

ENHANCEMENT OF CROP PRODUCTIVITY OF MUSTARD-MUNGBEAN-T. AMAN CROPPING PATTERN THROUGH NEW VARIETIES AND NUTRIENT MANAGEMENT

M. S. HOSSAIN¹, K. C. SAHA², M. M. ISLAM³
S. AKTER⁴ AND M. T. ISLAM⁵

Abstract

The experiment was conducted at the farmers' fields of Kalkini and sadar upazila of Madaripur, during two consecutive years 2019-20 and 2020-21 to evaluate the performance of yield, productivity and profitability of Mustard-Mungbean-T. *aman* cropping pattern through incorporating, short duration and high yielding crop varieties with integrated nutrient management. The experiment was laid out in a randomized complete block design with three dispersed replications. The cropping cycle was with three crops, nine varieties namely Mustard: var. BARI Sarisha-14, BARI Sarisha-17, BARI Sarisha-11; Mungbean: var. BARI Mungbean-6, BARI Mungbean-8, BINA Mungbean-8; T. *aman*: var. BRRI dhan 57, BRRI dhan 71 and BRRI dhan 75 and three fertilizer levels (F_1 = Recommended Fertilizer Dose, RFD from inorganic source as per soil test bases, STB; F_2 = RFD on STB + 5 t ha⁻¹ cowdung, integrated plant nutrient system, IPNS approach; F_3 = Farmers practices). Highest yield as well as by-product yield, rice equivalent yield (REY) (16.12 t ha⁻¹ yr⁻¹), gross return (3,86,880 Tk ha⁻¹ yr⁻¹), total variable cost (1,36,621 Tk ha⁻¹ yr⁻¹), gross margin (2,50,259 Tk ha⁻¹ yr⁻¹) and marginal benefit cost ratio (2.83) were obtained from the treatment combination of mustard var. BARI Sarisha-14, mungbean var. BARI Mung-6 and rice var. BRRI dhan71 with integrated plant nutrient system (IPNS) and the lowest from farmers' practices. IPNS based fertilizer management in this cropping pattern performed better compared to other fertilizer management practices. Higher REY indicates that improved cropping pattern Mustard (var. BARI Sarisha-14/BARI Sarisha-17)-Mungbean (var. BARI Mung-6)-T. *aman* (var. BRRI dhan57/BRRI dhan71/BRRI dhan75) could be suitable in Madaripur for increasing crop productivity cropping intensity as well as profitability.

Keywords: Cropping pattern, Cropping intensity, Gross return, Integrated plant nutrient system, Rice equivalent yield, System productivity.

Introduction

Bangladesh is the most densely populated country of the world but surprisingly it has to feed 149 million people, which is increasing annually at the rate of about 1.42% (BBS, 2019). Besides, the cultivable land is in a decreasing trend and it is

¹Senior Scientific Officer, Central Laboratory, Research Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, ²Scientific Officer, Oilseed Research Centre, BARI, Gazipur. ³Senior Scientific Officer, Plant Pathology Division, BARI, Gazipur, ⁴Director, Tuber Crops Research Centre, BARI, Gazipur. ⁵Director (Research), Research Wing, BARI, Gazipur, Bangladesh.

about 1% per year. Bangladesh covers about 14.84 M ha (million hectares) of total land and among this 3.74 M ha (25% of the total) is not appropriate for cultivation due to deployment for urban areas, commercial buildings, countryside homesteads, roads etc. Climate change, population expansion, food scarcity, poverty, starvation, accelerated land cover change and environmental degradation are the foremost challenges (Neamatollahi *et al.*, 2017). Therefore, to declare food security for increasing people in the future we need to produce huge food on a reduced amount of land (Islam *et al.*, 2015). So, increasing cropping intensity by producing more crops over the same piece of land in a year and to increase the production efficiency (productivity) of the individual crop by using optimum management practices (FAOSTAT, 2014; Dobermann *et al.*, 2013; Ladha *et al.*, 2016; Datta *et al.*, 2017; Islam *et al.*, 2017).

The cropping system of Bangladesh is usually rice-based as well as diversified, includes pulses, oilseeds, vegetables, tuber crops, and other winter cereals like maize and wheat. The productivity and sustainability of rice-based systems are threatened because of inefficient use of imputes (seed, fertilizer, scarcity of resources (water and labour), climate change, energy crisis and rising fuel prices and declining soil fertility (Alam *et al.*, 2017; Alam *et al.*, 2018). Oilseed and pulse are the important group of crops which are mostly grown in rabi season but area of those crops decreased due to increasing cultivation of irrigated (withdrawal of huge groundwater) Boro rice, caused the lowering of water tables (Shamsudduha *et al.*, 2009). Recently with the development of short duration varieties of rice, mustard, potato, pulse, vegetables and jute opportunities have been created to accommodate three more crops in same piece of land in a year. Rape-seed mustard production can be increased up to 20-25% only by replacing traditional variety (Tori-7) with high yielding short duration varieties like BARI Sarisha-14 and BARI Sarisha-17 in the existing rice based cropping system. Another potential way of achieving this is to switch short duration T. *aman* (var. BRRI dhan57/BRRI dhan71/BRRI dhan75) in place of long duration T. *aman* (var. BRRI dhan39/Gutisorna) variety and inclusion of high yielding mungbean varieties in Mustard-Mungbean-T. *aman* cropping system. It will increase the total system productivity, profitability and sustainability of the rice-based cropping system. Different cropping patterns are available in Bangladesh and these are well reported (Khan *et al.*, 2005; Anowar *et al.*, 2012; Nazrul *et al.*, 2013). Aziz *et al.* (2013) reported that multiple cropping system effects soil carbon and nitrogen status, and also improve soil functional properties. Nevertheless, continuous cropping cause's nutrient mining from soil while a blanket fertilizer dose for all regions without considering the soil nutrient status leads to tremendous damage to soil, environment and economy. Sultana *et al.*, (2015) also reported that actual recommended fertilizer dose is higher than actual need of fertilizer and this resulted soil nutrient imbalance. As soil fertility is a major determinant for the

success and failure of a crop production system. Therefore, an improved cropping system is needed that will reduce the production cost, increase crop productivity and soil health.

Madaripur district is located under Low Ganges River Floodplain (AEZ-12) and the soil is silty clay. The cropping intensity of this area is 201% and about 66% and 15% land areas are under double and triple cropped (DAE, 2016). About 72% lands are under medium high to low land in which 20% lands remains fallow after harvesting of *T. aman* rice. Potential adoption of improved cropping patterns Mustard-Mungbean-*T. aman* instead of *T. aman*-Fallow-*T. Boro* cropping system would be more productive and profitable for the farmers'. Considering the above issues, the study was undertaken to increase cropping intensity, productivity and profitability in rice based cropping system.

Materials and Methods

Site Description

The experiment was conducted in farmer's field at Kalkini and Madaripur sadar upazila under Madaripur district during 2019-20 and 2020-21. The initial soil samples were collected from 0-15 cm depth and soil chemical and microbiological properties were analyzed by Soil Science Division and Central Laboratory, BARI before sowing of the experiment. The soil was silty clay soil and it belongs to Ganges soil series under the Low Ganges Floodplain Soils (AEZ-12). Most of the soils contain less than 1.71% soil organic matter (SOM), and some soils have even less than 1% SOM. The sub-tropical humid climate causes rapid breakdown of SOM by heterotrophic microbes; consequently, nutrients loss occurs through different processes, viz. leaching, volatilization, runoff etc. The low SOM is a cause of low productivity and is considered as a serious threat to the sustainability of agriculture in Bangladesh. Thus, with advancement of time, soil fertility has declined and chronologically the deficiency of nitrogen, phosphorus, potassium, sulphur, zinc and boron has arisen in the soils. The initial farmer's field soil results showed that pH ranged from 8.06-8.21, total N (0.085-0.095%), calcium (21.16-21.77 meq 100 g⁻¹), magnesium (3.85-3.96 meq 100 g⁻¹), potassium (0.16-0.23 meq 100 g⁻¹), phosphorus (12-52 µg g⁻¹), iron (97.54-99.43 µg g⁻¹), zinc (0.89-0.91 µg g⁻¹), boron (0.37-0.43 µg g⁻¹) and sulphur (15-28 µg g⁻¹). Besides, initial soil microbial properties of experimental plots results showed that *Rhizobium* ranged from (3.8x10³-4.1x10³ cfug⁻¹soil), PSB from (2.5x10⁵-3.5x10⁵ cfug⁻¹soil) and *Azotobacter* from (3.6x10⁵-4.4x10⁵ cfug⁻¹soil) in Madaripur sadar and Kalkini upazila, respectively. A description of initial nutrient status of experimental plots of Madaripur district soils prior to fertilization has been presented in Table 1.

Table 1. Initial soil physical, chemical and microbial population of experimental soil at Kalkini and sadar upazila of Madaripur during 2019-20 and 2020-21

Initial chemical status of the experimental plots											
Location	pH	OM %	Ca	Mg	K	Total N%	P	S	B	Fe	Zn
			meq 100 g ⁻¹				µg g ⁻¹				
Madaripur sadar	8.06	1.71	21.16	3.85	0.16	0.095	52	28	0.43	97.54	0.91
Kalkini upazilla	8.21	1.65	21.77	3.96	0.23	0.085	12	15	0.37	99.43	0.89
Critical level	-	-	2	0.50	0.12	-	10	10	0.20	4.0	0.60
Physical and microbial population status of experimental plots											
Location	Sand	Silt	Clay	Moisture	<i>Rhizobium</i>	PSB	<i>Azotobacter</i>				
	%				cfug ⁻¹ soil						
Madaripur sadar	7	27	66	15	4.1x10 ³	2.5x10 ⁵	3.6x10 ⁵				
Kalkini upazilla	12	29	59	15	3.8x10 ³	3.5x10 ⁵	4.4x10 ⁵				

Monthly total rainfalls, along with average temperatures during the study period are presented in Fig. 1. The highest amount of average monthly rainfall occurred in June followed by August, June and July, whereas lowest amount of rainfall occurred in January followed by December and February. Rainfall increases gradually from the month of March to June and then decreases. The monthly mean maximum air temperature was 31.77, 32.53 and 33.86 °C and minimum 20.43, 19.47 and 17.65 °C during crop season of 2019-20 and 2020-21. There was no adverse climatic effect observed during study period.

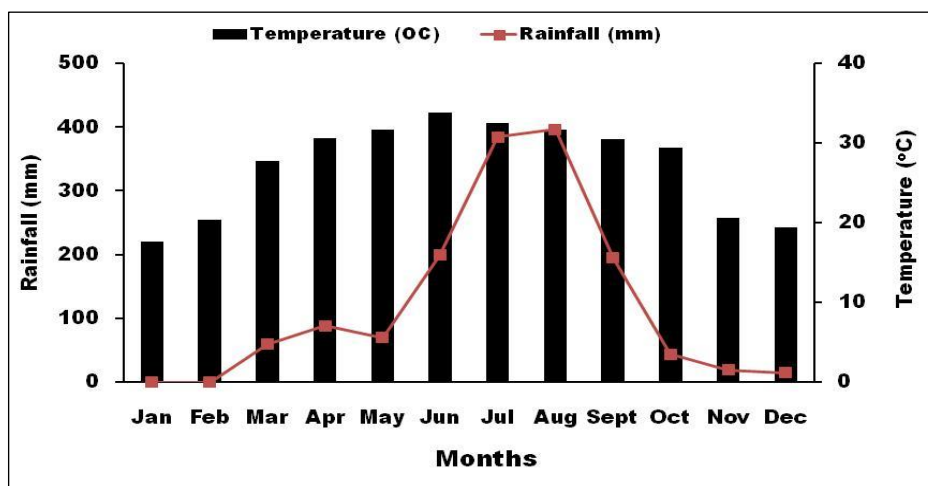


Fig. 1. Average of two years monthly total rainfall (mm) and temperature at Madaripur district during study period (2019-20 and 2020-21).

The cropping pattern of Mustard-Mungbean-T. *aman* were tested with mustard as the first crop in the pattern. After harvest of mustard, mungbean was sown in both the locations followed by T. *aman* rice. The experiment was laid out in a randomized complete block design with dispersed three replications. The study was comprised of the following crop varieties namely Mustard: BARI Sarisha-14, BARI Sarisha-17, BARI Sarisha-11; Mungbean: BARI Mung-6, BARI Mung-8, BINA Mung-8; T. *aman* rice: BRRI dhan57, BRRI dhan71 and BRRI dhan75 and three fertilizer management practices (F₁: Recommended Fertilizer Dose (RFD) from inorganic source as per soil test bases (STB); F₂: RFD on STB + 5 t ha⁻¹ cowdung, integrated plant nutrient system (IPNS) approach; F₃: Farmers' practices). Urea, TSP, MoP, gypsum, Zinc sulphate, boric acid were used as a source of N, P, K, S, Zn and B, respectively. In case of mustard, mungbean, T. *aman* all P, K, S, Zn and B were applied as basal during final land preparation. Cowdung @ 5 t ha⁻¹ was applied before ploughing and laddering as treatment only. All the intercultural operations such as irrigation, weeding, insect control etc were done as and when necessary. The total crop residues or after picking of pods the brown biomass of mungbean were incorporated into the soil before T. *aman* transplantation in both the years and experimental sites (Tables 2a and 2b).

Table. 2a. Crop managements of cropping pattern Mustard-Mungbean-T. *aman* at sadar upazilla of Madaripur during 2019-20 and 2020-21.

Parameters	Cropping pattern		
	Mustard	Mungbean	T. <i>aman</i>
Variety	BARI Sarisha-14 BARI Sarisha-17 BARI Sarisha-11	BARI Mung-6 BARI Mung-8 BINA Mung-8	BRRI dhan57 BRRI dhan71 BRRI dhan75
Date of sowing/ transplanting time	14-20 Nov. 2019 12-15 Nov. 2020	21 Mar. 2020 27 Mar. 2021	13 Aug. 2020 22 Aug. 2021
Seed rate (Kg ha ⁻¹)	6-7	15-18	50
Plot size	8m x 6m	8m x 6m	8m x 6m
Fertilizer dose	Fertilizer : 3 level F ₁ = Recommended Fertilizer Dose (RFD) from inorganic source on STB F ₂ = RFD on STB + 5 t ha ⁻¹ cowdung (IPNS approach) F ₃ = Farmers practices <u>Recommended dose</u> Mustard: N ₁₂₀ P ₄₆ K ₁₂₂ S ₂₆ Zn ₃ B ₂ kg ha ⁻¹ ; Mungbean: N ₂₄ P ₂₂ K ₂₄ S ₁₄ Zn ₂ B ₂ kg ha ⁻¹ ; T. <i>aman</i> : N ₁₂₀ P ₂₆ K ₁₀₀ S ₁₅ Zn ₂ kg ha ⁻¹		
Seedling age (Day)	-	-	25-30

Parameters	Cropping pattern		
	Mustard	Mungbean	T. <i>aman</i>
No of ploughing	3-4	2-3	3
No of irrigation	1 time at 23 DAS	1	10
No of weeding	1	2	2
No of pesticide application	IPM	IPM	IPM
Crop duration	85-88	65-68	110-115
Turnaround time	8-10	7-9	75-89
Date of Harvesting	4-10 Feb. 2020 2-8 Feb. 2020	22-28 July 2020 18-22 July 2021	26-28 Oct. 2020 22-26 July 2021

Table 2b. Crop managements of cropping pattern Mustard-Mungbean-T. *aman* at Kalkini upazilla, Madaripur during 2019-20 and 2020-21.

Parameters	Cropping pattern		
	Mustard	Mungbean	T. <i>aman</i>
Variety	BARI Sarisha-14 BARI Sarisha-17 BARI Sarisha-11	BARI Mung-6 BARI Mung-8 BINA Mung-8	BRRRI dhan57 BRRRI dhan71 BRRRI dhan75
Date of sowing/ transplanting time	18-22 Nov. 2019 16-20 Nov. 2020	28 Mar. 2020 30 Mar. 2021	17 Aug. 2020 27 Aug. 2021
Seed rate (Kg ha ⁻¹)	6-7	15-18	50
Plot size	8m x 6m	8m x 6m	8m x 6m
Fertilizer dose	<u>Fertilizer : 3 level</u> F ₁ = Recommended Fertilizer Dose (RFD) from inorganic source on STB F ₂ = RFD on STB + 5 t ha ⁻¹ cowdung (IPNS approach) F ₃ = Farmers practices <u>Recommended dose</u> Mustard: N ₁₂₀ P ₄₆ K ₁₂₂ S ₂₆ Zn ₃ B ₂ kg ha ⁻¹ ; Mungbean: N ₂₄ P ₂₂ K ₂₄ S ₁₄ Zn ₂ B ₂ kg ha ⁻¹ ; T. <i>aman</i> : N ₁₂₀ P ₂₆ K ₁₀₀ S ₁₅ Zn ₂ kg ha ⁻¹		
Seedling age (Day)	-	-	25-30
No of ploughing	3-4	2-3	3
No of irrigation	1 time at 25 DAS	2	12
No of weeding	1	2	2
No of pesticide application	IPM	IPM	IPM
Crop duration	84-86	69-72	112-117
Turnaround time	10-12	9-11	70-85
Date of Harvesting	09-14 Feb. 2020 13-18 Feb. 2020	22-28 July 2020 18-22 July 2021	16-28 Oct. 2020 22-26 July 2021

Estimation of Rice Equivalent Yield (REY)

Based on the existing market price of the individual crops, the yield of every single crop was converted into rice equivalent yield for making the relationship between crop sequences (Verma and Modgal, 1983).

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

Cost and return analysis

The economic analysis was done for gross return, gross margin and marginal benefit cost ratio (MBCR) and it was calculated on the basis of prevailing market price of the produces. Economic analysis involved collection of data on prices and quantities of inputs used and output produced. The inputs used included seed, fertilizer, labour and insecticides. The output and inputs were valued at market prices. 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) for it was computed as (CIMMYT, 1988).

$$\text{Marginal Benefit cost ratio (MBCR)} = \frac{\text{Gross return (E)} - \text{Gross return (F)}}{\text{Total variable cost (E)} - \text{Total variable cost (F) of production}} = \frac{\text{MVP}}{\text{MVC}}$$

Statistical analysis

Grain yield and straw yields were taken from whole plot. Rice equivalent yield and economics of different cropping systems were estimated to judge their performance. Mustard, mungbean and T. *aman* rice and total rice equivalent data were analyzed statistically and all the collected data related to cropping pattern were subjected to analysis using R software.

Results and Discussions

Mustard

The data regarding yield and yield contributing characters of different mustard varieties as influenced by the different nutrient management are presented in Table 3 and Table 4. Plant height, siliqua plant⁻¹, seeds siliqua⁻¹, 1000-seed weight, seed yield, straw yield and field duration of mustard at Madaripur sadar and Kalkini upazilla were differed significantly among the varieties (BARI Sarisha-14, BARI Sarisha-17 and BARI Sarisha-11). It was observed that IPNS based fertilized plots gave higher yield over farmers practices and RFD from inorganic source. Mustard var. BARI Sarisha-14 (1.74 to 1.78 tha⁻¹) yielded higher than BARI Sarisha-17 (1.46 to 1.59 tha⁻¹) and BARI Sarisha-11 (1.53 to 1.77 tha⁻¹) in both locations. About 21.92 and 16.33% higher yield was obtained in mustard than farmers practices. Similar trend of increased yield in mustard due to added fertilizers in

three or four crops pattern was also reported by Barman *et al.* (2021) and Saha *et al.* (2016). Dobermann *et al.* (2013) and Anowar *et al.* (2012) also reported that site-specific plant nutrient management (IPNS or STB) could increase yield as well as nutrient use efficiency of cropping patterns.

Table. 3. Performance of mustard varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21.

Treatment combination		Madaripur sadar upazila, Madaripur						
Variety	Fertilizer dose	Days to maturity	Plant height (cm)	Siliqua plant ⁻¹ (no)	Seed Siliqua ⁻¹ (no)	1000 seed wt. (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
BARI Sarisha- 17	F ₁	85b	86.67c-e	83.67a	22.67a-c	3.64ab	1.53c	2.11b
	F ₂	87b	84.67de	84.33a	25.02a	3.67a	1.62b	2.29a
	F ₃	85b	80.00e	75.67b	21.03cd	3.24cd	1.46d	1.95c
BARI Sarisha- 14	F ₁	87b	95.01bc	84.67a	25.01a	3.43a-c	1.64b	2.21ab
	F ₂	87b	95.02b-d	84.02a	24.67ab	3.56a-c	1.74a	2.31a
	F ₃	86b	89.67cd	73.33b	24.33ab	3.25cd	1.51cd	1.92c
BARI Sarisha- 11	F ₁	105a	107.00a	64.33c	21.67bc	3.32b-d	1.71a	2.23ab
	F ₂	106a	108.01a	66.67c	22.33a-c	3.46a-c	1.73a	2.30a
	F ₃	105a	102.03ab	59.67d	18.33d	3.01d	1.62b	2.08bc
CV (%)		5.96	7.74	4.08	7.64	5.71	2.89	2.06

*Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹cowdung (IPNS approach); F₃ = Farmers' practices.

Mungbean

The yield and yield contributing characters of mungbean varieties are presented in Table 5 and 6. Most of the yield contributing character, straw and seed yield of mungbean was influenced by the different fertilizer managements. The highest number of pods plant⁻¹ (32.01 to 36.67), seed pod⁻¹ (10.67 to 11.33) and seed yield (1.76 to 1.79 t ha⁻¹) in BARI Mung-6 was recorded from IPNS based fertilized plots in both years and locations. The lowest number of pods plant⁻¹ (21.00 to 27.00), seed pod⁻¹ (8.0 to 10.01) and seed yield (1.19 to 1.51 t ha⁻¹) in BARI Mung-8 and BINA Mung 8 were recorded from farmers' practices. Similarly, the highest biomass (4.09-4.91 t ha⁻¹) yield was recorded in IPNS based fertilized plots and lowest (2.89 to 3.07 t ha⁻¹) in BARI Mung-8 and BINA Mung 8 from farmers' practices, respectively. It was also observed that IPNS based fertilized plots yielded higher than farmer's practices and RFD. Similar results were obtained by Mondal *et al.* (2015), Nazrul *et al.* (2017), Khan *et al.* (2018). After picking of pods the brown biomass of mungbean was incorporated into the soil before *T. aman* transplantation in both the years and experimental sites.

Table 4. Performance of mustard varieties under integrated nutrient management system at Kalkini upazila, Madaripur during 2019-20 and 2020-21.

Treatment combination		Kalkini upazila, Madaripur						
Variety	Fertilizer dose	Days to maturity	Plant height (cm)	Siliqua plant ⁻¹ (no)	Seed Siliqua ⁻¹ (no)	1000 seed wt. (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
BARI Sarisha-17	F1	86.01b	83.33ef	72.01ef	27.33a	3.95ab	1.59c	1.99bc
	F2	87.67b	86.33de	77.67cd	29.33a	4.18a	1.67bc	2.19ab
	F3	84.33b	81.01f	68.33f	20.01bc	3.76ab	1.46d	1.75d
BARI Sarisha-14	F1	87.67b	87.67cd	78.67b-d	29.67a	3.70ab	1.57c	2.01bc
	F2	88.33b	91.02c	85.33a	28.02a	3.94ab	1.78a	2.24a
	F3	84.67b	85.67de	70.67f	21.67b	3.49ab	1.47d	1.82cd
BARI Sarisha-11	F1	106.01a	110.02a	81.01a-c	20.33bc	3.87ab	1.73b	2.20ab
	F2	105.67a	111.67a	83.33ab	19.03c	3.20b	1.77a	2.23a
	F3	105.01a	99.67b	76.02de	18.02c	3.37b	1.53cd	1.88c
CV (%)		5.41	8.62	5.71	5.79	12.23	3.96	2.21

* Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach); F₃ = Farmers' practices.

Table 5. Performance of mungbean varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21.

Treatment combination		Madaripur sadar upazila, Madaripur				
Variety	Fertilizer dose	Pod plant ⁻¹	Seed pod ⁻¹	100 seed wt. (g)	Stover yield (t ha ⁻¹)	Seed yield (t ha ⁻¹)
BARI Mung- 8	F ₁	27.01cd	12.02ab	3.36b	3.64bc	1.63c
	F ₂	29.33b	13.33abc	3.78ab	3.89ab	1.69bc
	F ₃	23.67e	10abc	3.07b	2.89e	1.39d
BARI Mung- 6	F ₁	29.67b	9.67bc	3.66ab	3.66bc	1.77ab
	F ₂	32.01a	10.67abc	3.94ab	4.09a	1.79a
	F ₃	26.33cd	9.01bc	3.08b	3.13de	1.31d
BINA Mung- 8	F ₁	26.01d	11.67ab	4.18ab	3.40cd	1.59c
	F ₂	28.01bc	12.01ab	3.91ab	4.08a	1.61c
	F ₃	21.00f	8.01c	5.78a	3.07de	1.19e
CV (%)		3.83	19.41	12.37	6.41	3.79

*Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach); F₃ = Farmers' practices.

Table 6. Performance of mungbean varieties under integrated nutrient management system at Kalkini upazila during 2019-20 and 2020-21.

Treatment combination		Kalkini upazila, Madaripur				
Variety	Fertilizer dose	Pod plant ⁻¹	Seed pod ⁻¹	100 seed wt. (g)	Stover yield (t ha ⁻¹)	Seed yield (t ha ⁻¹)
BARI Mung- 8	F ₁	33abc	10.67b-d	3.13cd	3.78c	1.71a-c
	F ₂	35.33ab	12.67a	3.50ab	4.57b	1.72ab
	F ₃	27bcd	8.33e	2.31f	3.26d	1.51de
BARI Mung- 6	F ₁	32.33a-c	11.33a-c	3.21b-d	3.40d	1.67a-c
	F ₂	36.67a	11.33abc	3.58a	4.91a	1.76a
	F ₃	25.33cd	10.01c-e	2.99de	3.06d	1.56cd
BINA Mung -8	F ₁	26.33cd	10.67b-d	3.17cd	3.74c	1.59b-d
	F ₂	28b-d	12.01ab	3.41a-c	4.94a	1.60b-d
	F ₃	22.67d	9.33de	2.77e	3.27d	1.40e
CV (%)		16.54	10.54	5.79	3.98	5.49

*Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach); F₃ = Farmers' practices.

T. aman

The third component of the cropping pattern was *T. aman* rice. Yield and yield contributing characters of different *T. aman* rice varieties as influenced by the different fertilizer rate has been presented in Table 7 and 8. Plant height, panicle m⁻², no. of grains panicle⁻¹, 1000-grain wt., straw yield and grain yield of *T. aman* at Madaripur sadar and Kalkini upazilla has been differed significantly among the varieties (BRRI dhan57, BRRI dhan71 and BRRI dhan75). Rice var. BRRI dhan71 (5.48 to 5.61 tha⁻¹) yielded higher than BRRI dhan57 (4.64 to 4.77 tha⁻¹) and BRRI dhan75 (5.41 to 5.44 tha⁻¹) in both locations. It was observed that IPNS based fertilized plots produce higher yield than farmers' practices and RFD (from inorganic source as per STB fertilizer treated plots). In the two consecutive years, about 20.21% and 17.61% more yield was obtained than farmers practices. Anowar *et al.* (2012) reported that the maximum grain yield was observed from IPNS based fertilized plots than farmer's practices. Similar results were also obtained by Mondal *et al.* (2015), Barman *et al.* (2019). Ali *et al.* (2009) showed that maximum grain yield from soil test value for high yield goal while Saha *et al.* (2016) reported higher yield from 20% higher yield from the STB dose in potato-maize-*T. aman* cropping pattern of AEZ-3.

Table 7. Performance of *T. aman* varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21

Treatment combination		Madaripur sadar upazila, Madaripur					
Variety	Fertilizer dose	Plant height (cm)	Panicle m ⁻²	Grain panicle ⁻¹ (no)	1000 grain wt. (g)	Straw yield (t ha ⁻¹)	Grain yield (tha ⁻¹)
BRRIdhan 57	F ₁	113de	461cde	164b	20.33d	4.24c	4.63abc
	F ₂	121cd	482bc	184a	25.00b	4.51c	4.77abc
	F ₃	105e	439e	150cd	18.33e	3.75c	3.96c
BRRIdhan 71	F ₁	132ab	502ab	179a	22.67c	5.84ab	5.51ab
	F ₂	138a	518a	188a	28.33a	6.44a	5.61a
	F ₃	120cd	472cd	153bc	20.67d	4.86bc	4.61abc
BRRIdhan 75	F ₁	137a	484bc	164b	23.00c	6.17b	4.94abc
	F ₂	140a	504ab	177a	27.33a	6.18a	5.41ab
	F ₃	125bc	455de	140d	21.67cd	4.82bc	4.50bc
CV (%)		4.71	3.14	4.11	4.65	12.44	11.91

*Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹cowdung (IPNS approach); F₃ = Farmers' practices.

Table 8. Performance of *T. aman* varieties under integrated nutrient management system at Kalkini upazila during 2019-20 and 2020-21

Treatment combination		Kalkini upazila, Madaripur					
Variety	Fertilizer dose	Plant height (cm)	Panicle m ⁻²	Grain panicle ⁻¹ (no)	1000 grain wt. (g)	Straw yield (t ha ⁻¹)	Grain yield (tha ⁻¹)
BRRIdhan 57	F ₁	119de	300b-d	23.23b	25b	6.25ab	4.38cd
	F ₂	125cd	311a-c	29.6a	28a	6.71a	4.64cd
	F ₃	108f	288d	21.5c	21d	5.73b	3.09d
BRRIdhan 71	F ₁	128bc	319ab	19.67d	21cd	6.06ab	5.41ab
	F ₂	134ab	322a	20.7cd	24bc	6.35ab	5.48a
	F ₃	113ef	301bcd	17.33e	16e	6.04ab	4.26ab
BRRIdhan 75	F ₁	130abc	314abc	21.7bc	22cd	5.85b	5.33ab
	F ₂	138a	323a	29.07a	29a	5.98ab	5.44ab
	F ₃	114.01f	296cd	20.7cd	19de	4.67c	4.87bc
CV (%)		3.76	3.63	3.80	8.05	7.98	7.01

*Figures in column followed by different letters differ significantly at 5% level of significance. F₁ = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂ = RFD on STB + 5 t ha⁻¹cowdung (IPNS approach); F₃ = Farmers' practices.

Bi-product yield of the cropping pattern

The Mustard-Mungbean-T. *aman* cropping pattern, highest biomass 3.06 to 4.91 tha^{-1} yield of mungbean and 1.99 to 2.24 tha^{-1} yield of mustard were recorded in IPNS and RFD based fertilized plots and lowest 2.89 to 3.27 tha^{-1} in mungbean and 1.99 to 1.75 tha^{-1} in mustard from farmers' practices, respectively. It was also observed that IPNS and RFD based fertilized plots bi-product yielded higher than farmer's practices in both the years and experimental sites. After picking of pods the brown biomass of mungbean was incorporated into the soil before T. *aman* transplantation. Mustard is providing special advantage regarding utilization of mustard straw as fuel instead of cowdung.

Table 9. Rice equivalent yield (REY) and total rice (system) yield of Mustard-Mungbean -T. *aman* cropping pattern at Kalkini upazila and sadar upazila Madaripur.

Treatment combination	Sadar upazila Madaripur				Kalkini upazila				Average REY $\text{tha}^{-1}\text{yr}^{-1}$
	T. <i>aman</i> yield (tha^{-1})	Rice equivalent yield (REY)		Total REY $\text{tha}^{-1}\text{yr}^{-1}$	T. <i>aman</i> yield (tha^{-1})	Rice equivalent yield (REY)		Total REY $\text{tha}^{-1}\text{yr}^{-1}$	
		Mustard	Mung			Mustard	Mung		
V ₁ F ₁	4.63	3.83	5.91	14.36	4.38	4.31	6.06	14.74	14.55
V ₁ F ₂	4.77	4.05	6.34	15.16	4.64	4.52	6.09	15.25	15.21
V ₁ F ₃	3.96	3.65	4.64	12.25	3.09	3.95	5.35	12.39	12.32
V ₂ F ₁	5.51	3.98	5.78	15.26	5.41	4.25	5.91	15.58	15.42
V ₂ F ₂	5.61	4.31	5.99	15.90	5.48	4.63	6.23	16.34	16.12
V ₂ F ₃	4.61	3.78	4.93	13.31	4.26	3.95	5.53	13.74	13.55
V ₃ F ₁	4.94	4.33	5.64	14.91	5.33	4.96	5.63	15.92	15.45
V ₃ F ₂	5.41	4.43	5.71	15.54	5.44	5.36	5.67	16.47	16.05
V ₃ F ₃	4.50	3.98	4.22	12.69	4.87	4.14	4.96	13.97	13.33

V₁: BARI Sarisha-17, BARI Mung-8, BRRI dhan57; V₂: BARI Sarisha-14, BARI Mung-6, BRRI dhan71; V₃: BARI Sarisha-11, BINA Mung-8, BRRI dhan75; F₁: Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂: RFD on STB + 5 t ha^{-1} cowdung (IPNS approach); F₃: Farmers' practices

Total rice (system) yield

Productivity of different crops on the rice based cropping system was determined by Rice Equivalent Yield (REY) which was calculated from yield of component crops. Average yield of component crops and REY of mustard and mungbean were shown in Table 9. Average yield of two years and locations, it was observed that the highest REY (16.12 t $\text{ha}^{-1}\text{yr}^{-1}$) was recorded from treatment combination of V2F2 (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha^{-1} cowdung (IPNS approach) and lowest REY (12.32 t $\text{ha}^{-1}\text{yr}^{-1}$) was recorded from treatment combination of V1F3 (BARI Sarisha-17 + BARI Mung-8 + BRRI

dhan57 with Farmers practices). Higher rice equivalent yield indicates higher productivity of the pattern. This finding was supported by Nazrul *et al.* (2017) and Khan *et al.* (2018). Barman *et al.* (2020) also documented higher rice equivalent yield of mustard from 25% NPK+ 100% STB dose. Mondal *et al.* (2015) also claimed of having 49 to 67% higher productivity from the intensified land use system under four cropped based cropping pattern. Inclusion of mustard in rice based cropping pattern increase REY about 45.3-51.6% (Hossain *et al.*, 2014).

Cost and return analysis

Cost and return analysis was done on the basis of prevailing market price of the commodities. Economics analysis of the cropping pattern Mustard-Mungbean-T. *aman* was shown in Table 10. It was observed that highest gross return (3,86,880 Tk ha⁻¹yr⁻¹), total variable cost (1,36,621 Tk ha⁻¹yr⁻¹), and gross margin (2,50,259 Tk ha⁻¹yr⁻¹) were obtained from treatment combination V₂F₂ (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach) and the lowest gross return (2,95,680 Tk ha⁻¹yr⁻¹), total variable cost (1,46,308 Tk ha⁻¹yr⁻¹), and gross margin (2,29,732 Tk ha⁻¹yr⁻¹) were obtained from treatment combination of V₁F₃ (BARI Sarisha-17 + BARI Mung-8 + BRRI dhan57 with Farmers practices). The maximum marginal benefit cost ratio (2.83) was also gained from treatment combination V₂F₂ (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach). These findings are supported by Sarker *et al.* (2014) who reported that Wheat-Mungbean-T. *aman* rice produced the higher economic benefit in terms of BCR. Marginal benefit cost ratio (MBCR) was found 2.83 which further indicated the superiority of the improved practice over farmers' one. Thus, inclusion of mungbean in the existing pattern might be agronomically viable and economically profitable for the farmers' in the study sites.

Table 10. Cost-benefit analysis of the cropping pattern Mustard-Mungbean T. *aman* at Madaripur during 2019-20 and 2020-21

Treatment combination	Gross return	Total variable cost	Gross margin	MBCR
	(Tk ha ⁻¹ yr ⁻¹)			
V ₁ F ₁	349200	136308	212892	2.56
V ₁ F ₂	365040	135308	229732	2.71
V ₁ F ₃	295680	146308	149372	2.02
V ₂ F ₁	370080	134560	235520	2.75
V ₂ F ₂	386880	136621	250259	2.83
V ₂ F ₃	325200	149360	175840	2.18
V ₃ F ₁	370800	143364	227436	2.59
V ₃ F ₂	385200	147862	237338	2.61
V ₃ F ₃	319920	133324	186596	2.41

Note: Price: Mustard = 70 Tk kg⁻¹, Mungbean = 90 Tk kg⁻¹, Rice = 30 Tk kg⁻¹, Urea = 16 Tk kg⁻¹, TSP = 25 Tk kg⁻¹, MoP = 15 Tk kg⁻¹, Gypsum = 12 Tk kg⁻¹, Zinc sulphate = 200

Tk kg⁻¹, Boric acid: 220 Tk kg⁻¹, Labour = Tk. 500 day⁻¹, Land preparation for all crops 3 times ploughing and laddering = Tk 1000 bigha⁻¹, Irrigation for T. *aman* = Tk. 800 bigha⁻¹; V₁: BARI Sarisha-17, BARI Mung-8, BRRRI dhan57; V₂: BARI Sarisha-14, BARI Mung-6, BRRRI dhan71; V₃: BARI Sarisha-11, BINA Mung-8, BRRRI dhan75; F₁: Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F₂: RFD on STB + 5 t ha⁻¹ cowdung (IPNS approach); F₃: Farmers' practices

Soil fertility status

Nutrient uptake by grain and straw of all crops of the cropping pattern were influenced by different fertilizer treatments. The status of soil pH, organic matter content, total N, available P, K, S, Zn and B in initial soil as well as after completion of two cropping cycle of Mustard-Mungbean-T. *aman* rice cropping pattern is shown in Table 11. Soil chemical and microbial status analysis of cropping pattern revealed that organic matter content of the soil increased due to biomass addition of the crops. Somewhere it was changed positively. As potassium showed negative balance, more potassium is to be added to improve soil fertility status. However, K in the improve pattern tended to be lower than the farmers one, which indicated to add more K in soil to improve K content. Rao and Bhardwaj (1980) conclusively proved that pulses receiving optimum fertilizer, especially P, had more pronounced residual effect both in terms of N and P on the succeeding cereals. Organic matter added to soil through incorporation of non-economic plant parts helped to maintain the quality of soil. These results are supported by Mondal *et al.* (2015) and Khan *et al.* (2018) who found that inclusion of mungbean in the existing farmer's cropping pattern improve the soil fertility status.

Table. 11. Physical, chemical and microbial status of post soil in experimental plots of Kalkini and sadar upazilla Madaripur during 2019-20 and 2020-21.

Chemical data of the experimental plots (post soil in Madaripur sadar upazilla)											
Location	pH	OM %	Ca	Mg	K	Total N%	P	S	B	Fe	Zn
			meq 100 g ⁻¹								
Madaripur sadar	8.08	1.89	22.32	4.06	0.13	0.109	78	21	0.41	8.69	0.93
Kalkini upazilla	8.11	1.77	23.77	3.89	0.18	0.088	10	11	0.37	8.55	0.88
Critical level	-	-	2	0.50	0.12	-	10	10	0.20	4.0	0.60
<i>Physical and microbial status of experimental plots</i>											
Location	Sand	Silt	Clay %	Moisture	<i>Rhizobium</i>	PSB cfug ⁻¹ soil	<i>Azotobacter</i>				
Madaripur sadar	7	28	65	16	5.1x10 ³	3.5x10 ⁵	4.6x10 ⁵				
Kalkini upazilla	11	31	60	16	5x10 ³	3.5x10 ⁵	4.6x10 ⁵				

Conclusions

It could be concluded that crop diversification in the existing T. *aman*-Fallow-Boro cropping cycle of Low Ganges River Floodplain of Bangladesh with the introduction of the high yielding and short duration mustard, mungbean and T. *aman* rice, improved cropping pattern Mustard (var. BARI Sarisha-14/BARI Sarisha-17)-Mungbean (var. BARI Mung-6)-T. *aman* (var. BRRI dhan71/BRRI dhan75) could be found economically profitable and biologically suitable. Similarly, IPNS based fertilizer management approach in this cropping pattern was found better perform compared to farmers' practices or other fertilizer management approaches. The farm level adoptions of improved oilseeds, pulses in rice based cropping system have already been created a wide range of socio-economic impacts that need to be evaluated properly to understand the output of research and development.

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