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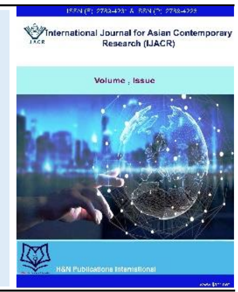

Effect of Integrated Nutrient Management on Maintaining Soil Fertility and Productivity Under Intensive Cropping Systems

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Abstract

The study was conducted at the Multi Location Testing (MLT) site of Bangladesh Agricultural Research Institute (BARI), Gabtoli, Bogura, Bangladesh during 2016-17 and 2017-18 to develop an improved soil fertility management package for Mustard-Boro-T.aus-T.aman cropping pattern. This study consisted of two fertilizer management packages i.e., Soil test-based IPNS fertilizer dose and Farmers' Practice. Standard crop production technology packages used in the study plot and farmers' traditional practices were followed by farmers' practices. Yield contributing characters and yield were found better in soil test-based IPNS fertilizer plot (Trial plot) against farmers practiced plots. Rice Equivalent Yield of the trial plot was (17.00 tha^{-1} against 11.45 tha^{-1} in farmers practice and 16.49 tha^{-1} against 10.18 tha^{-1} in farmers practice, respectively) higher in both years. This study shows the beneficial effect of soil test-based fertilizer dose on the succeeding crop and improves soil fertility levels.

Keywords: INM, IPNS, soil fertility, cropping systems, productivity.

Introduction

The long-term effect of continuous integrated nutrient management is that the use of readily available options which including green manuring, crop residue addition, and organic manure in combination with chemical fertilizers in a balanced form is effective at increasing the active carbon fractions in soil, which is critical for soil quality enhancement. Integrated nutrient management practices involving the addition of organics in balance with chemical fertilizers have demonstrated the potential for carbon sequestration, reversing the loss of SOC that occurs frequently under intensive cultivation and restoring SOC to new equilibrium. These practices can be considered best management practices for increasing carbon sequestration in rain fed soils, thereby improving soil quality and potentially mitigating some of the current effects of atmospheric carbon dioxide increase (Kharche *et al.,* 2013). INM practice encompasses identifying all available sources of plant nutrients in order to optimize nutrient inputs, spatial and temporal matching of soil nutrient supply and crop demand, and minimizing nitrogen loss while increasing crop yield. The interaction of agricultural inputs increases crop productivity while significantly reducing nitrogen loss and greenhouse gas emissions, judicious application of mineral and organic fertilizers with increased resource efficiency, and increased soil- plant-microbe- environmental sustaina - bility. A balanced use of organic manures is critical for crop productivity and environmental concerns, which should prioritize INM practices. This provides a “win–win” opportunity to increase crop productivity while also increasing agricultural sustainability (Jat *et al.,* 2015).

A gradual decline or stagnation in the yield of major crops was already observed almost throughout Bangladesh. This is primarily due to the soil's degraded fertility status. Low organic matter content, increased cropping intensity, improper cropping sequence, and poor management practices all contribute to soil fertility depletion. The widespread use of high yielding crop varieties has resulted in a dramatic increase in the removal of plant nutrients. Imbalanced fertilizer use is a significant issue for the country.

Additionally, the majority of area farmers did not use any organic fertilizers. Farmers typically apply fertilizer to individual crops without regard for the overall cropping pattern. However, some nutrients have a significant residual effect on the succeeding crop. Four crop-based cropping patterns have been developed recently in various parts of the country in response to food security concerns. As a result, it is critical to develop fertilizer recommendations for four crops based on cropping patterns under a variety of agro-ecological conditions in order to ensure sustainable crop production. To develop a cropping pattern-based fertilizer recommendation, nutrients present in soil, added as inorganic and organic sources, and nutrients harvested by crops should be considered. Therefore, it is critical to develop a cropping pattern (three or four crops)-based fertilizer recommendation system that takes into account the aforementioned issues when applying fertilizer to different agro-ecological conditions. Considering these facts, the present study was conducted to develop an optimized soil fertility management package for the Mustard-Boro-T.aus-T.aman cropping pattern, which will help to enhance crop yield and scheme productivity in a system of intensive crop production.

Materials and methods

The study was conducted in the farmers' field of the Multilocation testing site, Gabtoli, Bogura. Bangladesh (Figure 1). Four distinct farmer groups were formed in the vicinity to conduct the trials. Each group consists of eight to ten farmers and each farmer has committed at least one bigha of land to the trial. Mustard-Boro-T.aus-T.aman was the proposed cropping pattern. At each location, a similar set of data would be gathered from 5-10 randomly selected farmers who were not involved in the project. Two fertilizer management packages were used in the experiment: soil test-based (STB) IPNS

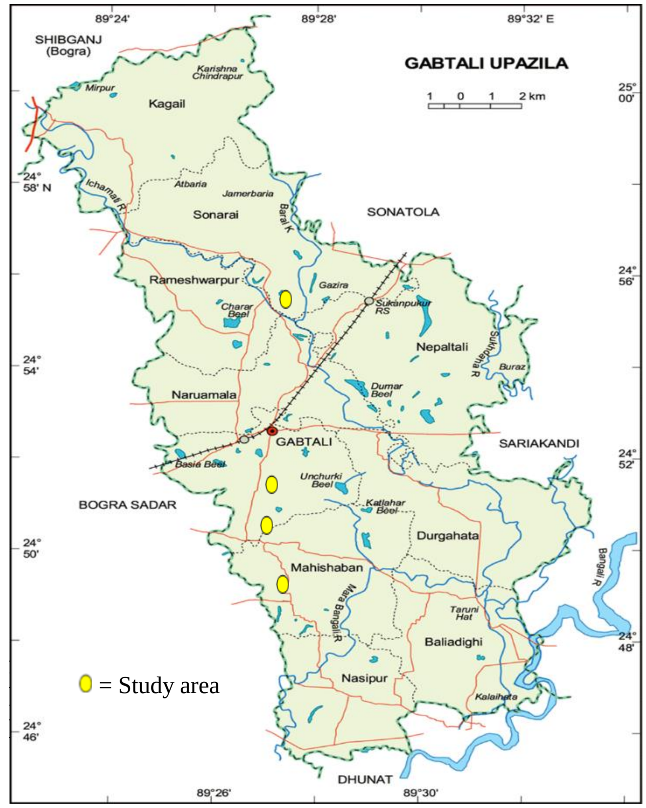

Figure 1. Study area of Gabtoli Upazilz (Doarpara, Tarafsartaz, Darial and Dhora).

identify major cropping patterns and suitable crop varieties (short duration HYV) to accommodate four crops in each location's existing pattern. Soil samples were collected from the selected farmer's field and then analyzed chemically at the SRDI laboratory in Bogura. The pH of the soil was determined using a digital pH meter at a soil-to-water ratio of 1:2.5. (Page et al., 1982). The organic matter concentration was determined using the wet oxidation method (Page et al., 1982). The total nitrogen concentration was determined using the Kjeldahl micro technique (Page et al., 1982). The method of 1N NH4OAc was used to determine the exchangeable K. (Jackson, 1973). The amount of available P was determined using the Olsen method (Olsen et al., 1954). The amount of available S was determined using the turbidity method with BaCl2 (Page et al., 1982). Obtainable The DTPA method was used to determine Zn (Lindsay and Norvell, 1978). Boron was quantified using the turbidity method (Jackson, 1973). Table 9 summarizes the chemical properties of the soil. After obtaining the soil analysis value, fertilizer doses for each group were estimated using the soil analysis value. The approximate amount of fertilizer dose in mustard was62-25.8-50.7-11.3-1.6-0.64 (Dhora), 65-23.2-48.5-16.5-2.4-0.97 (Tarof Sartaz), 65-21.2-50.7-14.52-1.9-0 (Darail) and 65-11.0-52.9-16.8-0-0.57 (Doar Para) kg ha^{-}

[1]NPKSZnB along with 5 t/ha cowdung, in boro130.5-25.9-93-11.3-1.6 (Dhora), 135-23.8-90-16.3-2.4 (Tarof Sartaz), 135-22.3-93.34-11.4-1.91 (Darail) and 135-14.4-96.67-16.77-0 (Doar Para) kg ha^{-1}NPKSZn in trial plots, respectively.The estimated fertilizer dose in T.aus was 49.3-14.78-34.22-6.79-0.96-0 (Dhora), 51.0-13.62-33.0-9.92-1.44-0 (Tarof Sartaz), 51.0-12.74-34.22-8.71-1.15-0 (Darail) and 51.0-8.23-35.44-10.06-0-0 $Kgha^{-1}$ of NPKSZnB (Doarpara).The estimated fertilizer dose in T.aman was 87.0-18.48-62.22-9.05-1.12-0 (Dhora), 90.0-17.02-60.0-13.23-1.68-0 (TarofSartaz), 90.0-15.92-62.22-7.61-1.34-0 (Darail), 90.0-10.29-64.44-13.42-0-0 $Kgha^{-1}$ of NPKSZnB(Doarpara). Fertilizer dose in farmers' plot was 85.3-15-37-13.3NPKSZn kg ha^{-1} in mustard and 104-18-37.5-13.5 NPKSkg ha^{-1} in boro.

In Mustard, BARI Sarisha-14 in the recommended plot against Tori-7 in farmers' plot. The seeds were sown on 15-20 November, 2016 and 06-15 November, 2017. All other fertilizers and half of the nitrogen were applied during final land preparation. The remainder of the N fertilizer was applied as a top dress 25 days after sowing. Irrigation began 25 days after top dress sowing. Karate (Lambda-Cyhalothrin) 250EC @ 1ml/l of water was sprayed in trial plots at 3, 45, and 60 days after germination (DAG) to control flea beetle and aphid, and Rovral @2g/l at 40 DAG to control alternaria and scrutenia blight. Crops were harvested between 1 and 16 February 2017 and 22 to 30 January 2018. At harvest, ten randomly chosen mustard plants from each plot were carefully uprooted to determine the plant height, the number of siliqua per plant, and the seed yield per siliqua.

Boro used BRRI dhan 28 in both plots. On 30 January-05 February 2017 and 01--05 February 2018, 30-35 day-old seedlings were transplanted into the plots at a 20 cm x 20 cm spacing. The full amount of TSP, 2/3 of MoP, and Gypsum were broadcast and incorporated into the soil during final land preparation. The remaining 1/3 of MoP was applied 5-7 days before panicle initiation. Urea was applied in three equal doses: 10 days after transplantation, during rapid tillering, and 5-7 days before panicle initiation. Folicur @ 0.5 ml/L was sprayed to control sheath blight, and Virtako 40 WG was sprayed to control sheath blight. 1.5g/10 L of water was sprayed on both plots at 40 DAT (days after transplantation) to control stem borer. Crops were harvested between 30 April and 5 May 2017 and between 11-16 May 2018.

BRRI dhan 48 was used in the trial plot in T.aus. On 10-20 May 2017 and 16-20 May 2018, 20-day-old seedlings were transplanted into the plots. The full concentration of PKSZn was used as a basal. At 18 and 45 days after transplantation, nitrogen was top-dressed in two equal splits (DAT). Folicur @ 0.5 ml/L was sprayed to control sheath blight, and Virtako 40 WG was sprayed to control sheath blight. 1.5g/10 L of water was sprayed on both plots at 40 DAT (days after transplantation) to control stem borer. Crops were harvested between 1 and 8 August 2017 and 6 and 9 August 2018.

In T.aman, the Trial plot was planted with BRRI dhan 62 and BINA dhan 7, while the Farmers plot was planted with BRRI dhan 49 and Mamun. A seedling of BRRI dhan 62/BINA dhan 7 25 days old was transplanted. Seedlings were transplanted into trial plots. On 10-17 August 2017 and 11-17 August 2018. On 02-04 August 2017 and 16-20 July 2018, seedlings were transplanted into a farmers' plot. As a basal dose, the entire amount of PKSZn was applied. At 17, 30, and 46 days after transplantation, nitrogen was top dressed in three equal splits (DAT). Folicur @ 0.5 ml/L was sprayed to control sheath blight, and Virtako 40 WG was sprayed to control sheath blight. 1.5g/10 L of water was sprayed on both plots at 40 DAT (days after transplantation) to control stem borer. The crop was harvested in the trial plot between 01-03 November 2017 and 01-03 November 2018. The farmers plot was harvested during the weeks of 10-12 November 2017 and 03-04 November 2018.

The yield and yield-contributing characteristics of the crops were meticulously recorded. We recorded the yield per plot and converted it to yield per hectare. The gross economic return was calculated using the commodities' current market prices.

Results and Discussion

In mustard (2016-17), Table 1 summarizes the yield and the characteristics that contribute to the yield. Maximum plant heights (89.0 cm) and no of seeds per siliqua (23.75) were obtained from the trial plot against farmers practice. The highest seed yield (1.35 tha^{-1}) was also obtained from trial plot due to maximum weight of seeds per plant which was 16.30% higher compared to farmer's plot. In mustard (2017-18), Table 2 shows the yield and the characteristics that add to the yield. Maximum plant heights (84.39 cm) and no of seeds per siliqua (23.47) were obtained from the trial plot against farmers practice. The highest seed yield (1.34 tha^{-1}) was also obtained from trial plot due to maximum weight of seeds per plant which was 20.72% higher compared to farmer's plot.

Table 3 summarizes the growth and yield contributing characters in boro (2016-17). The maximum plant height (101.30 cm), the number of tillers per hill (18.50), the number of grains per panicle (92.10), and the weight of 1000 seeds (20.40) were obtained from the trial plot, which was greater than farmers practice.

Table 1. Yield and yield contributing characters of mustard were evaluated using different management practices in Gabtoli, Bogura during 2016-17

Treatment	Plant height (cm)	Siliqua plant-^{1} (no)	Seed siliqua-^{1}(no)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Yield increased over FP (%)
IPNS fertilizer plot (BARI Sarisha-14)	89.00	60.00	23.75	3.28	1.35	3.17	16.30
Farmer's practice (BARI Sarisha-14)	87.21	58.62	21.27	3.19	1.13	2.97	
Level of Significance	*	*	*	NS	**	*	

** = Significance at 1% level

Table 2. Yield and yield contributing characters of mustard were evaluated using different management practices in Gabtoli, Bogura during 2017-18

Treatment	Plant height (cm)	Siliqua plant^{-1} (no)	Seed siliqua^{-1}(no)	1000 seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Yield increased over FP (%)
IPNS fertilizer plot (BARI Sarisha-14)	84.39	75.26	23.47	3.32	1.34	3.19	20.72
Farmer's practice (BARI Sarisha-14)	83.26	72.67	21.38	3.21	1.11	2.93	
Level of Significance	**	**	**	*	*	**	

** = Significance at 1% level

Table 3. Boro rice yield and yield-contributing characters under various management practices in Gabtoli, Bogura during 2016-17

Treatment	Plant height (cm)	Tiller hill^{-1} (no)	Grain panicle^{-1} (no)	1000 grain wt (g)	Yield (tha^{-1})	Straw yield (tha^{-1})	Yield increased over FP (%)
IPNS fertilizer plot	101.30	18.50	92.10	20.40	5.45	6.15	
Farmer's practice	98.21	15.82	82.93	19.69	4.62	5.13	17.96
Level of Significance	NS	*	*	NS	**	*	

** = Significance at 1% level

Table 4. Boro rice yield and yield-contributing characters under various management practices in Gabtoli, Bogura, during 2017-18

Treatment	Plant height (cm)	Tiller hill^{-1} (no)	Grain panicle^{-1} (no)	1000 grain wt (g)	Yield (tha^{-1})	Straw yield (tha^{-1})	Yield increased over FP (%)
IPNS fertilizer plot	101.13	18.48	91.60	20.18	5.37	6.04	
Farmer's practice	100.03	16.20	86.45	19.70	4.65	5.02	15.48
Level of Significance	NS	**	**	*	**	**	

** = Significance at 1% level

Additionally, the highest grain yield (5.45 tha^{-1}) was obtained from the trial plot, which was 17.96 percent greater than the farmer's plot. Table 4 shows the yield related contributing characters in boro rice (2017-18).

The maximum plant height (101.13 cm), the number of tillers per hill (18.48), the number of grains per panicle (91.60), and the weight of 1000 seeds (20.18) were obtained from the trial plot in comparison to farmers'

Table 5. Yield and yield contributing characters of mustard were determined using various management practices in Gabtoli, Bogra during 2016-17

Treatment	Plant Height (cm)	Tiller hill^{-1} (no)	Grain panicle^{-1} (no)	1000 grain wt (g)	Yield (tha^{-1})	Straw yield (tha^{-1})	Yield increased over FP (%)
Trial plot	100.25	16.25	83.25	18.05	3.45	4.57	15.65
Farmers' plot	99.31	15.16	81.11	17.96	2.91	4.01	
Level of Significance	NS	*	*	NS	*	*	
t value	2.99	5.33	5.46	1.99	3.66	3.38	

**Significance at 1% level

Table 6. Yield and yield contributing characters of mustard were determined using various management practices in Gabtoli, Bogra during 2017-18

Treatment	Plant Height (cm)	Tiller hill^{-1} (no)	Grain panicle^{-1} (no)	1000 grain wt (g)	Yield (tha^{-1})	Straw yield (tha^{-1})	Yield increased over FP (%)
Trial plot	99.41	16.11	88.21	17.92	3.90	4.16	14.03
Farmers' plot	97.23	15.08	84.17	17.34	3.42	4.48	
Level of Significance	**	*	**	**	**	*	

** Significance at 1% level

Table 7. Yield, and economic return on existing (Mustard-Boro-T.aman cropping pattern) and alternate cropping patterns (Mustard-Boro-T.aus-T.aman cropping pattern) in Gabtoli, Bogra in 2016-17

Parameters	**Existing Cropping Pattern**			**Alternate Cropping Pattern**			
Crop	*Mustard*	*Boro*	*T.aman*	*Mustard*	*Boro*	*T.aus*	*T.aman*
Variety	*BARI sorisha-14*	*BRRI dhan 28*	*BRRI dhan 49*	*BARI sorisha-14*	*BRRI dhan 28*	*BRRI dhan 48*	*BRRI dhan62*
Grain yield (t ha^{-1})	1.13	4.62	2.91	1.35	5.45	4.72	3.45
Straw yield (t ha^{-1})	1.47	5.13	4.01	3.17	6.15	5.55	4.57
Equivalent yield (t ha^{-1})		11.45			17.00		
Gross margin (Tk.ha^{-1})	27098	17460	22973	37223	28105	42879	32933
Total variable cost (Tk. ha^{-1})	32372	52350	41242	33447	54345	39021	41242
Gross return (Tk. ha^{-1})	59470	69810	64215	70670	82450	81900	74175
Whole pattern Gross margin (Tk. ha^{-1})		67531			141140		
MBCR (Whole pattern)				2.75			

Market price of Mustard @ 50 Tkkg^{-1} , Straw @ 1.0 Tkkg^{-1} ,Boro @ 15Tk kg^{-1}, T.*aman* @ 17Tk kg^{-1}, T.aus @ 16 Tkkg^{-1} , Straw @ 1.50 Tk kg^{-1}

Table 8. Yield, and economic return on existing (Mustard-Boro-T.aman cropping pattern) and alternate cropping patterns (Mustard-Boro-T.aus-T.aman cropping pattern) in Gabtoli, Bogura in 2017-18

Parameters	**Existing Cropping Pattern**			**Alternate Cropping Pattern**			
Crop	*Mustard*	*Boro*	*T.aman*	*Mustard*	*Boro*	*T.aus*	*T.aman*
Variety	*BARI sorisha-14*	*BRRI dhan 28*	*Mamun*	*BARI sorisha-14*	*BRRI dhan 28*	*BRRI dhan 48*	*BINA dhan 7*
Grain yield (t ha^{-1})	1.11	4.65	3.42	1.34	5.37	4.68	3.90
Straw yield (t ha^{-1})	1.42	5.02	4.48	2.09	6.04	5.12	4.16
Equivalent yield (t ha^{-1})		10.18			16.49		
Gross margin ($Tk.ha^{-1}$)	24636	50800	53177	35555	66122	77748	64475
Total variable cost (Tk. ha^{-1})	32284	52240	41283	33535	53358	40132	41345
Gross return (Tk. ha^{-1})	56920	103040	94460	69090	119480	117880	105820
Whole pattern Gross margin (Tk. ha^{-1})		128613			243900		
MBCR (Whole pattern)				3.70			

Market price of Mustard @ 50 $Tkkg^{-1}$, Straw @ 1.0 $Tkkg^{-1}$,Boro @ 20Tk kg^{-1}, T.*aman* @ 25Tk kg^{-1}, T.aus @ 23 $Tkkg^{-1}$, Straw @ 2.00 Tk kg^{-1}

Table 9. Average nutrient status of initial and final soil (0-15 & 15-30 cm depth) of the experimental fields at Gabtoli, Bogura during 2016

Matter	**pH**	**OM** (%)	**Total N** (%)	**K** (meq $100g^{-1}$ soil)	**P**	**S**	**Zn**	**B**
						μg g^{-1} soil		
Initial value	7.04	1.73	0.09	0.09	6.17	8.22	0.90	0.29
Final value	6.95	1.78	0.08	0.10	6.21	8.27	0.93	0.28
Interpretation	SA	M	L	VL	L	L	M	M

SA= Slightly alkaline, M=Medium, L=Low, VL=Very low

practices. Additionally, the highest grain yield (5.15 tha^{-1}) was obtained from the trial plot, which was 15.48 percent greater than the farmer's plot. T.aman (2016-17) displays growth and quality contributing characters in Table 5. The trial plot obtained a higher number of tillers per hill (16.25) and grain per panicle (83.25) than farmers practice. Similarly, the farmer's plot produced the highest grain yield (3.45 tha-1). T.aman (2017-18) provides yield related contributing characters in Table 6. The trial plot obtained a higher number of tillers per hill (16.11) and grain per panicle (88.21) than farmers practice. Similarly, the farmer's plot produced the highest grain yield (3.90 tha-1).

In 2016-17, Higher gross return (309195 $Tkha^{-1}$) and gross margin (141140 $Tkha^{-1}$) was recorded from trial plot. Rice equivalent yield (REY) was also higher in trial plot. REY of trial plot was 17.00 in Trial plot against 14.37 in farmers practice (Table 7). In 2017-18, Higher gross return (412270 $Tkha^{-1}$) and gross margin (243900 $Tkha^{-1}$) was recorded from trial plot. Rice equivalent yield (REY) was also higher in trial plot. REY of trial plot was 16.49 in Trial plot against 10.18 in farmers practice (Table 8).

Rice is the dominant crop in Bangladesh agriculture, accounting for nearly 73% of cropped area and accounting for 70% of total output value (Islam *et al.*, 2007). The cultivation of HYV crops and the adoption of modern technologies have resulted in a significant depletion of soil nutrients. Generally, farmers use unbalanced chemical fertilizers for individual crops without regard for the entire year's cropping pattern. As a result, a significant amount of fertilizer is wasted each year in crop cultivation (Noor et al., 2008). Bangladesh soil has a very low organic matter content and fertility status. It is widely accepted that depleted soil fertility is the primary impediment to increased crop production in Bangladesh, and yields of several crops are declining in some soils (Bhuian, 1991). In the present study, the application of soil test based IPNS fertilizer dose increased the soil fertility (Table 9) and finally increased the crop yield. The present findings are in conformity with findings of Davari *et al*. (2012) and Essan and Lattief (2014).

Conflict of interest

There is no conflict of interest among the authors.

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