INTEGRATED NUTRIENT MANAGEMENT FOR SUSTAINABLE CROP PRODUCTION IN BORO-FALLOW-T. AMAN RICE CROPPING PATTERN

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Abstract

Soil fertility is the ability of soil to sustain plant growth and optimize crop production. A field experiment was conducted at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh adding green manuring crops in Boro-Fallow-T. aman rice cropping pattern to improve soil fertility and crop productivity. The experiments comprised seven treatments for Boro-Fallow-T.aman rice were T_1 = Control (without fertilizer), T_2 = Soil Test Based (STB) 100% chemical fertilizers, T_3 = STB based 70% chemical fertilizers + cowdung (5 t ha^{-1}), T_4 = STB based 100% chemical fertilizers for boro rice (only N fertilizer in T.aman rice), T_5 = STB based 70% chemical fertilizers to each crop, T_6 = STB based 100% chemical fertilizers for boro rice + 50% chemical fertilizers for T.aman rice and T_7 = STB based 100% chemical fertilizers for boro rice + 50% chemical fertilizers for T.aman rice without green manuring in the system. Green manuring crop (Dhancha) was grown in a highland adjacent to this plot and transferred to the experimental plot @ 8 t ha^{-1} (fresh wt. basis) and mixed with the soil after harvesting first crop (boro rice). Initial and post-harvest soil samples were analyzed for chemical properties, grain yield and straw yield was collected as whole plot basis. The result showed significant difference between the treatments. The highest grain yield of Boro 7.21 (t ha^{-1}) was recorded in treatment T_4 ($N_{140}P_{45}K_{85}S_{35}Zn_4B_2$ kg ha^{-1}) which was statistically identical with T_2 (7.18 t ha^{-1}), T_6 (7.17 t ha^{-1}) and T_7 (7.12 t ha^{-1}) treatments. Results of T.aman rice indicated that application of cowdung @ 5 t ha^{-1} along with 70% chemical fertilizer applied in the first crop (boro) of the pattern showed beneficial effect on the second crop (T.aman rice). The highest net benefit of Tk. 96,272 ha^{-1} was recorded in treatment T_6. Nutrient uptake followed the order N>K>P> and S. Application of recommended dose of fertilizer in first crop (boro) of the pattern and incorporation of dhaincha (*sesbaniaacueleta*) as green manure 5-6 days before transplanting of T.aman rice along with 30% reduced dose application of inorganic fertilizers at the second crop may substantially increase the production of Boro-Fallow-T.aman rice as well as improve the soil fertility status.

Key words: Rice, Nutrient management, Soil fertility, Crop production, Cropping pattern.

Introduction

Rice (*Oryza sativa*) is the key staple food for the world's poorest and undernourished people living in Asia and Africa as they cannot afford or do not have access to nutritious foods (Bin *et al.*, 2022) and influences the livelihoods and economies of several billion people. In 2010, approximately 154 million ha were harvested worldwide, of which 137 million ha were in Asia of which 48 million ha were harvested in Southeast Asia alone

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(FAOSTAT, 2012). Rice is the principal cereal crop in Bangladesh. The national average rice yield (3.01 t ha^{-1}) is much lower than that of other rice growing countries (BBS, 2020). There is a yield gap between the farmer's field and the yield potential of a particular variety. Farmers do not follow the integrated use of improved management practices. Rice productivity and total rice production in Bangladesh still have scope to increase if the proper crop management systems are followed (Shelley *et al*., 2015). The urgent need of the cropping sector of Bangladesh is to produce more food to feed the country's ever growing population.

The nutrients of soil is declining with time due to intensive cropping and use of higher doses of nitrogenous fertilizers with little or no addition of organic manure (Ali *et al*., 2009). Low organic matter content has been considered as one of the main reasons for low productivity of many of our soils. Due to continued decline in soil organic matter content and soil fertility for sustainable crop production is being seriously threatened even with addition of mineral fertilizer.

Green manuring had been widely practiced in Asia. Complementary use of green manure along with mineral fertilizer has got significance at the present time. The inclusion of a legume crop in between the two cereal crops would help to improve the soil organic matter situation and utilization of soil nutrients from deeper soil. Rice-fallow-rice cropping pattern is still a major pattern in many parts of Bangladesh. Selection of crops and cropping pattern is an important factor for maintaining fertility status of a soil. Incorporation of green manuring crops in the cropping pattern has special significance in the maintenance of soil fertility and crop productivity because of its unique ability of fixing and utilizing atmospheric nitrogen (Rahman *et al*., 2013). Therefore, in order to sustain crop production it is necessary to introduce green manuring crops in cropping pattern to maintain and improve soil fertility and organic matter contents. Considering these points, the present study was carried out to develop cropping pattern based nutrient management with judicious integration of inorganic fertilizers with green manure to find out the profitable fertilizer recommendation for sustainable crop production.

Material and Methods

An experiment was conducted at BINA experimental field, Mymensingh for consecutive two years in 2013-14 and 2014-15. The experiments comprised of seven treatments. Treatments for Boro rice-Fallow-T.aman rice were T_1 = Control (without fertilizer), T_2 = STB based 100% chemical fertilizers, T_3 = STB based 70% chemical fertilizers + cowdung (5 t ha^{-1}), T_4 = STB based 100% chemical fertilizers for boro rice (only N fertilizer in T.aman rice), T_5 = STB based 70% chemical fertilizers to each crop, T_6 = STB based 100% chemical fertilizers for boro rice + 50% chemical fertilizers for T.aman rice and T_7 = STB based 100% chemical fertilizers for boro rice + 50% chemical fertilizers for T.aman rice without green manuring in the system. Details of the fertilizer management packages used in the experiment are given in the Table 1. The experiments were laid out in

Randomized Complete Block Design having a unit plot size (4m × 5m) replicated thrice. Composite soil samples were collected at 0-15 cm depth from the experimental site. Collected soil samples were analyzed in the laboratory for different parameters following standard methods. The initial nutrient status of the experimental site was pH 6.5, organic matter 1.12%, total N 0.09%. Available P,S,Zn and B were 13, 10, 1.3 and 0.78 ppm, respectively. The exchangeable cations were K, Ca and Mg 0.10, 1.15 and 0.67 meq%. The crop cycle was started by seedbed preparation of boro rice during December followed by transplanting of Boro rice (cv. Binadhan-6) from seed bed to main field during January. After harvesting of boro rice, green manuring crop (*Sesbaniaacuelta*) which was grown in a highland adjacent to this plot, transferred to the experimental plot @ 8 t ha^{-1} (fresh wt. basis) and mixed with the soil. Twenty five days old seedling (cv. Binadhan-7) was transplanted during July. Both for Boro and T.aman rice, all fertilizers except urea were applied at the time of final land preparation. Urea was applied in three equal splits at 10, 35 and 60 days after transplanting (DAT). Grain and straw yields were recorded per plot basis at 14% moisture level and the required amount of grain and straw samples were kept for determination of N,P,K and S content. Economic analysis of the product was done as described by Perrin *et. al.* (1979). After completion of two cycles soil samples were collected from each plot and analyzed for pH, organic matter, total N and available P,K,S and Zn to monitor the nutritional status of the soils.

Table 1. Treatment combinations with 100% & 70% fertilizers used for Boro-Fallow-T.aman rice cropping pattern

Treatment	Nutrient added (kg ha^{-1})										
	Boro (cv. Binadhan-6)							T. Aman (Binadhan-7)			
	N	P	K	S	Zn	B	CD t/ha	N	P	K	S
T_1	-	-	-	-	-	-	-	-	-	-	-
T_2 (100%)	140	45	85	25	04	02	-	75	15	45	08
T_3 (70%)	100	32	60	18	03	01	05	55	12	32	06
T_4 (100%)	140	45	85	25	04	02	-	75	-	-	-
T_5 (70%)	100	32	60	18	03	01	-	55	12	32	06
T_6 (100%)	140	45	85	25	04	02	-	40	08	25	04
T_7 (100%)	140	45	85	25	04	02	-	40	08	25	04

Green manure were applied @ 8 t ha^{-1} except treatment T_7

Results and Discussion

Yield of crops

Results indicated that application of different packages of fertilizers increased grain and straw yield significantly over absolute control treatment (Table 2). Grain and straw yields (mean of two years) of boro rice (cv. Binadhan-6) ranged from 2.48-7.21 and 3.28-8.36 t ha^{-1}, respectively. The highest grain yield 7.21 (t ha^{-1}) was recorded in treatment T_4 ($N_{140}P_{45}K_{85}S_{35}Zn_4B_2$ kg ha^{-1}) which was statistically identical with T_2 (7.18), T_6 (7.17) and T_7 (7.12) t ha^{-1}. On the other hand, treatment T_3 which received (70% chemical fertilizer of T_2 + cowdung 5 t ha^{-1}) produced 6.74 $tha^{-1}$of rice yields which were statistically identical

with treatment T_5 (70% chemical fertilizer of T_2 only). Like grain yields, the straw yields also differed significantly due to treatments. The lowest grain and straw yields were recorded in absolute control treatment.

Grain and straw yields of T.aman rice (cv. Binadhan-7) were also significantly influenced by the different treatment combinations of inorganic fertilizer along with residual effect of inorganic and organic fertilizer applied during boro season (Table 2). Grain and straw yields (mean of two years) ranged from 1.82-4.64 and 3.38-6.05 t ha^{-1}, respectively. The highest grain yield 4.64 t ha^{-1} was observed in treatment T_2 ($N_{75}P_{15}K_{45}S_8$ kg ha^{-1}) which was higher than those of all other treatments and statistically identical with treatment T_3 and T_6 (4.46 t ha^{-1}). On the other hand, treatment T_7 (4.34 t ha^{-1}), T_5 (4.20 t ha^{-1}) and T_4 (3.96 t ha^{-1}) produce statistically identical yield. The lowest grain and straw yields were recorded in control treatment. The results indicated that application of cowdung 5 t ha^{-1} along with 60% chemical fertilizer applied in the first crop of the pattern showed some beneficial effect on the second crop (T.aman rice). The results also demonstrated the nutrients NPKSZn for high yield goal applied during the boro season had some residual effect on aman season.

Table 2. Effect of different fertilizer management packages on the yield (t ha^{-1}) of Boro-Fallow-T.aman rice cropping pattern

Treatments	Boro rice (cv. Binahan-6)						T.aman rice (cv. Binadhan-7)					
	Grain Yield (t ha^{-1})		Straw Yield (t ha^{-1})		Mean Yield (t ha^{-1})		Grain Yield (t ha^{-1})		Straw Yield (t ha^{-1})		Mean Yield (t ha^{-1})	
	1st year	2nd year	1st year	2nd year	Grain	Straw	1st year	2nd year	1st year	2nd year	Grain	Straw
T_1	2.63d	2.32c	3.72c	2.83d	2.48	3.28	1.88c	1.76c	3.85d	2.91e	1.82	3.38
T_2	7.13a	7.23a	8.00a	8.26a	7.18	8.13	4.67a	4.60a	6.40a	5.69a	4.64	6.05
T_3	6.58b	6.89b	6.92b	7.10b	6.74	7.01	4.42a	4.50ab	6.62a	5.47b	4.46	6.05
T_4	7.25a	7.16a	8.13a	8.17a	7.21	8.15	3.52b	4.20d	5.09c	5.08d	3.96	5.09
T_5	6.22c	6.31b	6.42b	6.55c	6.27	6.49	4.08ab	4.32cd	5.22bc	5.23cd	4.20	5.23
T_6	7.23a	7.10a	8.67a	8.05a	7.17	8.36	4.47a	4.45bc	6.40a	5.43b	4.46	5.92
T_7	7.10a	7.13a	8.17a	8.05a	7.12	8.11	4.33a	4.35cd	6.08ab	5.31bc	4.34	5.70

Means followed by difference letters are significantly different among each other on DMRT at 5% level of significance.

Economics of Fertilizer Uses

Economics of fertilizer uses have been calculated on the total products of two cropping cycles (Table 3) following partial budget analysis and marginal analysis as described by Perrin *et. al.* (1979). The results of economic analysis of Boro-Fallow-T.aman rice cropping pattern indicated that the highest net benefit of Tk. 96,272 ha^{-1} was recorded in treatment T_6 followed by 96,097, 94,442 and 92,517 Tk. ha^{-1} in treatment T_2, T_7 and T_3, respectively. Another attempt also made to find out the marginal rate of returns (MRR%) against the undominated treatments (Table 4). However, the highest MRR (610%) was obtained in treatment T_5 followed by (415%) and (193%) in treatment T_6 and T_3 respectively.

Table 3. Economics of fertilizer use in crop production for Boro-Fallow-T.aman rice cropping pattern

Treatments	Economic Yield (t ha^{-1})		Gross Profit (Tk. ha^{-1})			Variable cost (Fertilizer) (Tk ha^{-1})	Variable opportunity cost (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Net benefit (Tk ha^{-1})
	Grain	Straw	Grain	Straw	Total				
T_1	4.30	6.66	34400	6660	41060	-	-	-	41,060
T_2	11.82	14.18	94560	14180	108740	12,043	600	12,643	96,097
T_3	11.20	13.06	86400	13060	99460	9,693	450	10,143	92,517
T_4	11.07	13.24	88560	13380	101940	9,794	450	10,244	91,696
T_5	10.47	11.72	80560	15580	92140	7,193	450	7,643	87,697
T_6	11.63	14.78	93040	14280	107320	10,448	600	11,048	96,272
T_7	11.46	13.81	91680	13810	105490	10,448	600	11,048	94,442

Price of N as urea = Tk. 13.0 kg^{-1}; P as TSP = Tk. 75.0 kg^{-1}; K as MP = Tk. 20.0 kg^{-1}; S as gypsum= Tk. 28 kg^{-1}; Zn as ZnO = Tk.111 kg^{-1}; B as Borax = Tk. 250 kg^{-1} and CD = Tk. 500 t^{-1}; Price of rice grain = Tk. 8.00 kg^{-1}; straw = Tk. 1000 t^{-1}.

Table 4. Marginal analysis of undominated fertilizer response data

Net benefit (Tk. ha^{-1})	Treatments	Variable cost (Tk. ha^{-1})	Changes from next highest benefit		
			Marginal increase in net benefit (Tk. ha^{-1})	Marginal increase in variable cost (Tk. ha^{-1})	MRR %
96272	T_6	11,048	3,755	905	4.15
92517	T_3	10,143	4,820	2,500	1.93
87697	T_5	7,643	46,637	7,643	6.10
41060	T_1	-	-	-	-

Nutrient Uptake

The total amount of nutrient (N,P,K & S) uptake by grain and straw of Boro-Fallow-T.aman rice cropping pattern as affected by different organic and inorganic fertilizer are presented in Table 5. The total nutrient uptake ranged from N (64-227), P (10-43), K (56-186), and S (6-26) kg ha^{-1}, respectively. Nutrient uptake of different nutrients of the cropping pattern found to follow the order: N>K>P> and S.

Table 5. Nutrient uptake (kg ha^{-1}) by Boro-Fallow-T.aman rice cropping pattern as affected by different treatment combinations

Treatments	N	P	K	S
T_1	64	10	56	06
T_2	227	43	186	26
T_3	187	29	148	21
T_4	207	38	155	23
T_5	161	25	121	17
T_6	202	37	164	23
T_7	205	38	162	23
Range	64-227	10-43	56-186	06-26

Soil Fertility Status

The status of soil pH, organic matter, total N and different available nutrients of initial soils as well as after completion of two cropping cycles of Boro-Fallow-T.aman rice cropping pattern are presented in Table 6. No appreciable changes in soil nutrient status occurred through the uses of varying fertilizer packages except absolute control plot. The changes of soil pH, organic matter, total N and available S contents were very low due to two years of cropping. However, there were considerable depressing effects on exchangeable K in soil resulted from the two years of cropping.

Discussion

This study was conducted for judicious and efficient nutrient management with green manure for getting higher yield, nutrient use as well as maintaining soil health. In the present study, Boro crop was considered as the first crop in Boro-Fallow-T.aman cropping pattern and received all necessary nutrients.

Results showed significantly higher yield in the treatments containing 100% chemical fertilizer than the treatment contained lower amount of chemical fertilizer and also than absolute control. But at the 2nd crop of cropping pattern (T.aman), results were found different. Application of different packages of fertilizers increased grain and straw yields significantly over absolute control treatment. Control treatment showed the lowest grain yield followed by treatment without green manure crop. That is green manure increase the yield of following crops. On the other hand treatment contained lower amount of chemical fertilizer but with 5 t ha^{-1} cowdung showed significantly similar yield with 100% chemical fertilizer but higher all other fertilizer treatment. From this result it can be said that application of less amount of chemical fertilizer along with cowdung followed by green manuring produced statistically similar yield with recommended dose of fertilizer. The results indicated that application of cowdung 5 t ha^{-1} along with 70% chemical fertilizer applied in the first crop of the pattern showed some beneficial effect on the second crop (T.aman rice).

Table 6. Change in soil nutrient status due to varying fertilizer packages under Boro-Fallow-T.aman rice cropping pattern after completion of two cropping cycles

Treat.	pH	Organic matter %	Total N %	Available nutrients (ppm)				Exchangeable cations (meq%)		
				P	S	Zn	B	K	Ca	Mg
Initial soil										
	6.5	1.12	0.09	13	10	1.30	0.78	0.10	1.15	0.67
Post-harvest soil										
T_1	6.5	1.08	0.08	11	09	1.35	0.72	0.08	1.12	0.68
T_2	6.3	1.10	0.08	12	09	1.32	0.72	0.09	1.14	0.68
T_3	6.4	1.09	0.07	12	08	1.32	0.76	0.09	1.11	0.69
T_4	6.2	1.11	0.07	12	09	1.32	0.71	0.09	1.13	0.69
T_5	6.4	1.08	0.09	12	09	1.33	0.79	0.08	1.14	0.69
T_6	6.3	1.09	0.07	12	10	1.34	0.76	0.08	1.11	0.66
T_7	6.4	1.09	0.07	13	10	1.31	0.74	0.07	1.12	0.69

Grain yield of rice was significantly increased due to application of green manure prior to T.aman rice (Irin *et. al,* 2020). Inclusion of green manure in Rice-fallow-Rice cropping pattern may be alternate options to sustain soil health as well as productivity. Cropping pattern containing legumes recorded a significantly higher content of microbial biomass C after 120 days of incubation due to N rich leguminous organic matter (Giller, 2000). In addition, fixation of atmospheric nitrogen, leguminous green manures play a significant role in conserving NO_3 (Yadvinder *et al*., 2005). Rahman *et al*. (2013) also observed that when farmyard manure was applied to maize, it had residual effect on the yield of rice. Legume residues mixed into crop rotation enrich not only to raise yield but also to ameliorate soil fertility by virtue of their ability to add ample quantities of atmospheric N (Rahman *et al*., 2014).

Grain and straw yields of T.aman rice were significantly influenced by the different treatment combinations of inorganic fertilizer along with residual effect of inorganic and organic fertilizer applied during Kharif-1 season. The addition of organic and inorganic fertilizers in an integrated form increased soil organic matter content that provides a carbon source and other nutrients for microbes (Courtney and Mullen, 2008) and altered the biochemical properties of the soil by increasing potentially mineralizable N and microbial biomass C and N (Monaco *et al*., 2008).

It is observed from the economic results that the application of fertilizers increased gross return and also net benefit. Application of recommended dose of fertilizer in first crop of the pattern and incorporation of dhaincha as green manure 5-6 days before transplanting of T.aman rice along with 50% reduced dose application of inorganic fertilizers at the second crop showed the highest net benefit than all other fertilizer package in Boro-Fallow-T.aman rice cropping pattern due to higher production of grain yield.

Conclusion

In cropping sequences the residual effect of fertilizers applied to the first crop should be evaluated and considered in formulating fertilizer recommendations for the subsequent crop. Application of recommended dose of fertilizer in first crop (boro season) of the pattern and incorporation of dhaincha as green manure 5-6 days before transplanting of T.aman rice along with 50% reduced dose application of inorganic fertilizers at the second crop may substantially increase the production of Boro-Fallow-T.aman rice cropping pattern as well as improve the soil fertility status. This fertilizer package is also economically viable for the farmers.

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