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Restoration of soil fertility and sustenance crop productivity in the Boro - T. Aman rice cropping pattern

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Abstract: An experiment was conducted at Bangladesh Institute of Nuclear Agriculture (BINA) experimental field, Mymensingh for two years during 2002-2003 to introduce green mauring in Boro-T.aman rice cropping pattern for maintainance of soil fertility as well as increased crop productivity. The experiment comprised of seven treatments and laid out in a randomized complete block design with three replications. Collected soil samples (Pre and Post harvest soils) were analyzed in the laboratory for different nutrients following standard methods. The highest grain yield of Boro 7.21 (t/ha) was recorded in treatment T_4 (N_{140}, P_{45}, K_{85}, S_{35}, Zn_4 and B_2 kg/ha) which was statistically identical with T_2 (7.18), T_6 (7.17) and T_7 (7.12) t/ha. The results of T. Aman rice indicated that application of cowdung 5t/ha 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 highest net benefit of Tk. 96,272/ha was recorded in treatment T_6. Nutrient uptake of the cropping pattern found to follow the order: N > K > P > and S. Application of cowdung in first crop (Kharif season) of the pattern and incorporation of Dhaincha (*Sesbania aculeata*) as green manure 5-6 days before transplanting of T.aman (Kharif II) rice along with recommended inorganic fertilizers may substantially increase the production of Boro-T.aman rice as well as improve the soil fertility.
Key words: Green manuring, Cropping pattern, Soil fertility, Sustainability.

Introduction

Rice (*Oryza sativa*) is the principal crop in Bangladesh. Almost every cropping pattern is rice based. Bangladesh is one of the most densely populated country in the world. Out of the total land area of 13.01 million ha, a little over 8.2 million ha are suitable for crop cultivation situated in the highlands and medium highlands, where the farmer's grow 2-3 crops. A crop production system with high yield target will not be sustainable unless nutrients inputs to soil are least balanced against nutrient removal of crops. Proper fertilization effectively improves quality and yield of crops, reduces cost and increase farmers income. Improper fertilization creates adverse effects on the soil environment. In the past, farmers used to supply the soil a certain amount of organic residues as compost, farmyard mantnres and green manures. This practices have been reduced to a greater extent as the major portion of organic residues is now-a-days used as fuel and fodder by the rural people. 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. Continuous use of inorganic fertilizers in crop cultivation is causing health hazards and creating problems to the environment including the pollution of air, water, soil etc. Indiscriminate use of chemical fertilizer is badly affecting texture and structure of soil, decreasing soil organic matter and hampering soil microbial activity due to soil toxicity (Brady,1990). Green manuring, wherever feasible, is the principal supplementary means of adding organic matter to the soil. The greenmanuring crops supplies organic matter as well as additional nitrogen, particularly if it is a legume crop which has the ability to fix nitrogen from the air with the help of its root-nodule bacteria. On an average a leguminous crop producing 10 tones of green biomass per hectare will add about 35kg of N (Gupta, 2007). Integrated use of organic manures and inorganic fertilizers would be quite promising for sustaining soil fertility, crop productivity and for improvement of soil health. 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 layers by the tap root system of the legume. Complementary use of green manure along with mineral fertilizer has got significance at the present time. Rice-fallow-Rice cropping pattern, is still a major pattern in many parts of the country. But in most cases farmers do not grow green manuring crops in between two cereals to restore soil health. Therefore, in order to sustain agricultural production it is necessary to introduce green manuring in Boro-T. Aman rice cropping pattern to maintain and improve soil fertility and organic matter status of soil.

Materials and Methods

The experiment was conducted at BINA experimental field, Mymensingh for two years during 2002-2003. The details of the fertilizer management packages used in this experiment is given in Table 1. Treatments for Boro-T.aman rice were T_1 = Control (Without any fertilizer), T_2 = 100% chemical fertilizers (recommended rates for high yield goal) to each major crop, T_3 = 60% chemical fertilizers in each major crop + cowdung (5 t/ha), T_4 = 100% chemical fertilizers for the first major crop (only N fertilizer in T.aman rice), T_5 = 60% chemical fertilizers to each major crop, T_6 = 100% chemical fertilizers for the first crop + 50% chemical fertilizers for T.aman rice and T_7 = T_6 with no green manuring crop in the system. The experiment was laid out in Randomized Complete Block Design (RCBD) 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 nutrients 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, Mg 0.10, 1.15 and 0.67 me%. The crop cycle was started by seedbed preparation of boro rice during December followed by transplanting of Boro rice (cv. Binadhan-6) from seedbed to main field during January. After harvesting of boro rice green manuring crop (*Sebania aculeata*) was grown in a highland adjacent to this plot and transferred to the main field @ 8t/ha (fresh wt. basis) and mixed with the soil. Thirty five days old seedling (cv. Binadhan-4) were 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 nutrient status of the soils.

Table 1. Details of treatment combinations used for Boro -T. aman rice cropping pattern

Treatment	Nutrient added (kg/ha)										
	Binadhan-6							T.aman (Binadhan-4) rice			
	N	P	K	S	Zn	B	CD (t/ha)	N	P	K	S
T_1	-	-	-	-	-	-	-	-	-	-	-
T_2	140	45	85	35	04	02	-	75	15	45	8
T_3	84	27	51	21	2.5	01	05	45	9	27	5
T_4	140	45	85	35	04	02	-	75	-	-	-
T_5	84	27	51	21	2.5	01	-	45	9	27	5
T_6	140	45	85	35	04	02	-	38	7.5	23	4
T_7	140	45	85	35	04	02	-	38	7.5	23	4

Results and Discussion

Yield of crops: Grain and straw yields of boro rice during 2002 and 2003 are presented in Table 2. Results indicated that application of different packages of fertilizers increased grain and straw yield significantly over absolute control treatment. 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, respectively. The highest grain yield of 7.21 (t/ha) was recorded in treatment T_4 (N_{140}, P_{45}, K_{85}, S_{35}, Zn_4 and B_2 kg/ha) which was statistically identical with T_2 (7.18), T_6 (7.17) and T_7 (7.12) t/ha. On the other hand, treatment T_3 which received (60%, chemical fertilizer of T_2 + cowdung 5 t/ha) produced 6.74 t/ha of rice yield which was statistically identical with treatment T_5 (60% 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.

Table 2. Effect of different fertilizer management packages on the yield (t/ha) of Boro- T. aman rice cropping pattern

Treatment	Boro rice (cv. Binadhan-6)						T.aman rice (cv. Binadhan-4)					
	Grain		Straw		Mean		Grain		Straw		Mean	
	2002	2003	2002	2003	Grain	Straw	2002	2003	2002	2003	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

Note: Green manure were applied @ 8 t/ha except treatment T_7.

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

Treatment	Economic yield (t/ha)		Gross profit (Tk./ha)			Variable money cost fertilizer (Tk./ha)	Variable opportunity cost (Tk./ha)	Total variable cost (Tk./ha)	Net benefit (Tk./ha)
	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	12043	600	12,643	96,097
T_3	11.20	13.06	86400	13060	99460	9693	450	10,143	92,517
T_4	11.07	13.24	88560	13380	101940	9794	450	10,244	91,696
T_5	10.47	11.72	80560	15580	92140	7193	450	7,643	87,697
T_6	11.63	14.78	93040	14280	107320	10448	600	11,048	96,272
T_7	11.46	13.81	91680	13810	105490	10448	600	11,048	94,442

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

Grain and straw yields of T. aman rice (cv. Binadhan-4) were significantly influenced by the different treatment combinations of inorganic fertilizer along with residual effect of inorganic and organic fertilizer applied during (Kharif-1) boro season (Table 2). Grain and straw yields (mean of two years) due to different treatments ranged from 1.82-4.64 and 3.38-6.05 t/ha, respectively. The highest grain yield of (4.64 t/ha) was observed in treatment T_2 (N_{75}, P_{15}, K_{45} and S_8 hg/ha) which was higher than those of all other treatments and statistically identical with treatment T_3 and T_6 (4.46 t/ha). On the other hand, treatment T_7 (4.34 t/ha), T_5 (4.20 t/ha) and T_4 (3.96 t/ha) produce statistically identical yield. The lowest grain and straw yields were recorded in control treatment. Sarker (2005) found the similar results that highest grain yield from 100 % fertilizer application which was comparable with 75 % inorganic fertilizer along with legume biomass incorporation. Sharma and Kuhad (1993) reported similar results; they stated higher rice grain yield by incorporation 12.5 t/ha of Dhaincha biomass with 120 kg N/ha application. The results indicated that application of cowdung 5 t/ha alone 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 kharif-1 season had some residual effect on kharif-II season.

Table 4. Marginal analysis of undominated fertilizer response data

Net benefit (Tk./ha)	Treatments	Variable cost	Changes from next highest benefit		
		(Tk./ha)	Marginal increase in net benefit (Tk./ha)	Marginal increase in variable cost (Tk./ha)	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	-	-	-	-

Table 5. Nutrient uptake (kg/ha) of Boro -T. aman rice copping 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

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

Treatment	pH	Organic matter (%)	Total N (%)	Available Nutrients (ppm)				Exchangeable Cations (me %)		
				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

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-GM-T. aman rice, cropping pattern indicated that the highest net benefit of Tk. 96,272/ha was recorded in treatment T_6 followed by 96,097, 94,442 and 92,517 Tk./ha 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.

Nutrient Uptake: The total amount of nutrient (N, P, K & S) uptake by grain and straw of Boro-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, respectively. Nutrient uptake of the cropping pattern found to follow the order: N > K > P > and S which was supported by Haque *et al.* (2002).

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 - 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. The study was also supported by Rijpma and Jahiruddin (2004) that the overall N balances of Bangladesh soil were negative, the P balances werw slightly negative or zero and K balances were highly negative.

For yearly cropping sequences the residual effect of (P & S) fertilizers applied to the first crop should be evaluated and considered in formulating fertilizer recommendations for the subsequent crop. Application of cowdung in first crop (Kharif season) of the pattern and incorporation of dhaincha (*Sesbania aculeata*) as green manure 5-6 days before transplanting of T.aman (Kharif II) rice along with recommended inorganic fertilizers may substantially increase the production of Boro -T. aman rice as well as improve the soil fertility.

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