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Impact of tubewell electrification and water management practices on *Boro* rice cultivation

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Abstract

A study was conducted to evaluate the impact of electrification of irrigation tubewells on farmers economy of *boro* rice production during 2002-2003 in Jamalpur district. Thirty electrified tubewells (20 shallow tubewells and 10 deep tubewells) and ten non-electrified shallow tubewells were randomly selected in the study area for evaluation purpose. It was evident that the owners of electrified tubewells were highly benefited from water selling to the farmers who were also more benefited than the farmers under non-electrified tubewells from their *boro* production. To see the water management effect, a field experiment was also carried out considering four irrigation treatments with three replication following the Randomized Block Design (RBD) in the same study area. In the experimental plots seedlings of BRRI Dhan 28 (Boro) were transplanted on 31 January 2003 on silty loam soil and they were harvested on 9 May 2003. The results showed that the yield and yield contributing characters of *boro* rice were significantly influenced by different irrigation treatments. The highest grain yield of 6.35 t/ha was obtained in treatment T_1 (Farmers' practice) using 1334 mm irrigation water. Alternatively the treatments T_4 (alternate wetting and drying), T_3 (irrigation at saturation) and T_2 (2-5 cm standing water) saved about 30, 20 and 8 percent of valuable water by sacrificing only 11, 6 and 1 percent of yield, respectively than that of treatment T_1. Thus, from the experimental findings, it revealed that T_4 was the best among all treatments for saving the costly irrigation input as well as for getting reasonably higher yield.

Keywords: Electrified tubewell, Water management, *Boro* rice, Water use efficiency

Introduction

In Bangladesh, about four million hectares of land has been brought under irrigation. Rice is cultivated to about 82 percent of total irrigated land and about 88 percent of the irrigated rice cultivation area is being covered by *boro* rice during dry winter period (BBS, 2000). Emphasis is given to grow more irrigated *boro* rice to meet the present food deficit (Saleh, 1987). *Boro* rice cultivation faces less natural disaster compared with *aus* and *aman*. So, the farmers are gradually inclined to cultivate *boro* rice. *Boro* rice cultivation under continuous standing water is a usual practice to the growers. Due to the lack of effective rainfall, huge amount of irrigation water is required in *boro* season. In Bangladesh about 50 percent irrigation water is lost through leakage, seepage and percolation (Biswas *et al.*, 1984). The increasing cost of tubewell operation and irrigation are the consequence of these losses. Irrigation requirement for *boro* rice is fulfilled through the use of 7,79,137 STWs, 32,941 DTWs, 80,044 LLPs and other traditional methods (NMIDP, 2001). Diesel engine or electric motor usually operates these irrigation equipments. The necessity and popularity of electric motor is increasing day by day because of its low operational cost (Mandal, 1989) as well as increasing cost of fuel for engines. About one million hectares of land is irrigated through 1,03,980 electrified tubewells (STWs, DTWs and LLPs) under Rural Electrification Board (REB, 2002). Rainfall scarcity during *boro* season severely declines groundwater table; on the other hand, power demand for all the sectors is increasing day by day. For this, efficient and effective use of water together with power in the field of agriculture is very important.

Therefore, with the above views in mind, an attempt was made to evaluate the impact of electrification of tubewells on farmers economy and different water management practices on yield and water use efficiency of *boro* rice production.

Materials and Methods

A study was conducted during 2002-2003 *boro* season in Jamalpur district to find out the owners' and farmers' benefit due to electrification of tubewells. Considering the density of electrified tubewells, water availability, land suitability and intensity of *boro* rice production, the area was selected for this study. The relevant information was collected from Palli Bidyut Samity (PBS) and Department of Agricultural Extension (DAE), Jamalpur. In order to fulfil the objectives of the study a set of questionnaire was developed and the owners, farmers, drivers, fieldmen and managers were interviewed for different information related to the study. The items of total cost were investment cost (capital cost, cost of pump house construction, installation cost), operation and maintenance (O&M) cost, seasonal electrical service charges and production cost. The investment cost was neglected for avoiding complexity of the study. The data were collected, simplified and analysed in order to bring them into useful form. The irrigation cost, electrical energy consumption, actual command area, cost-benefit analysis were determined for different soil conditions from the viewpoint of owner of the tubewells and farmers.

In addition, an experiment was conducted in the farmers' field to study the effect of different water management practices on yield and yield contributing characters for BRRI Dhan28 under three electrified STWs at Sadar Upazilla under Jamalpur district during the period from 20 January 2003 to 9 May 2003. Texturally, the soil was silty loam and average p^H value was 6.57 indicating the soil as acidic in nature. The following water management treatments were maintained in the field experiment:

T_1 = 2 to 5 cm continuous ponding depth of water up to vegetative stage and 2 to 7 cm continuous ponding depth for the rest part of the growing period (farmers' practice)
T_2 = Continuous ponding depth (2 to 5 cm) of water throughout the growing period of crop
T_3 = 3 cm water was applied after reaching of saturation condition
T_4 = 5 cm water was applied after appearing of hairy crack (alternate wetting and drying)

The experimental plots were laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 4m x 5m (20 m^2). After final land preparation, the field layout was made on 31 January 2003. For seepage control 24 cm compacted dikes were made. Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate at the rate of 220, 120, 85, 60, 10 kg/ha, respectively, were used. On 31 January 2003, forty days old seedlings of BRRI Dhan28 were transplanted in each plot at the rate of 4 seedlings per hill with 16 cm x 20 cm spacing. Intercultural operations were made as and when required. Water was applied to each plot according to the scheduled treatment. No water stress was given at crop establishment period (till 15 Days After Transplanting). The crop was harvested at their full maturity. Plant height, number of tillers/hill, number of productive tillers/hill, panicle length, number of grains/panicle, number of unfilled spikelets/panicle, 1000-grain weight, grain yield, straw yield, harvest index data were recorded. The collected data were analyzed using "Analysis of variance" technique with computer M-Stat package program and the least square differences were adjudged. A regression analysis of the experimental data was also done. Field and Crop water use efficiency of *boro* rice was calculated with the following formulae (Michael, 1978):

$$\text{Field water use efficiency} = \frac{Y}{WR}$$

$$\text{Crop water use efficiency} = \frac{Y}{ET}$$

where,
Y= Crop yield
WR= Total amount of water required in the field for boro rice production
ET = Evapotranspiration
Now, ET can be obtained as:
$ET = I + ER - RO - S\&P - LP$
where,
I = Total irrigation water
ER = Effective rainfall
RO = Runoff
S&P = Seepage and percolation
LP = Water required for land preparation

Amount of irrigation water applied in each treatment, water required for land preparation, rainfall, evaporation, temperature data were recorded. Standard values of seepage and percolation for particular soil and water level were assumed. Runoff was neglected.

Results and Discussion

The electricity bill and consumption of electrical energy during *boro* season (January to May) were 88.19 and 91.56 percent of the total electricity bill and the total consumption of energy in all the irrigation seasons, respectively (Table 1).

Table 1. Electricity bill and electrical energy consumption for *boro* rice production in Jamalpur district during 2002-2003 *boro* season

Electrical bill (Total), Tk.	Electricity bill (*boro*),Tk.	Percent of Total bill (%)	Electrical energy (Total), kWh	Electrical energy (*boro*), kWh	Percent of total electrical energy (%)
2,25,40,708	1,98,77,533	88.19	70,33,867	64,40,498	91.56

Table 2 shows the command area covered under different types of soil and irrigation cost in the study area. It was evidenced that the highest actual command area (29.50 ha) was covered under DTWs in clay loam soil and the lowest (2.50 ha) under STWs in sandy loam soil. Actual command area was found to be lower than the potential command area of 40 ha for DTW and 8 ha for STW (NMIDP, 2001). This reduction might be due to poor water management practices and high density of tubewells. The lowest irrigation cost of Tk.1,808/ha and energy consumption of 334 kWh/ha were found under DTWs in clay loam soil and the highest values of Tk.3,717/ha and 684 kWh/ha were found under STWs in sandy loam soil. This result indicated that the owners of electrified tubewells enjoyed more profit from water selling to the farmers. This is in conformity with the findings of Mandal (1986) who found that the owners were making huge profits annually by selling water.

Table 2. Command area, irrigation cost, energy consumption and net profit of the owners for water selling under electrified irrigation system for *boro* rice production in various soils

Soil type	Deep tubewells				Shallow tubewells			
	Command area, ha	Irrigation cost, Tk./ ha	Energy consumption kWh/ ha	Net profit for water selling Tk./ ha	Command area ,ha	Irrigation cost, Tk./ ha	Energy consumption kWh/ha	Net profit for water selling Tk./ ha
Clay loam	29.50	1,808	334	3,132	5.60	2,314	460	3,367
Silt loam	26.00	2,569	463	2,618	3.67	2,873	541	3,055
Sandy loam	20.50	2,802	524	2,632	2.50	3,717	684	2,454

Table 3 indicates that the farmers under non-electrified shallow tubewells had to bear the highest average production cost (Tk.26,328/ha) because of the highest irrigation charges and the lowest average production cost was (Tk.24,187/ha) for the farmers under electrified DTWs among all group of farmers. The average net return of the farmers under electrified DTWs and STWs and non-electrified STWs were Tk.10,955, Tk.10,213 and Tk.8,814 per hectare, respectively. The farmers obtained the highest net return in silt loam soil due to higher *boro* yield. The farmers under electrified tubewells were more benefited than the farmers under non-electrified tubewells. This result agrees with the findings of Islam (2000) who reported that motor operated tubewells were more profitable than that of engine operated. The highest and the lowest benefit-cost ratio for *boro* production were 1.51 in silt loam soil under electrified deep tubewells and 1.31 in sandy loam soil under non-electrified shallow tubewells, respectively.

The effects of different water management treatments on the yield contributing characters are summarized in Table 4. Yield contributing characters were significantly influenced by different irrigation treatments. The highest plant height (104.54 cm) was recorded from farmers' practice treatment (T_1) and the lowest (95.24 cm) in alternate wetting and drying treatment (T_4). It might be due to poor water management practices, sharing of water and nutrients with enormous weeds. At harvest, the maximum number (15.98) of tillers/hill was observed under treatment T_1 which was followed by treatment T_2 and treatment T_3 and the minimum number (14.51) of tillers/hill was observed in treatment T_4. The number of effective tillers/hill was significantly influenced by different irrigation treatments. The maximum number (12.10) of tillers/hill was found in treatment T_1 which was followed by treatment T_2. The lowest (11.46) number of effective tillers/hill was observed in treatment T_4. The increase of effective tillers/hill in treatment T_1 with water might be due to less weed density and water availability. The results are in conformity with the findings of Krisnamurty *et al.* (1980) who found that the continuous submergence produced the maximum number of productive tillers. The panicle length obtained under different treatments was statistically insignificant. However, the highest panicle length (20.28 cm) was observed in treatment T_1 and the lowest in treatment T_4 (19.45 cm). The reduction of panicle length in treatment T_4 might be due to insufficient photosynthesis from the less crop canopy and reduced leaf area for reduced water supply. The number of grains/panicle was significantly affected by different water management treatments. The highest number of grains/panicle was (71.89) found in treatment T_1 and treatment T_4 gave the lowest (67.81) number of grains/panicle. The result is in agreement with the findings of Stone *et al.* (1985) who stated that water stress reduced the number of grains/panicle. A significant variation was observed in the number of unfilled spikelets/panicle among different water treatments. The highest (17.10) number of unfilled spikelets/panicle observed in treatment T_4 might be due to water stress. The lowest (15.52) number of unfilled spikelets/panicle was obtained in treatment T_1. Weight of 1000-grain was significantly affected by different water treatments. Treatment T_1 produced the highest (23.84 g) 1000-grain weight. The lowest (22.62 g) 1000-grain weight was obtained in treatment T_4 which was statistically similar to treatment T_3. This result agrees with the findings of Morales *et al.* (1989) who stated that 1000-grain weight and grain yield increased with increase in water availability.

Table 3. Production cost (Tk./ha), net return (Tk./ha) and benefit-cost ratio (BCR) of *boro* growers under electrified and non-electrified tubewells in different soils

Soil type	Electrified deep tubewells			Electrified shallow tubewells			Non-electrified shallow tubewells		
	Production cost	Net return	BCR	Production cost	Net return	BCR	Production cost	Net return	BCR
Clay loam	23940	10010	1.41	24681	9269	1.37	25916	8034	1.31
Silt loam	24187	12363	1.51	24928	11622	1.46	26410	10140	1.38
Sandy loam	24434	10491	1.42	25175	9750	1.39	26657	8268	1.31
Average	24187	10955	1.45	24928	10213	1.41	26328	8814	1.35

Table 4. Effect of irrigation water level on different yield contributing characters of *boro* rice

Treatments	Plant height (cm)	Total No. of tillers/hill	Effective No. of tillers/hill	Panicle length (cm)	Grains per panicle	Unfilled spikelets per panicle	1000-grain weight (g)
T_1	104.54a	15.98a	12.10a	20.28	71.89a	15.52b	23.84a
T_2	104.00a	15.81a	12.04ab	20.18	71.30a	15.95b	23.72ab
T_3	99.46b	15.06ab	11.77bc	19.96	68.79b	16.78a	23.10bc
T_4	95.24c	14.51b	11.46c	19.45	67.81b	17.10a	22.62b
LSD	2.27	0.990	0.409		2.223	0.698	0.622
Level of significance	0.05	0.05	0.05	NS	0.05	0.05	0.05

Table 5 shows that effect of irrigation water level on yields and water economy of *boro* rice. Grain yield was significantly affected by different water management treatments. Treatment T_1 produced the highest (6.35 t/ha) grain yield and treatment T_4 gave the lowest (5.68 t/ha) grain yield. The highest grain yield obtained in the treatment T_1 was due to the highest values of yield contributing characters as effective tillers/hill, panicle length, grains/panicle and 1000-grain weight. Morales *et al.* (1989) also reported similar results. Irrigation water level significantly influenced straw yield. Treatment T_1 produced the highest (5.04 t/ha) straw yield. The lowest (4.21 t/ha) straw yield was found in treatment T_4. The reduction of straw yield was due to the lowest tillers/hill and plant height. Harvest index was significantly affected by different water management treatments. Treatment T_4 gave the highest (57.48) harvest index and the lowest (55.78) was obtained in treatment T_1.

Tables 5. Effect of irrigation water level on yields and water economy of *boro* rice

Treatments	Grain yield t/ ha	Reduction of grain yield (%) over the maximum	Straw yield T/ ha	Harvest index (%)	Irrigation water applied (mm)	Saved from farmers' practices (%)	Water use efficiency (kg/ ha-mm)	
							Field	Crop
T_1	6.35a	-	5.04a	55.78b	1334	-	4.76c	15.05b
T_2	6.30a	0.79	4.98a	55.75b	1230	7.80	5.12c	15.56a
T_3	5.94ab	6.46	4.50ab	57.18a	1062	20.39	5.60b	15.63a
T_4	5.68b	10.55	4.21b	57.48a	930	30.28	6.11a	15.78a
LSD	0.414		0.316	1.140			0.400	0.350
Level of significance	0.05		0.05	0.05			0.05	0.05

In a column the figures bearing same letter(s) or without letter are identical and those having dissimilar letter(s) differed significantly.
NS = Not significant

From table 5 it was found that the maximum amount (1334 mm) of water was applied in treatment T_1. It further showed that the reduction of total applied water in treatment T_4, T_3 and T_2 was about 30, 20 and 8 percent which sacrificed only 11, 6 and 1 percent of yield, respectively, compared to treatment T_1. Water use efficiency was significantly affected by different water management treatments. The highest field water use efficiency (6.11 kg/ha-mm) was obtained in treatment T_4 and the lowest (4.76 kg/ha-mm) in treatment T_1. Similarly the highest (15.78 kg/ha-mm) crop water use efficiency was found in treatment T_4 and the lowest (15.05 kg/ha-mm) in the treatment T_1. Similar result was observed by Dubey (1995) who stated that less water was required (as compared with continuous flooding) for rice production under intermittent flooding condition which resulted higher water use efficiency.

Relationship between total water used and grain yield of the field experiment is shown in Figure 1. Moreover, Table 6 shows the relationship between grain yield and yield contributing characters of *boro* rice. The results revealed that grain yields were significantly positively correlated with straw yield (r=0.896), plant height (r=0.795), number of effective tillers/hill (r=0.615), number of grains/panicle (R=0.896), 1000-grain weight (r=0.484) and total water used (r=0.822).

Table 6. Correlation coefficient between various characters vs. grain yield

Characters	Correlation coefficient
Straw yield vs. grain yield	0.896
Plant height vs. grain yield	0.795
Number of effective tillers/ hill vs. grain yield	0.615
Number of grains/ panicle vs. grain yield	0.896
1000-grain weight vs. grain yield	0.484
Total irrigation water vs. grain yield	0.822

Therefore, the experimental results lead to suggest that for *boro* rice cultivation irrigation practice of saturation to alternate wetting and drying saves 20 to 30 percent of the costly irrigation input which sacrifices only 6 to 11 percent of the yield. Thus, the finding would bring manifold results as: (a) This practice could bring more lands under cultivation with the saved water, (b) Farmers would be more benefited with less water cost and overall project yield would be increased, (c) It would ensure the judicious use of irrigation water by reducing its wastage, (d) Irrigation cost would be reduced, (d) Electrical energy would be saved for less water pumping and (e) Finally, optimum and economic water withdrawal would save the valuable groundwater resources thereby protecting the environmental hazards.

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