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Research Note

FARMERS' FERTILISER MANAGEMENT FOR IRRIGATED RICE :THE CASE OF THE GANGES KOBADAK PROJECT

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I. INTRODUCTION

About a quarter of the increase in rice production in Bangladesh between 1965-85 can be attributed to an increase in the use of chemical fertilisers (Hossain, 1985; Herdt and Capule, 1983). Despite the rapid increase in fertiliser consumption, however, the efficiency of fertiliser use remains low. According to one recent study , farmers produce only about 4.2 units of cereals per unit of fertiliser compared to an optimum productivity of about 9 units of cereals. Thus, farmers' yields in Bangladesh are only half of the potential (Hossain, 1985).

One explanation for such low efficiency is that farmers do not follow the recommended management practices. Fertiliser use efficiency depends on a variety of practices such as fertiliser rate, time and mode of application, weed control , water control, and other management factors. Farmers may have good reasons why they do not follow the recommended practices, or they may not know of them. Failure to follow the recommendations, however, lowers the efficiency of fertiliser use and increases the cost of rice production.

The objective of this study was to examine the efficiency, of fertiliser use in the Ganges-Kobadak (GK) Project. The GK Project is the largest surface irrigation scheme in Bangladesh. Phase l of the Project has a gross area of 85,000 ha of which about 42,000 ha is irrigable (MPO, 1987). Water is distributed by a network of secondary and tertiary canals. Irrigation is provided during the Aus and T. Aman seasons but not between mid-February to mid-November when the canals are repaired. Irrigation is essential for the

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cultivation of modern rice varieties (MVs) in the Aus season but in the Aman season it is supplementary to monsoon rainfall. About 65% of the irrigable area under MVs in the Aus season and about 80% under MVs in the T. Aman season. Thus, the GK Project provides a good case study of farmers' fertiliser practices for irrigated MV rice.

Recent research has revealed two puzzling features of fertiliser use in the Gk Project (BRRI/IRRI/BWDB, 1983, 1984, 1986). First , farmers use relatively high rates of nitrogen. The recommended fertiliser rate for a high yield of goal of 4.0–5.5 t/ha of MV Aus and MV T. Aman is 80–60–40 kg/ha of nitrogen (N), phosphorus (P), and potassium (K) (BARC, 1985). Farmers' fertiliser rates averaged 86–50 –31 kg/ha NPK for MV Aus and 93 – 49 – 29 kg/ha NPK for MV T. Aman (Orr et. al., 1989a, 1989b). Thus, farmers used the above recommended rate of nitrogen. Second, farmers' yields were low in relation to their fertiliser rates. In 1988/89, farmers reported yields of 2.9 t/ha for MV Aus and 3.7 t/ha for MV T. Aman. These yields were well below the 4.0–5.5 t/ha expected from the recommended fertiliser rate.

The specific objectives of this papers are to explain :

1. why farmers in the GK Project applied above the recommended rate of nitrogen; and

2. Whether low yield response to nitrogen was the result of poor fertiliser and water management.

II. METHODOLOGY

Two survey sites were purposively selected to represent tertiary canals at the head and tail of the Kushtia main canal. The two sites were located at tertiary 3 of secondary 4 (t_3/S4K), representing the head of the main cananl, and tertiary 2 of secondary 11 (T_2/S11K) representing the tail. At each site we selected farmers operating plots monitored by the BRRI/IRRI/BWDB project. The sample size was 77 famers in the Aus season and 76 in the Aman season. Data were collected by formal questionnaire survey and through case studies.

III. RESULTS AND DISCUSSION

Nitrogen Rates

Farmers in the GK Project applied nitrogen above the recommended rate. During the Aus season, the average rates of NPK applied by farmers to MV Aus were 86–50–31 kg/ha for BRI and 107–63–42 kg/ha for BR3. During the Aman season the average rate for MV T. Aman was 93-49–29 kg/ha NPK for BR11 and 96–47-30 kg/ha for BR10. The recommended fertiliser rate for a high yield goal under moderately fertile soil conditions is 80–60–40 kg/ha NPK (BARC, 1985).

The recommended nitrogen rate of 80 kg/ha derives from experiments conducted at research stations where conditions are very different from those found in farmers' fields. Under field conditions, nitrogen losses are expected to be higher and the recommended rate may thus be low.

To test the hypothesis that the recommended rate was low for farmers' field conditions, we compared the recommended rate with the optimum rate obtained from nationwide fertiliser trials in farmers' fields.

Yield response to nitrogen under farmers' field conditions was estimated using data from nationwide fertiliser trials conducted in 1970–75 and reported in Badruddoza (1976). Because of the small number of observations, the data were pooled and dummy variables used to separate the effect of variety and crop season. The equation was specified to estimate the response of yield to nitrogen. Accordingly, P and K were omitted as explanatory variables. The estimating equation is shown below :

$$YLD = b_0 + b_1N - b_2N^2 + b_3MV + b_4N \times MV + b_5 AMAN + b_6N \times AMA + U_t$$

Where

YLD = yield of paddy in kg/ha;

N = nitrogen in kg/ha;

N^2 = quadratic N ;

MV = dummy variable for modern variety (1=MV; 0=LV);

NxMV = interaction of N and MV;

AMAN = dummy variable for Aman season (1 = Aman; 0 = Aus);

N x AMAN = interaction of nitrogen and Aman; and

U_t = randomly distributed error term.

Table 1 shows the estimation results. The specification explained 90% of the variation in paddy yields. The Durbin–Watson statistic showed no autocorrelation. All the variables displayed the expected signs. Because of multicollinearity between the independent varialbes, however, the AMAN and N x AMAN variables were not statistically significant although they displayed the expected signs.

Table 1. Response of Rice (Paddy) to Nitrogen in Bangladesh.

Variable	Coefficient and T–Value
N	25.5933 (5.30) ##
N^2	-0.22 (-4.82) ##
MV	606.63 (2.60) ##
NXMV	12.83 (2.81) ##
AMAN	142.46 (0.60) ns
NXAMAN	1.59 (0.34) ns
INTERCEPT	1401.09
Adjusted R2	0.88
DW - Statistic	1.92
F-ratio	38.91

T- Values in parentheses
= significant at 1% level
ns= not significant

The equation can be interpreted as follows. Starting with a base yield of 1401 kg/ha, every unit (kg/ha) of N will add 26 kg/ha to paddy yields, with an average reduction of 0.44 kg/ha (2 x -0.2196) per additional unit of N. The equation shows a significant difference in the response of MVs and LVs to

nitrogen. MVs yielded 607 kg/ha more per unit of N than LVs. The interaction between MVs and N added a further 13 kg/ha to paddy yields. Finally, yields in the T.Aman season were 142 kg/ha higher than in the Aus season.

By substituting the appropriate values for N and the dummy variables in the equation we obtained the fertilizer response curves fof MV Aus and T.Aman. Maximum yield for MV Aus was 3,687 kg/ha at 90 kg/ha of N and maximum yield for MV T.Aman was 3,973 kg/ha at 92 kg/ha of N. Thus, the optimum rate of N under farmers' field conditions was higher than the recommended rate. We conclude that the recommended nitrogen rate of 80 kg/ha is low for farmers' field conditions.

To test the hypothesis that the notrogen rate in the GK was appropriate for farmers' field conditions, we compared the optimum rate from nationwide trials in farmers' fields with the rates used by farmers in the GK. We asked farmers to state their **optimum** rates of nitrogen and the expected yields from this rate.

Table 2 shows that farmers thought 195 kg/ha of urea (90 kg/ha N) was the optimum rate for MV Aus, and that with this rate of nitrogen they expected a yield of 3,811 kg/ha paddy. For MV. T.Aman, 201 kg/ha of urea (92 kg/ha N) was considered the best rate, and with this rate they expected a yield of 4,135 kg/ha paddy.

Table 2. Comparison of Farmers' Optimum Yields and Nitrogen Rates for MV Aus and MV. Aman in the Gk Project with those from Nationwide.

Kg / hectare

Season	Variable	GK Project	Bangladesh	T-values
Aus	Yield	3,811	3,687	1.31 ns
	N	89.7	90.2	-0.25 ns
T. Aman	Yield	4,135	3,973	1.48 ns
	N	92.5	91.0	0.60 ns

ns = not significant at 0.05 level.

The hypothesis that there was no significant difference between the rates and yields from notionwide trials and farmers' optimum rates was tested using the t–test for hypothesised means. The results in Table 2 show that there was no significant difference between the rates. Similarly, there was no significant

difference in yields. Thus, we conclude that farmers in the GK used the appropriate rate of nitrogen for MV rice.

The problem in the GK, therefore, is not that farmers use too much nitrogen; the problem is why yield response to nitrogen is so low.

Table 3 shows farmers' actual nitrogen rates and yields for the 1988–89 Aus and Aman seasons. The table shows that farmers' **actual** yields averaged 2.9 t/ha for MV Aus and 3.7 t/ha for MV T.Aman. These were significantly lower than the **optimum** yields farmers reported in Table 2 (3.8 t/ha for MV. Aus and 4.1 t/ha for MV T.Aman) .

Table 3. Farmers' Actual Yields and Nitrogen Rates in the Gk Project, Aus and T. Aman Seasons, 1988-89.

(kg / ha)

Season	Variable	Head	Tail	Average
Aus	Yield	2,477	3,295	2,923
	N	87	91	89
T. Aman	Yield	3,049	4,154	3,660
	N	85	109	98

Note : Head = T3/S4k;
Tail = T6/S11k.

Table 3 also shows that yield response to nitrogen in the GK was significantly lower at the head of the Kushtia main canal than at the tail. In the Aus season, farmers at the head applied the same amount of nitrogen as farmers at the tail, but obtained significantly lower yields. In the Aman season, farmers at the head applied significantly less nitrogen than at the tail and obtained significantly lower yields. Thus, farmers at the tail of the canal obtained a more favourable response to nitrogen than farmers at the head.

EXPLAINING LOW YIELD RESPONSE

Three hypotheses were formulated to explain low yield respose to nitrogen in the GK Project :

1. Poor fertiliser management;

2. Poor water management leading to nitrogen loss; and

3. Micronutrient deficiency.

Socio–economic factors may also influence fertiliser use and thus rice yields. An analysis showed no significant difference in average nitrogen rates between large, medum, and small farms at our two survey sites. Sharecropped plots received significantly more nitrogen than owner–operated plots in both the Aus and Aman seasons. Landlords normally shared half the cost of fertiliser with their tenants, and this may have encouraged higher rates. There was no significant difference in land tenure between our two survey sites, however, and this finding does not affect the comparison between head and tail of the canal (Orr et. al., 1989a, 1989b).

Fertiliser Management

Although farmers in the GK apply the appropriate rate of nitrogen, they may not follow the recommended management practices. To test the hypothesis that low yield response to nitrogen was the result of poor fertiliser management, we correlated yields with selected management practices. These included split application of urea (basal and two topdressings); use of triple superphosphate (TSP) and muriate of potash (MP); mulching after topdressing; and date of topdressing.

Table A-1 shows the correlation matrix. The significance of the correlation coefficients was judged by comparing the computed value of the linear coefficient , r, against the tabulated value at the 5% level of significance. Where the computed r value exceeded the tabular r value we concluded that the linear correlation coefficient was significantly different from zero at the 5% probability level.

The significance of a simple correlation coefficient is equivalent to significance of the coefficients on the independent variable in a simple linear regression. Inspection of the row for total yield per hectare (YIELD) shows that the following five variables would give significant coefficients in simple linear regressions with YIELD as the dependent variable: location at head or tail of the canal (LOCATION), the zero-one variable for mulching after second topdressing (MULCH 2), date of second topdressing (TD2DAT), the quantity of TSP (TSP), and the rate of urea at first topdressing (TD1). The variables are listed in order

according to the absolute magnitude of the correlation coefficient. All the coefficients were positive except for date of second topdressing.

Table A-2 shows the correlation matrix for yields and fertiliser management practices in the Aman season. This time, only location and urea fertiliser levels (UREA, TD1, TD2) were significantly correlated with yield.

These results do not suggest that poor fertiliser management was the primary cause of the low yield response to nitrogen in the GK Project. Firstly, the single most important factor correlated with YIELD was LOCATION at the head or tail of the canal. In the Aus season, Table 4 shows that 18% of the variation in yield was accounted for by location. In the Aman season, Table 5 shows that 37% of the variation in yield was accounted for by location.

Secondly, although higher yields were associated with higher rates of nitrogen in the Aman season, and with higher rates of TSP in the Aus season, this does not necessarily mean that farmers at the head could obtain higher yields by simply increasing fertiliser rates. Farmers at the head and tail of the canal seem to be operating on different fertiliser response curves . In the Aus season , farmers at the head applied the same quantity of nitrogen as farmers at the tail but obtained lower yields . In the Aman season, they applied significantly less nitrogen than farmers at the tail and obtained lower yields (Table 3). In both seasons, however, farmers at the head applied what they believed to be the optimum nitrogen rate.

Thirdly, the other management practices significantly correlated with yield (mulching urea after second topdressing, and date of second topdressing) were also correlated with location at the tail of the canal. More farmers at the tail mulched urea after second topdressing. This may have contributed to higher yields at the tail. But farmers at the tail also applied a second topdressing later than farmers at the head. This practice was negatively correlated with yield and reduced yields at the tail .

We conclude that the evidence does not support the view that higher yields at the tail reflected better fertiliser management. Rather , it suggests that farmers at the tail operated on a different yield response function and applied more nitrogen because they could obtain higher yields.

Water management

Another explanation for low yield response to nitrogen in the GK Project is poor water management resulting in nitrogen loss. Two important sources of nitrogen loss in farmers' fields are ammonia volatilization and surface runoff. Nitrogen losses through both mechanisms may be high in the GK Project. Firstly, few farmers drain their fields before applying fertiliser or incorporate urea after broadcasting. Farmers in the GK may be unwilling to drain their fields if they are uncertain about future water supplies. Similarly, they often cannot impound irrigation water because this interfers with other farmers seeking water for their crops. Secondly, farmers use more water than they really need. Experiments by the BRRI/IRRI/BWDB project show that, on average, farmers used 25% more water than necessary in the Aus season and 20% more in the Aman season (Orr et. al. ,1989a, 1989b). Thus, poor water management practices may encourage high rates of nitrogen loss.

To test the hypothesis that poor water management practices led to nitrogen loss, we correlated farmers' yields at the head and tail of the Kushtia main canal against depth of water in the plot during fertilisation and runoff during fertilisation. Draining water from the plot before fertilisation was not included as an explanatory variable because very few farmers reported this practice. Information on water levels during fertilisation and on runoff was obtained by farmer recall. Since we wished to determine the effect of nitrogen loss on yields, the correlations were made only for those farmers who applied fertiliser.

Table 4. Correlations Between Yield and Water Management Practices, Gk Project, Aus Season, 1988-89.

Variable	Fertiliser Application		
	Basal	First Topdress	Second Topdress
Yield	1.000	1.000	1.000
Water depth	0.109	0.026	0.227 *
Runoff	0.230	0.089	- 0.260 *
Location	0.495 *	0.456 *	0.393 *

Sample Size : basal application 26; first topdress : 75 second topdress : 62.

* = significant at .05 level.

Table 4 shows the results for the Aus and Aman seasons. The table shows that, in the Aus season, there was no significant correlation between water depth and runoff during basal application of urea or during first topdressing. During second topdressing, however, water depth and runoff were **positively** correlated with yield . This was because, contrary to expectation, the highest water level during fertlisation and the highest incidence of runoff were found at the tail end of the canal. More farmers at the tail grew MV rice on low-lying plots in order to reduce the risk from low water supply or untimely deliveries later in the season. Because yields were higher at the tail, higher water levels and a higher incidence of runoff were correlated with higher yields.

Results were essentially the same for the Aman season (Table 5). . This time, water depth and runoff during basal application, first topdressing, and second topdressing, were all positively associated with yield. Again, this was explained by higher water levels and incidence of runoff at the tail of the canal, for the reasons given above.

Table 5. Correlations Between Yield and Water Management Practices, Gk Project, Aman Season, 1988-89.

Variable	Fertiliser Application		
	Basal	First Topdress	Second Topdress
Yield	1.000	1.000	1.000
Water depth	0.424 *	0.476 *	0.388*
Runoff	na	-0.230 *	- 0.226 *
Location	0.654 *	0.611 *	0.597 *

Sample Size : basal application: 22: first topdress : 76: second topdress : 74.

* = significant at .05 level.
na= not available.

We conclude that poor water management leading to nitrogen loss did not explain low yield response to nitrogen in the GK project. Water levels and runoff were highest at the tail of the canal where yields were also higher than at the head.

Micronutrient deficiency

Since low yield response to nitrogen cannot be easily explained by poor fertiliser management, or by poor water management leading to nitrogen loss, the most likely explanation seems to be micronutrient deficiency .

Sulphur and zinc deficiencies have been widely reported in Bangladesh. According to recent estimates, 3 million acres are deficit in sulphur and 4 million acres deficit in zinc (Zaman, 1987). Shortages of micronutrients are particularly severe in irrigated rice land (Andriesse, 1982).

Several findings point to micronutrient deficiency. Firstly, soil analyses showed that soils at our survey sites were calcareous, moderately alkaline (pH 7.9–8.4) and with low organic matter (1.3 – 1.8 %), (BRRI/IRRI/BWDB, 1986). These are factors associated with zinc and sulphur deficiency (BRRI, 1984a, 1984b, Mazid, 1986).

Secondly, our survey data showed that very few farmers applied zinc or sulphur to MV rice. In the Aus season, none of the sample farmers applied sulphur and only 8 (10%) applied zinc. In the Aman season, none applied sulphur and only 13 (17%) applied zinc.

Thirdly, experiments conducted by BRRI's Water Management Division suggested to existence of sulphur and zinc deficiencies at our survey sites. In the 1988 Aman season , experiments at the head of the canal showed that the addition of 20 kg/ha zinc increased yields of MV T. Aman by over 20% (BRRI, 1989, Table 4). Similarly , in the 1989 Aus season , experiments at the head of the canal showed that the application of 20 kg/ha zinc and 25 kg/ha sulphur increased yields of MV Aus by 45% (BRRI, 1990, Table A-2).Interestingly, there was no comparable response to zinc and sulphur at the tail of the canal. This is consistent with our survey results which showed that yield response to nitrogen was higher at the tail. Previous studies have also noted low levels of zinc and sulphur in the GK (Andriesse, 1982 ; Ali et. al., 1986). A study conducted in 1981 showed " critical and below--critical levels of Zn and S in almost all of the samples, wheather they were sampled on control (healthy plants) or as Zn and S deficiency specimens "' (Andriesse, 1982.)

IV. CONCLUSIONS

Two main conclusions emerge form this case study of fertiliser management for irrigated rice in the Ganges–Kobadak Project.

Firstly, the recommended rate of 80 kg/ha of nitrogen is too low for farmers' field conditions . The technically efficient level of nitrogen under farmers field conditions was estimated as 90 kg/ha for MV T. Aus and 93 kg/ha for MV T. Aman. These were also what farmers regarded as the **"optimal"** nitrogen rates Thus recommended fertiliser rates based on yields under controlled conditions should be adjusted to reflect the conditions found in farmers' fields, and tailored to suit different locations.

Secondly, although farmers in the GK Project applied the appropriate rate of nitrogen to MV Aus and Mv T. Aman, yield response to nitrogen was low, especially at the head of the Kushtia main canal. Our analysis suggested that low yield response was not due to poor water management or to nitrogen loss caused by poor water management but to deficiency of micronutrients , particularly sulphur and zinc. Very few farmers in the GK Project applied these micronutrients to their rice crops. Micronutrient deficiency was most severe at the head of the Kushtia main canal, where yields were significantly lower than at the tail. This may reflect the greater incidence of waterlogging at the head. We conclude that to increase yields of irrigated rice in the GK Project it will be necessary to convince farmers of the benefits from applying sulphur and zinc to MV rice.

The case of the GK Project suggests that without effective management of micronutrient deficiencies, particularly sulphur and zinc, yields from irrigated MV rice may be higher than yields under rain fed conditions. The government's current strategy to increase foodgrain production by expanding the area under minor irrigation will require carefull attention to such deficiencies if the expected yield gains from irrigated rice are to be realised.

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Table A-1: Correlation matrix of yield and selected management practices. GK Project , Aus Season, 1988-89. 51

	Yield	Location	Urea	Basal	TD1	TD2	TSP	MP	Mulch1	Mulch2	D1DAT	TD2DA
Yield	1.000											
Location	0.427 *	1.000										
Urea	0.160	0.226 *	1.000									
Basal	-0.031	0.326 *	0.045	1.000								
TD1	0.189 *	0.046	0.214*	0.172	1.000							
TD2	-0.071	0.218*	0.657*	-0.255*	-0.188	1.000						
TSP	0.201*	0.188	-0.008	-0.163	0.153	-0.050	1.000					
MP	0.143	0.269*	0.094	-0.287*	0.229 *	-0.011	0.782 *	1.000				
Mulch1	0.159	0.192*	-0.022	-0.016	0.075	0.116	0.054	-0.074	1.000			
Mulch2	0.251*	0.022	0.316*	-0.250*	0.305 *	0.668 *	-0.121	-0.166	0.055	1.000		
TD1DAT	0.115	-0.128	0.082	0.146	0.481 *	-0.149	0.058	0.095	0.059	-0.140	1.000	
TD2DAT	-0.247	-0.082	0.338*	-0.234*	0.215 *	0.69 *	-0.063	-0.135	-0.044	0.803 *	0.032	1.000

Sample Size= 77
* = Significant at 5% level.
Critical Value (1 tail, .05) = + or - .189
Critical Value (2 tail, .05) = +/- .224
VARIABLES :
LOCATION : Dummy variable for location on canal (Head=0; Tail=1);
Urea : Total quantity of urea.
BASAL : Quantity of basal urea;
TD1 : Quantity of urea applied at first topdressing;
TD2 : Quantity of urea applied at second topdressing
TSP : Quantity of TSP;
MP : Quantity of MP;
Mulch 1 : Dummy variable for mulching after first topdressing (0=No;1=Yes);
Mulch2 : Dummy variable for mulching after second topdressing (0=No;1=Yes);
TD1DAT : Date of First topdressing:
TD2DAT : Date of second topdressing;

Table A -2. Correlation matrix of yield and selected management practices. GK Project , Aman Season 1988-89.

	Yield	cation	Urea	Basal	TD1	TD2	TSP	MP	Mulch1	Mulch2	D1DAT	TD2DA
Yield	1.000											
Locatio	0.611*	1.000										
Urea	0.486*	0.395*	1.000									
Basal	0.161	0.075	0.500*	1.000								
TD1	o.405*	0.218 *	0.797*	0.192*	1.000							
TD2	0.472*	0.500*	0.713*	0.123	0.376*	1.000						
TSP	0.080	0.241*	0.240*	0.225*	0.143	0.279*	1.000					
MP	0.115	0.370*	0.187	0.205*	0.099	0.258*	0.724*	1.000				
Mulch1	0.068	0.224*	-0.038	-0.050	-0.121	0.073	0.099	0.139	1.000			
Mulch2	0.074	0.081	0.073	0.152	-0.124	0.245*	0.243*	0.086	0.020	1.000		
TD1DAT	0.103	-0.068	-0.022	-0.019	0.203*	-0.170	-0.036	-0.085	-0.076	-0.096	1.000	
TD2DAT	0.128	0.178	0.238*	0.051	0.192*	0.327*	0.104	0.018	-0.062	0.516*	0.275*	1.000

Sample Size= 76

* = Significant at 5% level.

Critical Value (1 tail, .05) = + or - .1902

Critical Value (2 tail, .05) = +/- .22550

VARIABLES : See Table 4