khan, "On-Farm evaluation of production potential and economic returns of potato-rice based improved cropping system," *Bangladesh Agronomy Journal*, vol. 16, no. 2, pp. 41–50, 2013.

[18] M. A. Khan, S. M. A. Hossain, and M. A. H. Khan, "A study on some selected jute-based cropping patterns at Kishoregonj," *Bangladesh Journal of Agricultural Research*, vol. 31, no. 1, pp. 85–95, 2006.

[19] M. A. H. Khan, M. A. Quayyum, M. I. Nazrul, N. Sultana, and M. R. A. Mollah, "On-farm evaluation of production potential and economics of mustard-rice based improved cropping system," *Journal of Social and Economic Development*, vol. 2, no. 1, pp. 37–42, 2005.

[20] A. Krishna and A. K. Reddy, "Production potential and economics of different rice (*Oryza sativa*) based cropping systems in Andhra Pradesh," *Indian Journal of Agricultural Sciences*, vol. 67, no. 12, pp. 551–553, 1997.

[21] C. Amossé, M. H. Jeuffroy, F. Celette, and C. David, "Relay-intercropped forage legumes help to control weeds in organic grain production," *European Journal of Agronomy*, vol. 49, pp. 158–167, 2013.

[22] M. M. Kamrozzaman, M. A. H. Khan, S. Ahmed, and A. F. M. Ruhul Quddus, "On-farm evaluation of production potential and economics of Wheat Jute-T.aman rice-based cropping system," *Journal of the Bangladesh Agricultural University*, vol. 13, no. 1, pp. 93–100, 2015.