Opportunities of Water Saving and Cost Reduction in Irrigated Boro Rice at Farmers' Level in Bangladesh

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KEYWORDS
Boro rice irrigation, Alternate wetting and drying (AWD) method, Irrigation cost.

ABSTRACT:
Boro rice, which is almost entirely irrigated, contributes to about 60% of the total rice production in Bangladesh. With decreasing water availability for irrigation and increasing demand for rice, the future prospects of irrigated rice production is at a crossroad. The high cost of rice cultivation in the recent years has been aggravated due to the ever-increasing price of fuel. To cope with these emerging issues, many researchers have been conducted on technologies that improve the irrigation water use efficiency. Most of the research works on irrigation water saving techniques including the alternate wetting and drying (AWD) method have been limited to individual field experiments and/or simulation models, and the farmers who would be the ultimate users of the technology have remained as bystanders. The study was conducted at the farmers' field in the eight different upazilas (sub-district) of north-west region of Bangladesh during the Boro season. In this study two strategies of AWD were superimposed on the farmers' present field water status; to apply irrigation only when the standing water level falls to 10 cm below the field level and to re-irrigate five days after the disappearance of standing water. The average irrigation water savings with AWD techniques varied from 10% to 28%. The corresponding reductions in irrigation costs were about 11% to 29%, respectively. The farmers' survey revealed that the uncertainty in irrigation water availability and infestation of weeds are the two major constraints to the adoption of AWD method. But, the farmers are willing to adopt the AWD technology gradually keeping their present practice at the critical crop growth stages.

1. INTRODUCTION

Irrigated Boro rice, which produces about 60% of the total rice production, has been and would continue to be the mainstay of agricultural development in Bangladesh. But with the spiraling cost of irrigation, which is now the highest among the regional countries and ranges from USD 100 to 150 per hectare (Bosworth et.al., 2002; BADC, 2005), may thwart the future development of irrigation. With decreasing water availability for irrigation and increasing demand for rice, the future prospects of irrigated rice production is at a crossroad. The ever increasing price of energy and its intermittent supply (especially electricity) have only aggravated the problem. In a study, it has been observed that irrigated rice production is now marginally profitable if either land or labour is hired (Saleh and Amin, 2005). Moreover, the estimated returns to water when used in irrigation are much lower compared to culture fishery or urban water supply (WARPO, 2002). Therefore, the reduction of water use in rice production and the increase of water productivity through its management have become imperative. Special impetus has been given both in the National Water Policy (MoWR, 1999) and the National Water Management Plan (WARPO, 2001) on improved on-farm water management and increasing the efficiency of water use in irrigation.

As a semi aquatic plant, rice does not need standing water for a successful harvest. However, due to uncertainty of water supply, either from irrigation or rain, better management of fertilizer and to reduce weed infestation, rice is traditionally cultivated under continuous standing water of about 2-7 cm throughout the season. Increasing water scarcity and rising demand for irrigation worldwide, have led to developments of water saving techniques in rice production. Out of several such techniques, the alternate wetting and drying (AWD) technology has been widely studied and advocated (IRRI, 2004). In AWD, irrigation is applied a few days after water has disappeared from the field during the entire growing season and the technology has been researched extensively in countries such as Australia (Borrell et. al., 1997), Bangladesh (Rashid et. al., 2005), China (Belder et. al., 2004 and Feng, et.al., 2007), India (Mishra et. al., 1997 and Krishasamy et. al., 2003), and the Philippines (Tabbal et. al, 2002 and Belder et. al., 2004). The rice yields in AWD studies were similar to that of continuous standing water but saved 15% to 70% water with significantly higher water productivity.

Most research on water saving techniques using AWD method has been limited to individual field experiments and/or simulation models and the farmers, who would be the ultimate users of the technology, have remained as the bystanders. The objectives of this paper are to evaluate the prospect of water savings at farmers' fields considering their perceptions about water saving techniques and to assess the potentials of reducing the cost of irrigation of Boro rice production through AWD.

2. METHODOLOGY

The study was conducted at the farmers' field in eighteen upazilas (sub-distrcit) under four districts of north-west region of Bangladesh, namely Panchagarh, Thakurgaon, Dinajpur and Joypurhat during the 2008 Boro season (January to May). But, due to pilferage of equipment, missing data and inconsistency in measurements, field data from only eight sites of different upazilas namely Joypurhat Sadar, Birampur, Ghoraghat, Hakimpur, Parbatipur, Khanshama, Tentulia and Panchbibi were finally used in the analysis. The locations of the water status measurement sites are shown in Figure 1. Almost the entire area is covered by piedmont deposits derived from the foothills of the Himalayas. The soil texture of the study sites varies from silty loam to silt. Although the mean annual rainfall varies from 1800 mm to 2600 mm, the mean rainfall during the period January to April varies from only 85 to 150 mm.

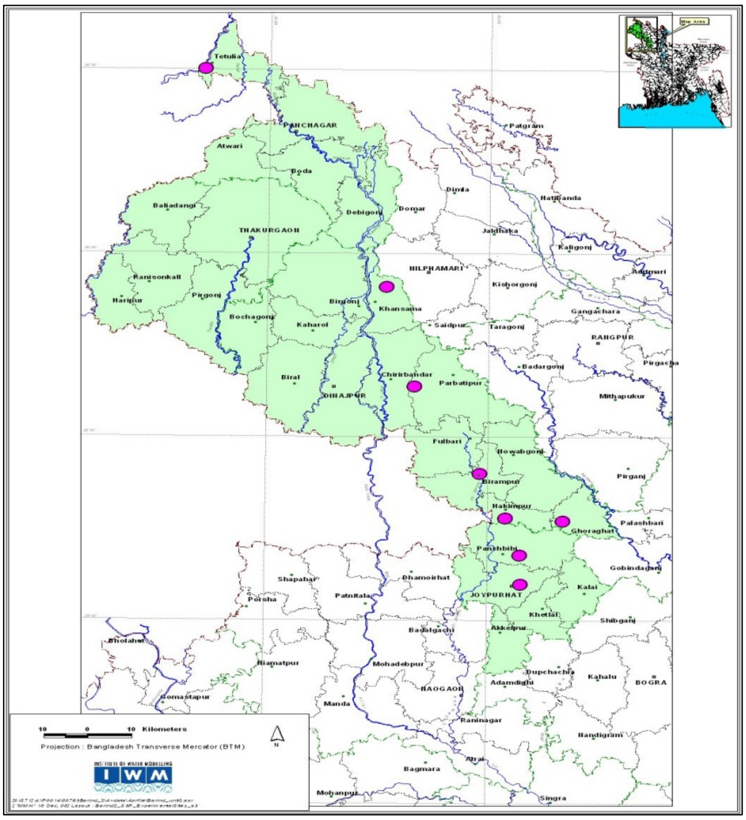

Figure 1. Map showing Locatoins of Experimental Sites.

The field water status of the irrigated Boro rice fields as maintained by the farmers was measured by installing 1 m long and 2.5 cm diameter PVC tube (50 cm above and the rest below the ground level) at each site. In a bunded rice field, the difference of the standing water levels of successive days (without any rainfall or irrigation) is the amount of daily crop water use. The water level in the tube was recorded each day at the same time. The measurement of water levels in the tube was continued till the harvest of rice.The cumulative daily water use together with the total rainfall and irrigation during the entire crop season was taken as the present on-farm water use for growing irrigated Boro rice.

The potential water savings from irrigated Boro rice at the farmers' level were estimated by following two strategies of AWD: (1) re-irrigation only when the standing water level falls 10 cm below the field level; and (2) re-irrigation 5 days after the disappearance of standing water. The first strategy was recommended by International Rice Research Institute (IRRI) with slight modification and has been selected for field demonstration by the Directorate of Agricultural Extension (DAE, 2008). The IRRI recommended AWD for re-irrigation when the water level falls to 15 cm below the ground level (IRRI, 2004; Tuong, 2007). But, such a strategy was not acceptable to the farmers due to development of cracks in the rice field. The second strategy was introduced after discussion with the farmers as they would not install PVC tubes for the measurement of field water level. Moreover, as the farmers would not accept any water stress during the crop establishment (30 days after transplantation) and flowering stages (51-70 days after transplantation), additional treatments with standing water (no AWD) during these stages were also introduced.

Thus the water saving analysis was conducted by superimposing the following six different AWD water treatments on the base condition (farmer's field water status):

T1 = Traditional practice by farmers; no AWD
T2 = AWD with irrigation when water level falls to 10 cm from field surface
T3 = AWD (same as T2) from 30 days after transplantation
T4 = AWD (same as T2) but not in critical stages (crop establishment and flowering)
T5 = AWD with irrigation 5 days after disappearance of standing water
T6 = AWD (same as T5) from 30 days of transplantation
T7 = AWD (same as T5) but not in critical stages (crop establishment and flowering)

In order to assess the amount of irrigation water saved for the different treatments (T2 to T7), the time of re-irrigation was determined from the slope of the falling standing water level of T1, till it reached 10 cm below the ground level (strategy 1) and from 5 days after the depletion of the standing water in the field (strategy 2). Time of occurrences of rainfall and their magnitudes were kept unchanged for all the treatments (same as T1). From the differences of total amount irrigations of T1 and the cumulative re-irrigations of treatments T2 to T7, the water savings of different AWD treatments compared to the present practice (T1) were ascertained.

The cost of irrigation was estimated from the fixed cost for getting access to irrigation and from the cost of diesel for providing irrigation. The costs of water savings for treatments T_2 to T_7 were estimated from the savings from the diesel (for the fewer number irrigations provided compared to treatment T_1) for the different treatments.

A questionnaire survey of fifty farmers (including the eighteen farmers in whose field water status were measured) was conducted to assess the present cost of different components of rice production focusing mainly on irrigation. Interviews with the farmers conducted during field visits also revealed many pertinent details about the new approach of AWD and the impediments to its adoption for Boro cultivation.

3. RESULTS & DISCUSSIONS

3.1 On-farm Water Use by the Farmers

In the study area, the land preparation is completed by the farmers within a week and requires 2-3 irrigations, each of 50-75 mm. Rice is transplanted by early February and harvested by early May. Generally, 40-45 day old seedlings are transplanted. The time interval between transplantation to harvest is generally about 100 days. In the analysis, a 100-day field duration (from transplantation to harvest) with 50, 30 and 20 days for vegetative, reproductive and ripening stages respectively, has been considered.

The total on-farm water use for the eight different sites varied from 736 - 982 mm, with an average use of 827 mm. Considering that the average water required for land preparation was 127 mm, the average on-farm water use by the crop was 700 mm. The total on-farm water uses at the different sites are shown in Table 1.

Table 1. Total On-Farm Water Use by the Farmers During 2008 Boro Season**.**

Total water requirement (mm)								Average water requirement (mm)
Joypurhat	Birampur	Ghoraghat	Hakimpur	Parbatipur	Khansama	Tentulia	Panchbibi	
856	786	982	880	736	764	767	845	827

3.2 Analysis of Water Savings with AWD Method

Due to similarity in analysis, the detail analysis on the water savings with AWD method for one of the eight sites (Joypurhat Sadar Upazila) is presented in Figure 2. The figure shows analyses for treatments T3 and T6. Similar analyses were carried out for the other treatments. The farmers' survey revealed that among the selected treatments, these two (T3 and T6) were most likely to be adopted by the farmers. At Joypurhat Sadar site, rice was transplanted on 31 January and harvested on 10 May, 2008. Figure 2(a) shows the actual field water status in the farmer's field during the Boro season. The circles indicate application of irrigation and the triangles indicate rainfall. The figure shows that the farmer maintained standing water in his field throughout the crop season. For maintaining standing water the farmer applied 12 irrigations in addition to rainfall. Two irrigations were applied by the farmers for land preparation before transplanting.

Irrigation was applied whenever the water level fell to about 2 cm above the ground level and was raised to about 6 cm. Figure 2(b) shows the field water status in the same field with treatment T3 (AWD from 30 days after transplantation with re-irrigation when the water level fell to 10 cm below the ground level). With T3, the number of irrigations was reduced to 9, keeping the timing and amount of rainfall the same as in T1. Thus T3 saved three irrigations compared T1. Similarly, Figure 2 (c) shows the field water status for T6 (AWD from 30 days after transplantation with re-irrigation 5 days after disappearance of standing water). For T6, 10 irrigations were required keeping the rainfall amount and timing the same as in T1. Thus, T6 saved two irrigations compared to T1.

Table 2 shows the details of water savings from different treatments over T1 at Joypurhat station. The table shows that the maximum water saving was for T2 (about 30%) and the minimum for T4 (about 6%). This is logical because T2 required the least frequent irrigation with application of AWD throughout the crop season. On the other hand, for T4 AWD was practiced only for about 50 days. From figures 2(b) and 2(c) it can be seen that for re-irrigation, the time interval was about 7 days for the water level to reach 10 cm below ground level (T2) compared 5-day interval treatments (T4). Hence, T4 required less irrigation (more savings) compared to T7.

The water savings from the other treatments over the present farmers' practice (T1) at all the eight sites are shown in Table 3. The table shows that the average maximum water saving over the present farmers' practice was for treatment T2 (about 28%). The minimum water saving was for treatments T7 (about 10%).

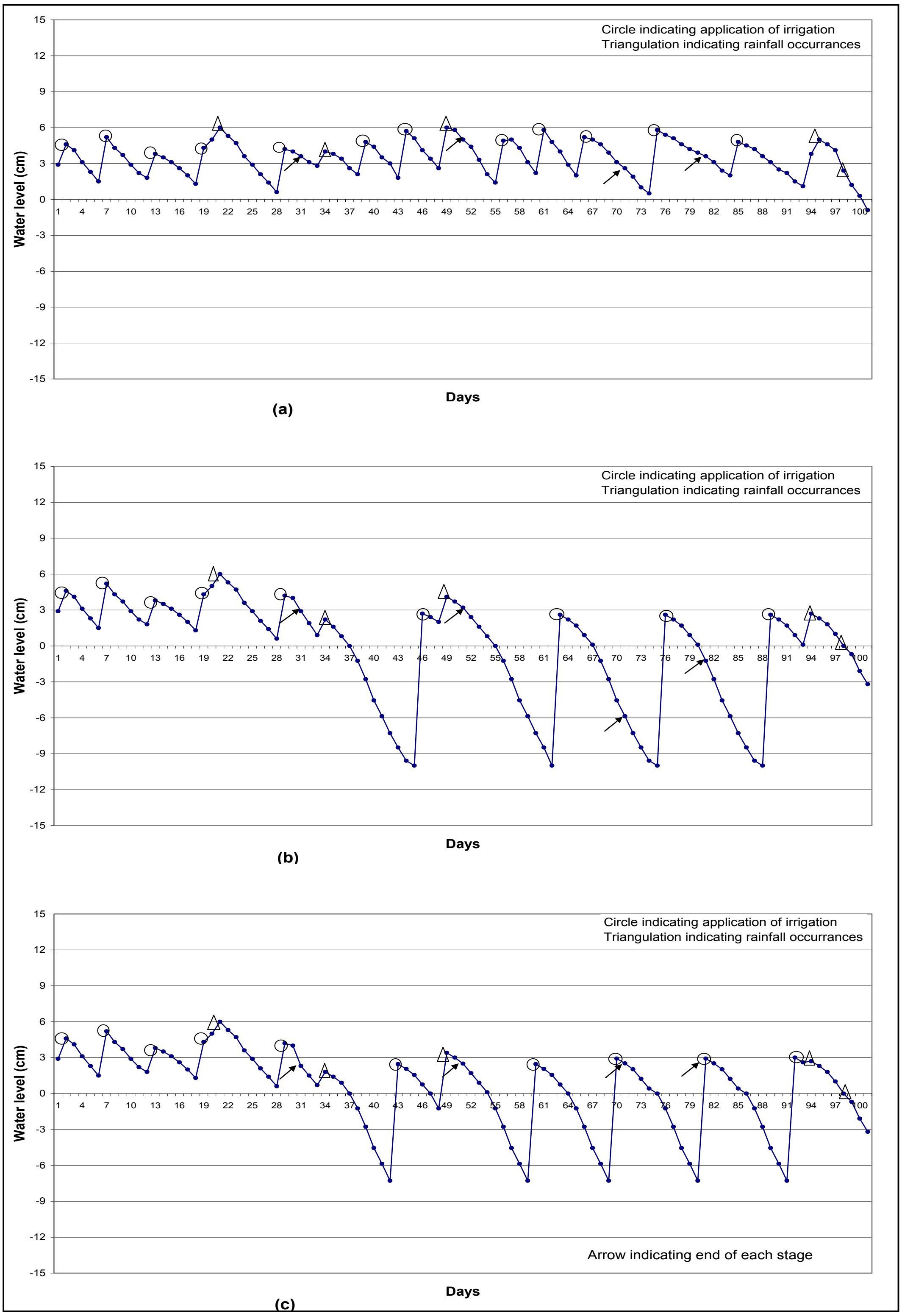

Figure 2. Comparison of different field water status for Joypurhat Sadar upazila at (a) actual condition, (b) water level falls up to 10 cm (T3), and (c) application of irrigation after 5 days of drying (T6).

Table 2. Impact of different AWD water treatments on-farm water use at Joypurhat Sadar upazila.

Treatments	Irrigation water depth at different phases						Rainfall	Total water use	Water saved over T1 (%)
	Land preparation (45 days)	Vegetative (30 days)	Vegetative (20 days)	Reproductive (20 days)	Reproductive (10 days)	Ripening (20 days)			
	mm	mm	mm	mm	mm	mm	mm	mm	
T1	127	240	106	163	73	48	99	856	-
T2	127	144	58	58	58	58	99	602	29.7
T3	127	240	58	58	58	58	99	698	18.5
T4	127	240	58	162	58	58	99	802	6.3
T5	127	192	54	108	58	58	99	696	18.7
T6	127	240	54	108	58	58	99	744	13.1
T7	127	240	54	211	0	58	99	789	7.8

Table 3. Impact of different AWD water treatments on-farm water use (in mm) at the study sites.

Treatments	Total water requirements (mm)								Irrigation water saved (on average) over T1 (%)
	Joypurhat Sadar	Birampur	Ghoraghat	Hakimpur	Parbatipur	Khansama	Tentulia	Panchbibi	
T1	856	786	982	880	736	764	767	845	-
T2	602	574	679	594	531	581	602	614	27.8
T3	698	634	810	687	599	637	633	606	19.8
T4	802	690	858	723	700	629	748	677	12.0
T5	696	621	799	644	531	567	640	640	22.3
T6	744	673	855	714	589	619	689	643	16.5
T7	789	757	853	785	705	620	747	710	9.8

3.3 Analysis of Cost Savings with AWD Method

The cost of irrigation mainly depends on the number of irrigations applied to the rice fields. In the study area irrigation water for Boro cultivation mainly comes from privately owned shallow tubewells, which generally use diesel as the source of energy. From the interview with the farmers and pump operators it was revealed that on average 1.5 litres of diesel were required for applying one irrigation in 0.135 ha (0.33 acre or 1 Bigha). The average local price of diesel was Tk. 43/litre during the year of 2008. The farmers provide the diesel to the pump operator for providing irrigation to their fields. The pump operator charges Tk. 500 per 0.135 ha as fixed cost for providing irrigation during the season. Thus, the total irrigation cost is the summation of fuel cost for the number of irrigations provided and the fixed cost.

The detail analysis of irrigation cost for all the treatments at Joypurhat is shown in Table 4. The cost of irrigation water was highest for T1 i.e., the traditional practice by the farmers. The savings of irrigation cost for a treatment depended on the number of irrigations saved by the treatment. Hence, the savings of irrigation cost were similar to the savings of the amount of irrigation (Table 2). The maximum savings of irrigation cost was for treatment T2 (with 5 savings of irrigation over treatment T1) and the minimum were for treatments T4 and T7 (with saving of 1 irrigation).

Table 4. Comparison of irrigation costs for different AWD treatments at Joypurhat Sadar Upazila.

Treat-ments	No. of total irrigation	No. of irrigation saved over T1	Total cost of irrigation (Tk./0.135 ha)	Irrigation cost Saved over T1 (Tk./0.135 ha)	Irrigation cost saved over T1 (%)
T1	14	-	1446	-	-
T2	9	5	1108	838	23.4
T3	11	3	1243	703	14.0
T4	13	1	1378	568	4.7
T5	11	3	1243	703	14.0
T6	12	2	1311	635	9.4
T7	13	1	1378	568	4.7

The savings of irrigation costs for all the treatments at the eight sites are shown in Table 5. The table shows that the average maximum saving of irrigation cost from the present practice is for T2 (29%) and the minimum is for treatment T7 (about 11%).

Table 5. Irrigation cost (Tk./0.135 ha) and savings of different water treatments at study sites.

Treatments	Joypurhat	Birampur	Ghoraghat	Hakimpur	Parbatipur	Khansama	Tentulia	Panchbibi	Cost saved (on average) over T1(%)
T1	1446	1597	1726	1919	1532	1468	1403	1597	-
T2	1108	1145	1145	1210	1145	1081	1081	1081	29.0
T3	1243	1274	1403	1468	1210	1210	1210	1145	19.9
T4	1378	1403	1468	1532	1339	1210	1339	1274	13.6
T5	1243	1210	1274	1274	1145	1081	1145	1145	24.9
T6	1311	1339	1468	1532	1210	1210	1274	1210	16.8
T7	1378	1532	1468	1661	1339	1210	1339	1339	11.2

4. EFFECT OF RAINFALL ON THE COMPUTED WATER AND COST SAVINGS

During the study year (2008 Boro season), the total seasonal rainfall was 99 mm. In order to ascertain the effect of rainfall on the water and cost savings by AWD, an analysis of long-term rainfall in the study area was made. In this regard, rainfall data were collected from three stations namely Tentulia, Khansama and Khetlal. The rainfall during the 2008 Boro season (99 mm) was about 12% of the total on-farm water use by the farmers. The average rainfall in the study area is 112 mm during the period of 3rd decade of January to the 3rd decade of April. Thus, the rainfall in 2008 Boro season was close to the average rainfall. But, in a dry year (1 in 5 year), the rainfall in the study area is only about 13 mm. If AWD method is applied in a dry year, both the water and cost savings would increase as the deficit in rainfall would have be provided through irrigation.

5. EFFECT OF AWD TREATMENT ON RICE YIELD

Although six different AWD treatments were superimposed on the farmers' present water management practice, it was not possible to ascertain the effects of such treatments on the yield. But past experimental studies on AWD practice by a number of researchers (both local and foreign) have shown that AWD practice has no adverse effect on rice yield. Local studies (DAE, 2008 and Rashid et. al.,2005) have shown that AWD practice produced similar or even higher yields than the traditional practice. Studies in China (Feng et. al., 2007), India (Mishra et. al., 1997) and the Philippines (Belder et.al., 2004) showed that there was no significant difference in yield between continuous flooding and AWD practices.

6. FARMERS' PERCEPTION ABOUT AWD METHOD

To the farmers, the Boro rice has turned out to be the main rice crop due its low risks of damages from natural calamities like floods and droughts. Hence, ensuring production inputs including irrigation for a sustainable Boro yield is not only a priority of the government but also is required for the sustenance of the farmers and the economic stability of the country. The reduced availability of irrigation water and the ever increasing irrigation cost are impediments to a stable Boro production and have dented its profitability. As this study has shown that the AWD technique can save a number of irrigations without reducing the rice yield, the farmers were asked about their awareness about the AWD technology and the constraints to its adoption.

From the questionnaire survey it was observed that the farmers are willing to accept the AWD technology only after field demonstrations (pilot study) show that it would not affect the rice yield. But, AWD throughout the crop season is not acceptable to the farmers as this would increase the weed infestation and increase the cost of weeding. There is an apprehension that the increased cost of weeding may offset the savings from irrigation costs. Moreover, the farmers also do not want AWD during the flowering stage, as any water deficit at that stage would affect the yield. Application of irrigation with the field water level at 10 cm blow the ground level was difficult for the farmers to perceive and instead they preferred re-irrigation at 5-days after disappearance of standing water. Thus, if AWD were adopted, treatment T6 or T7 (with about 11-17% cost saving) would initially be the most acceptable technology to the farmers.

7. CONCLUSIONS

Because of water scarcity and increased cost of irrigation, water saving techniques are gradually being adopted in the rice growing countries. One such technique, the alternate wetting and drying (AWD) method has gained popularity and is advocated by IRRI. In this study the AWD method was superimposed on the farmers' existing field water status and it was found that 10% to 28% irrigation water was saved over the traditional method of continuous flooding. The saving in irrigation cost varied between 11% and 29%. If AWD method is applied in a dry year, both the irrigation water and cost saving would increase subsequently. The farmers' survey revealed that because of cost reduction, the farmers are positively about adopting the technology. But, because of apprehension about weed infestation and yield loss, the farmers are willing to adopt the technology with continuous flooding during the 30 days after transplantation and at early flowering.

ACKNOWLEDGEMENTS

This paper is a part of a research project entitled "Opportunities of Water Saving and Cost Reduction in Irrigated Boro Rice" conducted jointly by Institute of Water Modelling (IWM), Bangladesh and Institute of Water and Flood Management (IWFM) of Bangladesh University of Engineering and Technology (BUET),Bangladesh. The authors gratefully acknowledge the support provided by IWM, IWFM and Barind Multipurpose Development Authority (BMDA) of Ministry of Agriculture of the Government of Bangladesh. Authors thank the field staffs of IWM at Dinajpur Project Office for their cooperation.

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