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Integrated Nutrient Management in Mustard (HYV)-Boro Rice (HYV)-transplanted Aman Rice (HYV) Cropping System

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Abstract: Seven different fertilizer combinations on cropping system basis were studied to develop a fertilizer package for mustard–boro rice–transplant aman rice cropping system. Significantly higher grain yield of mustard, boro rice and transplant aman rice were obtained when the recommended rate of fertilizer was applied. When P or K was not applied in boro rice after full NPKS application in the preceding mustard, gave similar yield to when received its recommended dose but when P or K was not applied for two consecutive boro (spring rice) and transplant aman rice (monsoon rice) it significantly reduced the transplant aman rice yield indicating that P or K had residual effect up to one succeeding crop. On the other hand, transplant aman need an extra application of both P and K fertilizer. Sulfur had a residual effect up to two succeeding crops if applied in full dose along with NPK in the preceding mustard. After application of full recommended dose of NPKS in the preceding mustard, a reduced (50%) dose of P + K along with a full N in the succeeding boro and transplant aman rice gave a similar yield to when recommended NPKS or NPK was used. To maintain soil fertility and to sustain crop yield this fertilizer practice may be considered as a good alternative compared to recommended fertilizer dose.

Key words: Nutrient management, mustard–rice-rice cropping system

Introduction

Generally, fertilizers are applied on a mono crop basis without considering the residual effect of the applied fertilizer to the succeeding crops or cropping system. It was reported that phosphorus and potassium had residual effects on succeeding crops (Anonymous, 1983; Abedin and Mukhopadhyay, 1990). Quasem and Mallik (1984) also reported that if an optimum dose of P and K was applied in winter crops (wheat, potato etc.) the succeeding rice crop might be grown without P and K provided adequate nitrogen was applied. With the introduction of modem and high yielding varieties of crops and use of relatively higher quantity of fertilizers which had already become a costly input, it was felt that, there was an urgent need to develop fertilizer management practices in such a way that it suited farmers' resource constraints and at the same time ensured higher efficiency of the applied fertilizer (Abedin and Mukhopadhyay, 1990). Considering the above facts the present study was undertaken to develop a fertilizer package based on a mustard (HYV)-boro rice (HYV)-transplant aman rice (HYV) cropping system.

Materials and Methods

A farmers' field experiment was conducted at Farming Systems Research (FSR) site, Agricultural Research Station, Bogra, Bangladesh from 1996-97 to 1998-99. The site belongs to "Level Barind Tract" Agro-ecological zone (No. 25) of Bangladesh. The land was medium high and the soil was clay loam in texture. The soils are low in moisture holding capacity and organic matter content. The mean annual rainfall was 1560 mm. The mean maximum temperature was observed in April (35°C) and minimum was in January (11.3°C). The experiment was laid out in randomized complete block design with three replications and repeated for three years in the same layout. Seven different fertilizer combinations on cropping system basis were evaluated. The treatment combinations are given below :

Treatments (N - P_2O_5 - K_2O - S kg ha^{-1})		
Mustard (HYV)	Boro rice (HYV)	Transpalent aman rice (HYV)*.
T1 =80-60-40-20	100-60-40-20	80-60-40-0
T2=80-60-40-20	100-30-20-10	80-30-20-0
T3=80-60-40-20	100-0-0-0	80-0-0-0
T4=80-60-40-20	100-0-40-20	80-0-40-0
T5=80-60-40-20	100-60-0-20	80-60-0-0
T6=80-60-40-20	100-60-40-0	80-60-40-0
T7=80-0-0-0	100-0-0-0	80-0-0-0

T_1 - is recommended fertilizer dose, T_7- is the control
HYV= High Yielding Variety,
* Transplant aman rice (T. aman rice)

Table 1: Grain and stalk/straw yield of Mustard–Boro rice–Transplanted aman (T. aman) rice as affected by different fertilizer combinations

	Grain yield (ton ha^{-1})								
	1996-97			1997-98			1998-99		
	Mustard	Boro rice	T. aman rice	Mustard	Boro rice	T. aman rice	Mustard	Boro rice	T. aman rice
T1	0.82a	5.93a	5.25a	0.53a	5.90a	4.93a	0.78a	5.30a	4.71a
T2	0.85a	5.67a	4.97a	0.51a	5.89a	4.66ab	0.74a	4.98a	4.50abc
T3	0.75a	5.37a	4.80d	0.51a	5.10a	3.90de	0.68a	4.82a	3.61d
T4	0.80a	5.46a	4.43bc	0.54a	5.78a	4.22cde	0.70a	4.94a	3.92bcd
T5	0.75a	5.50a	4.38cd	0.57a	5.89a	4.25bcd	0.67a	4.88a	3.78cd
T6	0.84a	5.86a	5.06a	0.55a	5.80a	4.55abc	0.76a	5.11a	4.16ab
T7	0.52b	3.89b	4.55c	0.34b	3.57b	3.40f	0.39b	3.15b	2.69c
Stalk / straw yield (t ha^{-1})									
T1	1.22a	6.28a	5.74a	1.00a	5.50ab	5.09ab	0.95a	5.75a	5.55a
T2	1.26a	6.00ab	5.53a	0.88ab	6.70ab	5.22a	0.94a	5.42ab	5.14a-c
T3	1.12a	5.76ab	5.62c	0.77b	5.49bc	4.73a-d	0.85a	5.16b	4.86c
T4	1.17a	5.71b	4.82bc	0.91ab	6.57ab	4.48de	0.88a	5.35ab	4.82c
T5	1.12a	5.78a	4.70c	0.94a	6.86a	4.55b-e	0.89a	5.22b	4.99bc
T6	1.24a	6.07ab	5.54a	0.93a	6.66ab	5.05a-c	0.97a	5.37a	5.40a
T7	0.74b	4.63c	4.30d	0.61c	4.33c	3.57f	0.57b	3.48c	3.41d

T_1- is recommended fertilizer dose, T_7 - is the control
In a column means followed by the same letter(s) did not differ significantly at 5% levels of probability.

Mustard: The cultivar "Tori 7" was broadcast sown on 14, 16 and 16 November in 1996, 1997 and 1998 respectively and was harvested on 04, 07 and 08 February in 1997, 1998 and 1999, respectively. One weeding and thinning was done on 15 days after sowing (DAS) in each year. Single irrigation was done at 24, 25 and 26 DAS in 1996, 1997 and 1998, respectively. Other intercultural operations were taken as and when necessary. Fertilizer dose was maintained as per treatment mentioned above. Entire amount of P_2O_5, K_2O, S and ½ N were applied during final land preparation. The rest of the N was applied at 26-28 DAS following the irrigation in each year.

Boro rice (spring rice): Forty days old seedlings of boro rice cultivar "Purbachi" were transplanted on 08, 10 and 11 February in 1997, 1998 and 1999 respectively, maintaining 20x15 cm^2 plant spacing. The crop was harvested on 14, 15 and 17 May in 1997, 1998 and 1999, respectively. One weeding was done on 22 days after transplanting (DAT) in each year. Irrigation was done as and when necessary. To control "rice stem borer" Furadan 5G was applied at 10 kg ha^{-1} on 41 DAT in 1997 and Dimecron 100 EC was applied at 850 ml ha^{-1} on 43 DAT in 1998 and 48 DAT in 1999. Fertilizer dose was maintained as per treatment mentioned above. Entire amount of P_2O_5, K_2O, S and 1/3 N were applied during final land preparation. The rest of the N was applied with two equal splits at 23 and 45 DAT in each year.

Transplant aman rice (t. aman rice): Thirty eight days old seedlings of t.aman rice (monsoon rice) cultivar "BR11" were transplanted on 15, 17 and 17 July in 1997, 1998 and 1999, respectively maintaining 20x15 cm plant spacing. The crop was harvested on 10, 12 and 16 November in1997, 1998 and 1999, respectively. One weeding was done on 26, 20 and 20 DAT in 1997, 1998 and 1999, respectively. To control "rice stem borer", Dimecron 100EC was applied at 850 ml ha^{-1} on 45, 42 and 45 DAT in 1997, 1998 and 1999, respectively. Irrigation and other intercultural operations were done as and when necessary. Fertilizer dose was maintained as per treatment mentioned above. Entire amount of P_2O_5, K_2O, S and 1/3 N were applied during final land preparation. The rest of the N was applied with two equal splits on 26 and 45 DAT in each year.

The initial and final soil samples (after nine crops) were collected and analysed (Table 3). Data on grain and stalk/straw yield were recorded and mean values were adjusted by Duncan's multiple range test (Gomez and Gomez, 1976).

Results and Discussion

Grain yield of mustard was significantly higher over control (T_7) when the full recommended dose of fertilizer was received (Table 1). The result showed a similar trend over three cropping cycles. The maximum yield of mustard was found to be 0.85, 0.57 and 0.78 ton ha^{-1} in 1997, 1998 and 1999, respectively. Similar to mustard, application of full recommended dose of fertilizer to each subsequent boro (T_1 = 5.93, 5.90 and 5.30 ton ha^{-1} in 1996-1997, 1997-1998 and 1998-1999, respectively) and t. aman rice (T_1= 5.25, 4.93 and 4.71 ton ha^{-1} in 1996-1997, 1997-1998 and 1998-1999, respectively) also gave the highest yield. The results are in agreement with the findings of Anonymous (1986) in wheat–mungbean–t.aman rice cropping system. Nitrogen alone had a highly deleterious effect on the yield of each of the component

Table 2 : Marginal analysis of the dominant fertilizer treatments of the intensive Mustard-Rice-Rice cropping system (three years mean)

Treatments	Gross return (Tk ha^{-1})	Turn variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	Marginal gross margin (Tk ha^{-1})	Mraginal variable cost (Tk ha^{-1})	Benifit MRR (%)	Cost ratio
T1	70940	28245	42695	1644	280	587	2.51
T6	68576	27965	40611	90	1307	07	2.45
T2	67179	26658	40521	4505	478	942	2.52
T4	62195	26180	36015	981	1386	141	2.37
T3	59828	24794	35034	17614	1839	957	2.41
T7	40375	22955	17420	-	-	-	1.75

$$\text{MRR(\%)} = \text{Marginal Rate of Return (\%)} = \frac{\text{Marginal Gross Margin}}{\text{Marginal Variable Cost}} \times 100$$

Marginal gross margin = Additional increase in gross margin, Marginal variable cost = Additional increase in variable cost

$$\text{Benefit–Cost ratio} = \frac{\text{Gross Return}}{\text{Total Variable Cost}}$$

1$ = Tk. 48.41

crops of the cropping system over three cropping cycles, thereby indicating the need for balanced fertilizer application as it is popularly known to have mined other nutrients, particularly P and K. The results are in agreement with the findings of Abedin and Mukhopadhyay (1990). When the recommended dose of NPKS was given to preceding mustard, the application of P or K or PK or ½ PK along with full N (T_5 or T_4 or T_6 orT_2) applied to the subsequent boro rice gave a similar yield to when the recommended NPKS (T_1) was used over three cropping cycles. This result clearly indicated that there is a residual effect of P and K on the subsequent boro rice. But to stabilize the crop yield and to maintain the soil fertility, at least ½ PK along with full N must be applied to boro rice.

For the next following crop t. aman rice, application of only P or only K along with full N (T_5 or T_4) drastically reduced the grain yield (T_5 = 4.38, 4.25 and 3.78 ton ha^{-1} in 1996-199, 1997-1998 and 1998-1999, respectively; T_4 = 4.43, 4.22 and 3.92 ton ha^{-1} in 1996-1997, 1997-1998 and 1998-1999, respectively) over three cropping cycles, thereby indicating the need of both P and K fertilizer in t.aman rice crop. This can be further explained by the fact that when only P or only K in full dose (T_4, T_5) were not applied for two consecutive boro and t. aman rice, it significantly reduced the t. aman rice yield though preceding mustard received full dose of NPKS. This is again indicated the need for both P and K in t. aman rice crop. This might be due to heavy uptake of plant nutrient by exhaustive crop mustard (HYV) and boro rice (HYV) from a low fertile soil, the absence of P or K to t.aman rice fell short of its requirement. The application of full PK (T_6) or its reduced (50%) dose (T_2) along with full N gave statistically similar yield (T_6 = 5.06, 4.55 and 4.16 ton ha^{-1} in 1996-1997, 1997-1998 and 1998-1999, respectively ; T_2 = 4.97, 4.66 and 4.50 ton ha^{-1} in 1996-1997, 1997-1998 and 1998-1999, respectively) of t. aman rice to its recommended dose (T_1) after application of full NPKS to preceding mustard. Therefore, to stabilize the yield of t. aman rice, application of at least ½ P + ½ K along with full N (T_2) is most essential. Data again indicated that when the recommended dose of NPKS was applied to preceding mustard, whether S was not applied with NPK (T_6) to subsequent boro and t. aman rice, it gave a similar yield to their recommended (T_1) fertilizer dose, indicating that S had residual effect up to two crops. But to maintain the soil fertility and to stabilize the crop yield in future at least ½ S is essential for the subsequent boro and t. aman rice. Data were perfectly in line with the soil analytical data (Table 3), where organic matter was low (1.10%) with P-fixation problem in a relatively less acid soil (pH 5.4) with low available P (17 ppm) and exchangeable K^+ (0.24 me%) resulted response to even ½ P + ½ K in t. aman rice but no response was found when P or K or both were not applied. The results are in partial agreement with the findings of Abedin and Mukhopadhyay (1990) who reported that with low organic matter (1.14%) and low available P (10 ppm) there was a response to even ½ P applied to t. aman rice but no response was found for K (exchangeable K^+ 0.26 me%) in boro rice - t. aman rice cropping system. The stalk yield of mustard and straw yield of boro and t. aman rice followed a similar trend to the result of grain yield with minor deviations.

While considering economic performance of the treatment combinations based on cropping system (3 years mean) the result indicated that the highest gross return (Tk. 70940 ha^{-1}) and gross margin (Tk. 42695 ha^{-1}) were obtained when recommended rate of fertilizer

Table 3 : Soil analysis data at the end of nine crop seasons

	pH		Organic matter (%)		Available N (μ/g)		Available P (μ/g)		Exchangeable K [me (%)]		vailable S (μ/g)	
Treatments	Initial	Present*	Initial	Present*	Initial	Present*	Initial	Present*	Initial	Present*	Initial	Present*
T1	5.4	5.5	1.10	1.00	36	43	17	32	0.24	0.27	13	16
T2	5.4	5.3	1.10	1.00	36	41	17	27	0.24	0.25	13	16
T3	5.4	5.4	1.10	1.08	36	45	17	16	0.24	0.22	13	14
T4	5.4	5.2	1.10	1.09	36	47	17	24	0.24	0.23	13	17
T5	5.4	5.4	1.10	1.12	36	51	17	38	0.24	0.21	13	16
T6	5.4	5.3	1.10	1.10	36	44	17	33	0.24	0.25	13	14
T7	5.4	5.5	1.10	1.11	36	48	17	16	0.24	0.23	13	13

* Present : After the end of three cropping cycles (i.e. after nine crops season)
Initial: One composite soil sample was taken from the large plot before starting of the crop (Mustard).

was applied (T_1) for each crop (Table 2) (1 $ was ~ Tk.48.41). This was very close to the gross return (Tk. 67179 ha^{-1}) and gross margin which were obtained when reduced (50%) dose of P + K along with full dose of N were applied (T_2) in subsequent boro and t. aman rice after the application of full recommended NPKS in preceding mustard. This treatment (T_2) also gave the highest benefit cost ratio of 2.52. The lowest gross return, gross margin and benefit cost ratio were obtained when all the crops received only N fertilizer.

Marginal analysis of the dominant fertilizer treatments based on cropping system indicated that the highest marginal rate of return (MRR) of 957% was obtained from T_3 (full NPKS in preceding mustard and only recommended N to subsequent boro and t. aman rice) followed by T_2 (942%) and T_1 (587%) (Table 2). The treatment T_3 on the other hand gave very lower gross margin (Tk. 35034 ha^{-1}) and benefit cost ratio (2.41) with significant lower grain yield in t. aman rice compared with T_1 and T_2. The gross margin obtained from T_1 (Tk. 42695 ha^{-1}) was slightly higher than that of T_2 but having lower MRR (587%) and benefit cost ratio (2.51) compared with T_2. The gross margin (Tk. 40521 ha^{-1}) of T_2 [full NPKS in preceding Mustard and reduced (50%) dose of P + K with full N in subsequent Boro and t. aman rice] was very close to T_1 (full recommended NPKS to each crop) but having higher MRR (942%) and benefit cost ratio (2.52) than T_1 and statistically identical grain yield to T_1. Hence, from overall economic and agronomic performance this treatment (T_2) may be considered the most beneficial. Again, considering reduction of fertilizer cost, increased efficiency of applied fertilizer as well as to sustain soil fertility and to stabilize the crop yield, the treatment T_2 may be one of the best alternative.

It has been assumed from earlier discussion that the productivity of mustard–boro rice-t. aman rice cropping system was perfectly maintained or least affected by continuous application of full recommended dose of fertilizer in each crop or by full NPKS in preceding mustard followed by reduced (50%) dose of P + K along with full N to the succeeding boro and t. aman rice.

Data about the changes in soil fertility status indicated that the available N and P content of the soil have improved in most of the treatments after three years of crop cycle as against their initial values. The results are in agreement with the findings of Soni *et al.* (1988) in rice - wheat cropping sequence. In case of the control (N only), substantial improvement of soil N was observed which indicated lack of utilization of applied N in absence of P and K. Application of N only in cropping system heavily mined soil P-reserves with substantial drop in crop yield. A similar observation was also made by Abedin and Mukhopadhyay (1990). When full P along with full N and K was applied in each crop a considerable improvement in available soil P was observed. The sulfur contents of most of the treatments were either maintained or slightly improved. The soil pH and organic matter content were not affected by the fertilizer treatments, while the values of exchangeable K^+ over three years cycle were either maintained or declined. The decline was more appreciable in the control (N only) and in treatments where two consecutive crops (boro and t. aman rice) had not received any K fertilizer. Thakur *et al.* (1999) also observed K depletion in rice–rice cropping system.

In conclusion the application of full recommended dose of fertilizer to each crop of mustard - boro rice-t. aman rice cropping system was found good to stabilize the yield and soil fertility. However, considering the reduction of fertilizer cost and the increased efficiency of applied fertilizer as well as to sustain the soil fertility and the stability of the crop yield, the application of a full NPKS dose to the preceding mustard crop and a reduced (50%) dose of P + K along with a full N dose to the succeeding boro and t. aman rice may be a better alternative.

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