ISSN 0258-7122
Bangladesh J. Agril. Res. 34(1) : 5-13, March 2009

EFFICIENCY OF IPNS-BASED CHEMICAL FERTILIZER APPLICATION IN WET LAND RICE

P.K. SAHA[1] AND M. A. M. MIAH[2]

Abstract

A field trial was conducted to validate some fertilizer application approaches for Boro-Green manure (GM) -T. Aman cropping system at the Bangladesh Rice Research Institute (BRRI) Farm, Gazipur (AEZ-28: high land) during the period from Boro 1999-2000 to T. Arnan 2000. Five different application approaches of inorganic and organic fertilizers along with their residual values were evaluated. A positive effect of GM on the yield of T. Aman rice was observed. Application of cowdung (CD) @ 6 t/ha (at 15 % moisture) along with integrated plant nutrient system (IPNS) based chemical fertilizer in Boro season followed by green manuring with dhaincha (in Kharif-l season) and then growing T. Aman rice (in Kharif-ll season) with reduced doses of chemical fertilizer (60% N, 50% P, 50% K, and 50% S) substantially increased grain yield and narrowed down the N, P, and K balance in soil. This fertilizer application approach may be practiced for sustainable crop production. No appreciable yield loss in T. Arnan rice (2nd crop) occurred due to the application of reduced doses of P, K, S, and Zn indicating the beneficial residual effect of fertilizer applied to the first crop (Boro rice) of the cropping pattern. The N uptake was in excess of the N added as fertilizer. An improved balance of P, S, and Zn was observed. But the K balance was negative. However, application of cowdung and incorporation of dhaincha slightly improved the K balance of the soil. The highest gross return of Tk. 86,270 was obtained with the above practice (treatment T_4)

Kew Words: Chemical fertilizer, application, wet land rice.

Introduction

The need of the hour is to achieve substantially higher crop yield than the present yield levels from our limited land resources on a sustainable basis. A crop production system with high yield targets cannot be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops (Bhuiyan *et al.*, 1991). Proper soil fertility management, therefore, is one of the prime importance in an endeavor to increase crop productivity. Available data indicate that the fertility of most of our soils has deteriorated over the years (Karim *et al.*, 1994 and Ali *et al.*, 1997), which is responsible for stagnating and in some cases; even declining crop yields (Anonymous, 1996 and Cassman *et al.*, 1995). On the other hand, about 70% of the net cultivable area in high and medium lands has soil organic matter content below 2% (Bhuiyan *et al.*, 1991). This low and

[1]Principal Scientific Officer, Soil Science Division, BRRI, Gazipur-l701, [2]Chief Scientific Officer, Soil Science Division, BRRI, Gazipur-1701.

declining organic matter content may be one of the main reasons for declining/ stagnating productivity of many soils in Bangladesh. Unless the organic matter factor is seriously considered in our cropping systems, we may not achieve the goal of increased and sustained soil productivity. Now, it is the demand of the time to develop an integrated inorganic-organic soil fertilization programme for higher crop yield and for improved soil health. In this respect, inclusion of a green manure crop within the cropping system deserves special attention. Moreover, the use of organic fertilizer reduces the need of chemical fertilizer.

Considering these points, a field study was conducted with an integrated nutrient management practice in Rice-GM-Rice system in Madhupur Tract (AEZ-28) to evaluate the IPNS-based chemical fertilizer application approach.

Materials and Method

A field trial with Boro-GM-T. Arnan cropping pattern was conducted at the BRRI Farm, Gazipur (AEZ-28; high land) during the period of Boro 1999-2000 toT. Arnan 2000. The soil of the experimental field was silty clay loam in texture and neutral in reaction. Organic C, total N, available P (Modified Olsen's) and exchangeable K (N NH_4OAc) of the soil were 1.45%, 0.10%, 13 ppm and 0.23 meq/100 g soil, respectively. The available S (calcium dihydrogenphosphate) and Zn (DTPA) were 20 ppm and *5* ppm, respectively.

The experiment was laid out in a randomized complete block design with three replications. The treatment combinations for the first crop (Boro) of the cropping pattern were, no fertilizer (T_1) BARC recommendation as FRG, 1997 (T_2), soil test based (STB) (T_3), CD at the rate of 6 t/ha (at 15% moisture) + IPNS based chemical fertilizers (T_4), and local farmers' practice (based on interview of 10/15 local farmers) (FP) (T_5). In Kharif-l, each original plot under treatments T_2, T_3 and T_4 was divided into four sub-plots. The treatments were No GM for T_1 T_{2a}. T_{3a} T_{4a} and T_5 and GM for rest of the treatments. Dhaincha (S. *acu1eata,* was the second crop (Kharif I) as a green manure. In T. Arnan, the treatments for these sub-plots were full inorganic fertilizer doses as for the first crop without green manure ($T_{2a/3a/4a}$), full inorganic fertilizer doses plus green manure ($T_{2b/3b/4b}$), 60% N and 50% other nutrients plus green manure ($T_{2c/3c/4c}$), and 60% N only plus green manure ($T_{2d/3d/4d}$). The detailed treatment combinations are presented in Table I. The sources of N, P, K, S, and Zn were urea, triple super phosphate, muriate of potash, gypsum, and zinc sulfate, respectively. In treatment T_4 CD @ 6 t/ha (at 15% moisture) was applied once a year at final land preparation and incorporated into soil before transplanting. Boro rice and the chemical fertilizers were applied as IPNS based in this plot. Nutrient content in CD (decomposed) were as follows: total N-1%, total P-0.2%, total K-1.5%, total S-0.16%, and total Zn-0.012%. Chemical fertilizers were applied to each crop (except dhaincha) as per treatments following the usual procedure. In Boro,

BRRI dhan-29 and in T. Aman, BRRI dhan-31 were tested with 20 cm x 20 cm spacing. At the first week of May, dhaincha was grown in respective plots without any fertilization by broadcasting seed at the rate of 50 kg/ha. Fifty-five-day old dhaincha plants were incorporated at 7-8 days prior to T. Aman planting. Appropriate management practices including plant protection measures were followed during each growing season. The plot size was 4 m × 4 m. The crops were harvested at maturity from 2.5 m × 2 m area at the centre of each plot. Grain yields were recorded at 14 % moisture content and straw yields at oven dry basis.

In Boro and T. Aman, a portion of straw and grain samples were analyzed for P, K, S, and Zn content by digesting with di-acid mixture of nitric and perchznoric acid at the ratio 5:2 following the method described by Yoshida et al. (1976) and N by Micro-Kjeldahl distillation method (Yoshida *et al.*, 1976).

Statistical analyses were performed and means were compared by DMRT. Economic analyses were done for net benefit and benefit cost ratio for different treatment combinations.

Results and Discussion

Grain and straw yields: In Boro season, the highest grain yield 5.92 t/ha of BRRI Dhan-29 was obtained with the treatment (T_4), in which CD 6t/ha (at 15% moisture) + IPNS based inorganic fertilizer was applied. This result confirmed the data obtained by other experiments conducted by Soil Science Division, BRRI (Miah, 2006). Grain yield with FP (T_5) was statistically low, 4.30 t/ha, about 1.62 t/ha less than that obtained with (T_4). The BARC recommended fertilizer dose (T_2) (FRG- 1997) also gave better yield (5.89 t/ha), which was comparable to the yield of T_3 and T_4 (Table 2).

In T. Aman 2000, the grain yield of BRRI dhan-3l ranged from 2.63 t/ha (in the control plot. (T_1) to 4.59 t/ha (in T_{4a}) (Table 2). The highest grain yield was obtained with treatment (T_{4a}), in which STB fertilization was applied in T. Aman season and CD was applied in the previous Boro crop. The grain yields in 'b' sub-plots were consistently lower than that with 'a' sub-plots; however, the yield difference was not significant except T_{3a} and the treatment (T_{3b}) yielded significantly lower than T_{3a}. It might be the reason that in this treatment (T_{3b}) more N chemical fertilizer (in both Boro and T. Aman) was added (Table 1) as well as additional N was added from the GM (dhaincha). As a result, it was infested by bacterial blight (BB) disease and resulted in poor yield. It was reported that higher doses of nitrogenous fertilizer increased the incidences and severity of BB and leaf scald (LSc) (Anonymous, 2008). The beneficial effect of in *situ* dhaincha growing was remarkable at low dose of chemical fertilizer application. In dhaincha, green manured plots, no noticeable yield loss occurred due to the application of 60% N + 50% reduced doses of PKS fertilizers or even

only 60% N fertilizer application indicating a beneficial residual effect of those fertilizers applied to the first crop (Boro) of the cropping sequence. The significant effect of green manure, grown in Kharif-l was observed in Kharif-Il, i.e., in T. Aman. The residual effect of cowdung applied in Boro season was found in the subsequent T. Aman crop.

Table 1. Integrated fertilization regime for the Boro- GM- T. Aman cropping pattern, BRRI, Gazipur, 1999-2000.

Treat.	Rabi (Boro)					Kharif-1 (GM)		Kharif 11 (T.Aman)					
	Nutrient (kg/ha)					Treat		Treat	Nutrient (kg/ha)				
	N	P	K	S	Zn				N	P	K	S	Zn
T_1= Check	0	0	0	0		T_1	No GM	T_1	0	0	0	0	0
T_2=FRG, 1997 base dose	110	25	60	15	1	T_{2a}	No GM	T_{2a}	50	10	40	5	0
						T_{2b}	GM	T_{2b}	50	10	40	5	0
						T_{2c}	GM	T_{2c}	30 (60%)	5 (50%)	20 (500%)	2.5 (50%)	0
						T_{2d}	GM	T_{2d}	30 (60%)	0	0	0	0
T_3=Soil test base dose	115	19	26	13	0	T_{3a}	No GM	T_{3a}	80	II	17	7	0
						T_{3b}	GM	T_{3b}	80	II	17	7	0
						T_{3c}	GM	T_{3c}	50 (60%)	5.5 (50%)	8.5 (50%)	3.5 (50%)	0
						T_{3d}	GM	T_{3d}	50 (60%)	0	0	0	0 0
T_4 = (T_3) CD (6 t/ha at 15% moisture)+IPNS* based chemical fertilizers	65	9	0	6	0	T_{4a}	No GM	T_{4a}	80	1 I	17	7	
						T_{4b}		T_{4b}	80	II	17	7	0
						T_{4c}	GM	1_{4c}	50 (60%)	5.5 (50%)	8.5 (50%)	3.5 (50%)	0
						T_{4d}	GM	T_{4d}	50 (60%)	0	0	0	0
T_5=Farmer's dose	80	15	21	15	0	T_5	No GM	T_5	60	20	17	10	0

Dhaincha was grown in Kharif-I season and 2.2 t/ha (OD basis) biomass was obtained.
Nutrient content of 5 ton CD on oven dry basis (6 ton CD at 15% moisture): 50-10-75-8-0,6 kg N-P-K-SZn, respectively.
Note: IPNS* is a system where nutrient doses were estimated on soil test basis (STB) for the high yield goal (BARC, 1997) and then required total nutrient content is adjusted from the organic fertilizer and the remaining amount of required nutrients is added from the inorganic fertilizers.

The straw yield of Boro rice was generally higher with the application of different fertilizer doses (T_2 T_4), varying from 5.10 to 5.34 t/ha, compared with that obtained without any fertilization (1.65 t/ha) and FP (4.02 t/ha). The trend of the effect of different fertilizer doses on the straw yield was similar to that of the grain yield (Table 2). In the T. Aman 2000, the straw yield ranged from 3.33 t/ha to 8.63 t/ha (Table 2). The highest straw yield was obtained with treatment (T_4). The straw yields in "b sub-plots were superior to that of "a" sub-plot indicating the beneficial effect of green manure.

Table 2. Effect of different fertilizer packages estimated by different application approaches on the yield (t/ha) of Boro rice (BRRI dhan-29) and T. Aman (BRRI dhan-3l) in a Boro -GM. -T.Aman cropping pattern at BRRI, Gazipur, 1999-2000.

Treatments	Boro (BRRI dhan-29) 1999- 2000		Treatments	T. Aman (BRRI dhan-31) 2000	
	Yield (t/ha)			Yield (t/ha)	
	Grain	Straw		Grain	Straw
T_1	1.63 c	165.c	T_1	2.63 c	3.33 f
T_2	5.89 a	5.34 a	T_{2a}	4.23 ab	6.27 de
			T_{2b}	4.41 ab	8.11 ab
			T_{2c}	4.39 ab	6.47 de
			T_{2d}	3.87 ab	5.78 de
T_3	5.69 a	5.10 a	T_{3a}	4.55 a	6.79 cde
			T_{3b}	3.80 b	7.94 ab
			T_{3c}	4.23 ab	6.50 de
			T_{3d}	4.15 ab	6.52 de
T_4	5.92 a	5.12 a	T_{4a}	4.59 a	6.83 sde
			T_{4b}	3.93 ab	7.77 abc
			T_{4c}	4.44 ab	8.63 a
			T_{4d}	4.41 ab	7.28 bcd
T_5	4.30 b	4.02 b	T_5	4.30 ab	6.36 de
CV (%)	5.20	6.90		8.80	8.10

After completion of one crop cycle, the yield of the IPNS fertilizer doses and green manuring with dhaincha was found higher than those of the BARC recommendation and farmers' doses. The results indicate that the general recommended fertilizer doses and low doses of farmers' practices were inferior to the IPNS treatment and are not enough for high or sustainable yield.

Nutrient uptake: The nutrient uptake of Boro rice was increased with the increase of fertilizer application (Table 3). The N, P, and K uptake form the control plot was 25.76, 4.85, and 21.46 kg/ha. respectively. The N uptake with the T_2, T_3, and T_4 treatments were 88.23, 88.43, and 86.38 kg/ha, respectively,

which was significantly higher than that of the control (T_1) and FP (T_5). But there was no significant difference among these three treatments (T_2-T_4). The FP treatment showed N uptake of 58.78 kg/ha. Similar trend was also found in case of P and Zn uptake. The difference in P uptake with the T_2, T_3, and T_4 treatments was minimal, but the K uptake with these three treatments was quite greater. The K uptake with T_2 was 92.57 kg/ha, while with T_3, it was only 42.29 kg/ha. The significantly highest S uptake (15.89 kg/ha) was obtained with the T_4 treatment.

Table 3. Effect of different fertilizer packages estimated by different application approaches on the nutrient uptake (kg/ha) by Boro rice (BRRI dhan29) in a Boro-GM-T. Aman cropping pattern at BRRI, Gazipur, 2000.

Treat.	Nutrient uptake (kg/ha)				
	N	P	K	S	Zn
T_1	25.76c	4.85c	21.46d	3.68d	0.18 c
T_2	88.23a	15.33a	92.57a	13.13b	0.56 a
T_3	88.43a	17.09a	42.29c	12.84b	0.56 a
T_4	86.38 a	17.01 a	65.52 b	15.89 a	0.55 a
T_5	58.78 b	10.93 b	36.50 c	9.20 c	0.32 b
CV (%)	6.7	10.0	13.4	5.2	5.4

The nutrient uptake by T. Aman rice is presented in Table 4. The total N uptake by T. Aman rice in the control plot was only 42.66 kg/ha and with the fertilized treatment the N uptake was increased to 99.57 kg/ha (T_4). The application of fertilizer increased P, K, S, and Zn uptake substantially. The highest K uptake (80.12 kg/ha) by T. Aman rice was observed with T_{4b} treatment.

Table 4. Effect of different fertilizer packages estimated by different application approaches on the nutrient uptake (kg/ha) by T. Aman rice (BRRI dhan-31) in a Boro-GM-T. Aman cropping pattern at BRRI, Gazipur, 2000.

Treat.	Nutrient uptake (kg/ha)				
	N	P	K	S	Zn
T_1	42.66 e	7.18 e	32.10 e	4.89 f	0.37 f
T_{2a}	77.52 cd	13.05 d	56.77 cd	8.70 ef	0.73 de
T_{2b}	94.08 ab	17.78 a	76.51 ab	14.71 abc	1.12 a
T_{2c}	75.17d	14.36bcd	60.3Ocd	10.96cd	0.83cd
T_{2d}	76.63cd	12.11 d	48.14d	10.O7de	0.81 ed
T_{3a}	95.38 a	17.80 a	68.65 abc	12.78 a-e	0.87 cd
T_{3b}	98.61a	18.29a	62.49bcd	14.87abc	I.lOah
T_{3c}	89.75 abc	14.08 cd	56.54 cd	11.79 b-c	0.86 cd
T_{3d}	80.86bcd	14.33bcd	49.03d	9.l4def	0.58e
T_{4a}	93.59ab	18.76a	62.l6bcd	12.42b-e	0.9Ocd
T_{4b}	94.84ab	17.31 abc	80.12 a	13.40a-d	0.92 bcd
T_{4c}	99.57a	17.54ab	71.80abc	17.18a	0.88cd
T_{4d}	94.20 ab	17.98 a	59.83 cd	15.86 ab	0.97 abc
T_5	75.05 d	13.94 d	61.94 bed	8.57 ef	0.73 de

Apparent nutrient balance

Nitrogen replenishment through chemical fertilizer, green manuring, and CD addition either singly or in combination was not sufficient to balance N removal by crops since much of the applied N was lost from the soil. The N balance thus. -68 to -120 kg N/ha/yr appeared to have been removed in excess of the amounts added (Table 5). The minimal P was accumulated in P fertilized plots (T_{2a}, T_{2h}, and T_{2c}). But, in case of K, it was evident that this element was removed in large excess of the amount added as fertilizer in most treatments. The negative balance of K ranged from -36 to -81 kg/ha/yr. However, T_{4a}, T_{4h}, T_4, and T_{4d}, where cowdung was applied, exhibited a less negative balance of K. A negative balance of K may lead to K deficiency in soil in the long run. The K fertilizer dose, therefore, needs to be fixed with caution.

Table 5. Effect of different fertilizer packages estimated by different application approaches on the nutrient uptake, addition and balance through fertilizer management in a Boro-GM.-T. Aman cropping pattern at BARI, Gazipur, 2000.

Treat.	Nutrient added (kg/ha/yr)					Nutrient uptake (kg/ha/yr)					Nutrient balance (kg/ha/yr)				
	N*	P	K	S	Zn	N*	P	K	S	Zn	N*	P	K	S	Zn
T_1	0	0	0	0	0	68	12	54	9	1	-68	-12	-54	-9	-1
T_{2a}	64	35	100	20	1	166	28	149	22	1	-102	+7	-49	-2	0
T_{2b}	64	35	100	20	1	182	33	169	28	2	-118	+2	-69	-X	-1
T_{2c}	56	30	80	18	1	163	30	153	24	1	-107	0	-73	-6	0
T_{2d}	*56*	25	60	15	1	165	27	141	23	1	-109	-2	-81	-8	0
T_{3a}	78	30	43	20	0	184	35	111	26	1	106	5	68	-6	1
T_{3b}	78	30	43	20	0	187	35	105	28	2	-109	-5	-62	-8	-2
T_{3c}	66	*25*	35	17	0	178	31	99	*25*	1	-112	-6	-64	-8	-1
T_{3d}	66	19	26	13	0	169	31	91	22	1	-103	-12	-65	-9	-1
T_{4a}	78	30	92	20	0.6	180	36	128	28	1	-102	-6	-36	8	-0.4
T_{4b}	78	30	92	20	0.6	181	34	146	29	1	-103	-4	-54	-9	-0.4
T_{4c}	66	25	84	17	0.6	186	35	137	33	1	-120	-10	-53	-16	-0.4
T_{4d}	66	19	75	13	0.6	181	35	125	32	2	-115	-16	-50	-19	-1.4
T_5	56	24	38	25	0	134	25	98	18	1	-78	-1	-60	*7	-1

Cost and Return

An economic analysis of different fertilizer management systems was done assuming that the variable cost except fertilizer and manure purchase and costs involved in handling and application, labour cost for cutting dhaincha, and additional labour cost for harvest of additional product, were the same for all the treatments. Marginal benefit cost ratio (MBCR) was calculated on the basis of the additional benefits due to the fertilizer and for manure application. The application of fertilizer increased gross return and gross margin in all the treatments (Table 6).

The gross return from the control plot was only about Tk. 34,800 and the application of fertilizer increased the gross return, which ranged from Tk. 70.580 in T_5 to Tk. 86,270 in T_4. The highest gross return of Tk. 86.270 was obtained with T_4 compared to the gross return with the FP of Tk. 70,680 and T_{3a} (STB) of Tk. 83.570. It is observed from the economic results that the treatment T_4 gave reasonable higher gross margin (72909 Tk/ha/yr) as good as T_{3a} (STB) (73148). It is marked that the MBCR was higher in those treatments where cowdung was not applied. The above economic considerations, however, may be misleading for fertilizer recommendations if the question of maintaining soil fertility for sustainable crop production is considered. As CD was costly, inclusion of this valuable source of organic matter for soils made this fertilizer strategy' economically least profitable. But, if CD can be supplied from the farmers own cattle, CD will not be an additional financial burden, and using CD and GM for crop production will be both agronornically and economically profitable. This should be carefully evaluated in making fertilizer recommendations.

Table 6. Economic analysis of a Boro-GM-T. Aman cropping pattern. BRRI, Gazipur, 2000.

Treat.	Boro yield (t/ha)		T. Aman yield (t/ha)		Gross return (Tk./ha/yr)	Gross margin (Tk./ha/yr)	*TVC (Tk./ha)	MBCR
	Grain	Straw	Grain	Straw				
T_1	1.63	1.65	2.63	3.33	34800	34800	0	
T_{2a}	5.89	5.34	4.23	6.27	82450	71076	11374	3.19
T_{2b}	.89	5.34	4.41	8.11	85550	73001	12549	3.04
T_{2c}	5.89	5.34	4.39	6.47	83770	72322	11448	3.28
T_{2d}	5.89	5.34	3.87	5.78	79440	69152	10288	3.34
T_{3a}	5.69	5.10	4.55	6.79	83570	73148	10422	3.68
T_{3b}	5.69	5.10	3.80	7.94	79470	68468	11002	3.06
T_{3c}	5.69	5.10	4.23	6.50	81040	70844	10196	3.54
T_{3d}	5.69	5.10	4.15	6.52	80500	71045	9455	3.83
T_{4a}	5.92	5.12	4.59	6.83	85520	72041	13479	2.76
T_{4b}	5.92	5.12	3.93	7.77	81840	67724	14116	2.33
T_{4c}	5.92	5.12	4.44	8.63	86270	72909	13361	2.85
T_{4d}	5.92	5.12	4.41	7.28	84710	72058	12652	2.94
T_5	4.30	4.02	4.30	6.36	70580	62325	8255	3.33

Price of urea = Tk. 6.00/kg; TSP= Tk.14.00/kg; MP= Tk. 9.00/kg; Gypsum=Tk. 5.00/kg; and Zinc sulphate= Tk. 25.00/kg; Price of cowdung= Tk. l000/t; Price of dhaincha seed= Tk. 10000/t; Price ol rice grain=Tk. 7000/t; and rice straw=Tk. l000/t. Seven additional man days are required for cutting dhaincha (GM) per hectare. Four additional man days are required for applying chemical fertilizers per hectare, eight additional man days are required for I ton of additional product including byproduct, Labour wage/day= Tk.80.00

*Total variable cost (TVC) (Tk./ha)=Total fertilizer cost including chemical fertilizer, cow dung and dhaincha seed + Fertilizer application cost (Tk./ha) including dhaincha + Labor cost for additional product (Tk./ha).

Conclusion

Application of cowdung @ 6 t/ha (at 15% moisture) along with IPNS based chemical fertilizer in Boro season followed by green manuring with dhaincha (in Kharif-I season) and then growing T. Aman (in Kharif-II season) with reduced doses of chemical fertilizer (60% N, 50% P, 50% K, and 50% S) in the field trial substantially increased grain yield and partially improved the P, S, and Zn balance of the soil. This fertilizer package appeared to be economically most viable and may be practiced for sustainable crop production.

References

AlL M. M., S. M. Shaheed and D. Kubota. 1997. Soil degradation during the period 1967-1995 in Bangladesh. 11. Selected chemical characters. *Soil Sci. Plant Nutr.* **43:** 879-890.

Anonymous.1996. Annual Report for 1996. The Bangladesh Rice Research Institute. Gazipur, Bangladesh.

Anonymous. 2008. Annual Research Review for 2006-2007. XII Rice Disease Management. The Bangladesh Rice Research Institute, Gazipur, Bangladesh. 14-17 January 2008.

BARC (Bangladesh Agricultural Research Council). 1997. Fertilizer Recommendation Guide-1997. Published by: The Bangladesh Agricultural Research Council. Farrngate, New Airport Road, Dhaka 1215.

Bhuiyan, N. I., A. L. Shah and G. M. Panaullah. 1991. Effect of NPK fertilization on the grain yield of transplanted rice and soil fertility - A long-term study. Bangladesh *J. Soil Sci.* **22** (1&2): 4 1-50.

Cassman, K. G., S. K. De Datta, D. C. 01k, J. Alcantra, M. Samson, J. Descalsota and M. Dizon. 1995. Yield decline and the nitrogen economy of long-term experiment on continuous irrigated rice systems in the tropics.pp.181-222. In: R. Lal and [3. A. Stewart (eds.) Soil Management: Experimental basis for sustainahility and environmental quality, Lewis Pub., London, U.K.

Karirn, Z., M. M. U. Miah and S. Razia. 1994. Fertilizer in the national economy and sustainable environmental development. *Asia Pacific J. Environ. Dev.* **1:** 48-67.

Miah M. A. M.. 2006. Completion Report on Integrated Soil Fertility and Fertilizer Management for Rice Based Cropping Systems 1999-2000 to 2004-2005. Soil Science Division, BRRI, Joydebpur, Gazipur, June 2006. p. 128.

Yoshida, S., A. F. Douglas, J. H. Cock, K. A. Gornez. 1976. Laboratory Manual tbr Physiological Studies of Rice, IRRI, Los Banos. Laguna, Philippines, 14-18 and 27-34.