Impact of Alternate Wetting and Drying Technique on Rice Production in the Drought Prone Areas of Bangladesh

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ABSTRACT

A project implemented in six Upazilas under six districts of Rajshahi and Rangpur divisions in Bangladesh to assess the impact of AWD technique on rice production, where totally 108 farmers were selected as the participant of this study included Project farmers/AWD technique followers(54) and non-project farmers/conventional practice followers(54). Trial's in two seasons (Boro 2012 and 2013) were conducted in each nine selected locations of six Upazilas under six districts, where farmers cultivated six selected rice varieties. The data were collected by simple random sampling model, while Focus Group Discussion (FGD) were held by the researchers and collected data were analyzed by using t-tests. Findings revealed that, frequencies of irrigation used in AWD technology practice were lower than those of conventional technique. However, AWD practice required 22.0 per cent less irrigation water than conventional technique. It implied that the use of AWD practice increased (6.0%) yield of rice compared to the farmers' traditional practices. The findings and suggestions for this study might be useful for policy makers and planners in formulating and redesigning the water management strategies. There may have wide range circulation of AWD technique in all over the country demonstrating its importance on irrigation water savings, increased yield of rice and reduced insect and pest infestations especially in the Boro season.

Key words: *AWD technique; Conventional technique; Project farmer; Non-project farmer;*

Rice is the major staple food for more than 164 million denizens of Bangladesh (*UNESA - PD, 2008*). About 54 per cent of all households are involved in the agricultural sector, whereas 89.0 per cent cultivable lands smaller than 1.0 ha (equivalent to 2.5 acres). In fact, about 14.0 per cent of households are landless share croppers (*BRRI, 2008; BBS, 2008)*. This fragmented agrarian structure forebodes the pressures imposed on agricultural lands, where the cropping intensity has consequently increased over the last decades to reach a nationwide average of 180.0 per cent (*BBS, 2007*). Irrigation water in Asia is becoming increasingly scarce. *Tuong and Bouman (2003)* estimated that, by 2025, about 2.0 million ha of Asia's irrigated dry-season rice and 13.0 million ha of its irrigated wet-season rice will experience physical water scarcity. Therefore, in order to fulfill the food demand of a rapidly growing population amidst this increasing water scarcity, more efficient water management practices - water-saving technologies - are needed so that rice production levels in Asia (i.e., the main staple food in the continent) can still be maintained or increased even with the use of less irrigation water (*IRRI, 2010*).

On the global average, 3400.0 liters of water are used to grow one kilogram of rice (*Hoekstra, 2008*), which makes rice a very water-intensive crop. From its research, the IRRI postulates significant scope for water-saving in rice irrigation based on the fact that it takes an average of 1,432.0 liters of evapotranspired water to produce 1.0 kg of rough rice (*IRRI, 2010*). In order to irrigate rice paddies, electricity or fuel is needed to bring water to the surface. However, the demand for energy grossly exceeds the available supply by far (*Economist Intelligence Unit, 2008*). As a consequence, Bangladeshi rice growing farmers have to cope with unreliable irrigation water supply, either deriving from the physical unavailability of surface and groundwater resources, or caused by insufficient electricity or fuel supply for pumping. In order to address farmers' needs to save water, energy and fuel in irrigated rice, the International Rice Research Institute (IRRI) has developed the Alternate Wetting and Drying technology, which has been introduced in Bangladesh in 2004. Alternate Wetting and Drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can apply to reduce their water use in irrigated fields. In AWD, irrigation water is applied to flood the field a certain number of days after the disappearance of ponded water. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days. The threshold of 15 cm water depth (below the surface) before irrigation is called "Safe AWD" as this will not cause any yield decline. In Safe AWD, water savings are in the order of 15.0- 30.0 per cent.

In Bangladesh, three rice growing seasons are differentiated: Aus (early monsoon rice), Aman (monsoon rice) and dry season Boro rice. Boro rice production in the 2007-2008 season amounted to 17.8 million ton (*BBS, 2009*), which is over 60.0 per cent of the total annual rice production in Bangladesh (*Hussain, 2009*). Therefore, the production of dry season irrigated rice has a predominant importance for national food security (*Fujita, 2004*). Approximately 60.0 per cent of the country's 28.0 m tons rice production is grown during the dry (Boro) season *Shahid, 2010*) and more than 70.0 per cent of that is irrigated using groundwater resources (*Faisal and Parveen*, 2004). The environmental downside of Boro season cultivation is that agricultural pumping lowers the water table year on year as monsoonal recharge is insufficient to replenish the aquifers (*Faisal and Parveen, 2004; Ali et al.,2012*).

Drought has become a recurrent natural phenomenon of north-western Bangladesh, where crop loss ranges 20.0-60.0 per cent or even more for T. Aman and other rice varieties. About 61.0 per cent of the north-western part of the country faces moderate to very severe risk from drought and depending on the intensity of drought, the estimated yield reduction of different crops varies from 10.0-70.0 per cent (*Hussain, 2009*). Generally speaking, this particular region of the country is hot and considered as a semi-arid region, in which experiences of the two extremities that clearly contrast with the climatic condition of the rest of the country. Higher maximum and minimum temperature can decrease rice yields due to spikelet sterility and higher respiration losses. Boro rice yields reduce at range of 2.6 to 13.5 per cent due to increase 2°C maximum temperature and 0.11 to 28.7 per cent for 4°C maximum temperature. It is observed that, a significant increase in the average annual rainfall of Bangladesh at a rate of 5.52 mm/year over the 1958-2007 time periods, no significant changes to monsoon, post-monsoon, or winter rainfall were observed (*Shahid, 2009*).

The declining ground water tables and increasing water scarcity are even more critical issues for the north-central, north-western, and south-western areas of the country. So, the decrease of groundwater levels, falling at the rate of 0.1-0.5m/yr., has been clearly linked to the intensive abstraction of groundwater due to dry season rice farming (*Shamsudduha et al., 2009*). Farmers are currently paying an equivalent of 25.0-30.0 per cent of their rice harvest for irrigation and these costs are tending to increase (*Sattar et al., 2009*). This is another factor for the economic relevance of water-saving at the farm level. Experts state that on a national level, the implementation of AWD could save costs for irrigation of up to 56.4 million Euros in electricity or 78.8 million Euros in fuel or 30.0 liter diesel/ha (*Miah et al., 2009*).Keeping this view in mind, following objectives were put forward in present study:

- To describe the selected socio-demographic characteristics of the participants;
- To find out the yield difference between AWD technique and that of farmers' practice (conventional technique);
- To compare the irrigation requirements and, disease and insect infestations between AWD technique and farmers' practice (conventional technique); and

In order to guide relevant data collection, analysis and interpretation of data, a set of hypothesis were formulated for empirical testing. As stated by *Good* *and Hatt (1952)* "a hypothesis is a proposition, which can be put to test to determine its validity. However, the following null hypotheses were formulated to give proper direction of the study:

- There is no significant difference between the yield of rice grown under AWD technique and that of farmers' practice (conventional technique).
- There are no significant differences in terms of irrigation requirements and disease and insect infestations in rice production between AWD technique and farmers' practice (conventional technique).

METHODOLOGY

Research methodology is the underlying principles and rules of organization of philosophical system or inquiry procedure (*Urdong, 1968*). A project implemented in the north-western part of Bangladesh, including only six Upazilas under six districts of Rajshahi and Rangpur divisions to assess the impact of AWD technique on rice production, where totally 108 farmers were selected as the participant of the study. Project farmers (54) used irrigation water following AWD technique, while non-project farmers (54) followed the conventional practice (conventional technique). Farmers cultivated six selected rice varieties namely BR26, BRRI dhan28, BRRI dhan29, BRRI dhan45, Minikit and Nerica, following both AWD technique and farmers' practice (FP) in each Upazilla. The entire process of data collection took two months from January to March, 2013.

In order to collect relevant information from the participants, an instrument was carefully designed keeping the objectives of the study in mind. The instrument contained both open and closed questions. Ten farmers similar to the study group were interviewed through pre-testing testing. The final version of the instrument was prepared on the basis of reliability and the suggestions and comments of the panel of experts. The descriptive and diagnostic research design was applied in the present study, because the descriptive research design supports in stating characteristics of a particular situation, or a group or individuals and used for fact finding with appropriate interpretation. Contrastingly, diagnostic and analytical research design helps on testing of hypothesis and specifying and interpreting relationship of variables. The variables of this study were participant's age, education, family size, farm size, training experience, extension contact, annual family income, organizational participation and impact of AWD technique on rice production, which were determined by comparing yield difference, irrigation requirements, labor requirements and pest infestations between AWD and farmer's practice. Different variables of the experiment like age, education, farm size, family size, family income, training experience, extension contact and impact of AWD on rice production were measured on the basis of different scale.

Factors affecting cultivation of rice was measured on the basis of 22 selected factors under biophysical, technical, socio-economic and institutional category. A 4-point rating scale was used for the measurement, where a participant was asked to indicate the extent of problems of each factor. The possible responses in the scale representing extent of problems were "no problem", "low", "medium" and "high" while the assigned scores for the responses were 0, 1, 2 and 3, respectively. The SPSS software program version 16.0 was used to perform for data analysis. Descriptive statistical measures like range, mean, number and per cent age distribution, standard deviation were used to describe and interpret the data. Paired sample t-test is a statistical technique that is used to compare two population means in the case of two samples that are correlated. For exploring the impacts of AWD technique paired t-test was used in this study. Throughout the study 5 per cent (0.05) level of probability with an accompanying 95 per cent confidence level was used as a basis for rejecting or accepting the null hypothesis. Here the following formula was used to measure the value of parameter with 5 per cent level of significance with n-1 d.f.

$$t = \frac{\bar{d}}{\sqrt{\frac{S^2}{n}}}$$

RESULTS AND DISCUSSION

Socio-economic profile of the participants : Highest portion of project and non-project participants (57.4 and 42.6%) belonged to middle and young age categories presented in Table 1. However, big majority of the project farmers (85.2%) were under middle and old age categories, while large majority of the non-project participants (74.1%) were observed under young and

Table 1. Socio-demographic profiles of the participants

Profile characters	Classification	Project Farmers				Non-project Farmers			
		No.	%	Mean	S.D.	No.	%	Mean	S.D.
Age	Young (<30)	8	14.8	41.79	11.73	23	42.6	39.44	13.68
	Middle (31-50)	31	57.4			17	31.5		
	Old (>50)	15	27.8			14	25.9		
Education	Illiterate	14	25.9	7.24	4.82	18	33.3	6.03	5.03
	Primary (1-5)	2	3.7			6	11.1		
	Secondary (6-10)	26	48.1			19	35.2		
	Above (>10)	12	22.2			11	20.4		
Family size	Small family (<5)	22	40.7	5.88	3.06	9	16.7	4.81	2.02
	Medium family (5-7)	20	37.0			38	70.4		
	Large (>7)	12	22.2			7	13.0		
Farm size	Marginal (0.02-0.19 ha)	1	1.9	0.80	0.50	9	16.7	0.61	0.45
	Small (0.20-1.0 ha)	41	75.9			38	70.4		
	Medium (1.01-3.03ha)	12	22.2			7	13.0		
	Large (>3.03 ha)	0	0			0	0		
Training experience	No trained (0)	21	38.9	1.88	1.92	41	75.9	0.77	1.71
	Low trained (1-2)	10	18.5			5	9.3		
	Moderately trained (3)	18	33.3			6	11.1		
	Highly trained (above 3)	05	09.3			2	3.7		
Organizational participation	Low (less than 2)	31	57.4	1.259	1.429	48	88.9	0.37	0.807
	Medium (3-4)	23	42.6			6	11.1		
	High (above 4)	0	0			0	0		
Contact with information source	Low (up to7)	11	20.4	13.37	6.35	20	37	11.85	6.53
	Medium (8-20)	33	61.1			29	53.7		
	High (above 20)	10	18.5			5	9.3		
Annual family income (in thousand)	Low (up to50)	0	0	146.52	69.21	2	3.7	113.37	53.87
	Medium (51-150)	39	72.2			45	83.3		
	High (above 150)	15	27.8			7	13		

middle age categories. Related results were reported by *Ferrous (2014)*. Data also revealed that, almost three-fourths (*74.1%*) of the project farmers had literacy and it was two-thirds (67%) for the non-project farmer participants. The national literacy level of the country is 48.8 per cent for the age 15 or above (*BBS, 2013*), which is lower than both project and non-project participant farmers. It means that people in the study areas are lucky enough to achieve education as one of their fundamental needs.

In case of family size, the large portion of the project farmer participants (77.7%) was found under small to medium family categories, whereas the non-project farmer participants were 92.2 per cent. The average family size of the participant farmers both project and non-project was higher than the national family size 4.35. Incessant results were found by *Rahman (2011)* and *Chowdhury (2011)*. Depending on farm size, both the project and non-project farmer participants, greater part of them (project 98.1%, non-project 83.4%) were found under small to medium farm size categories. However, the national average of land holding in Bangladesh is 0.81 ha (*Anon, 2009*), while the average farm size of project and non-project participant farmer was 0.80 ha and 0.610 ha, respectively. These findings are akin to those of *Islam (2000*).

About 38.9 per cent and 75.9 per cent of the project and non-project farmers had no training experience, while 42.6 per cent and 14.8 per cent had moderate to high training experience (Table 1). It was also observed that project farmers were more trained (61.1%)

compared to non-project farmers (24.1 per cent). This might be due to the reason that project farmers after their involvement in the project received several trainings on drought management in rice production. Related results were reported by *Rahman (2011)* and *Chowdhury (2011)*. Results displayed in Table 1 indicate that, highest portion of participant farmers belonged to lower organizational participation for project (57.4%) and non-project (88.9%) farmers followed by medium organizational participation (project 42.6% and non-project 11.1%). Interestingly no farmer was found under high organizational participation both in project and non-project farmers. *Haider (2010)* in his study also found the analogous results.

Maximum portion of the project (61.1%) and non-project (53.7%) participant farmers had medium contact with information sources as compared to project farmers 20.4 per cent and non-project farmers 37.0 per cent had low contact with the information sources observed in Table 1. About one-fifths (18.5%) of the project participants and one out of ten non-project participants showed high contact with the information sources. Therefore, greater part of the project (81.5%) and non-project (90.7%) participant farmers exhibited low to medium extension contact with the sources of information. *Hamidi (2004)* and *Rahman (2008)* also showed similar results in their studies. It is evinced from the information presented in Table 1 that highest part of the project (72.2%) and non-project farmers (83.3%) belonged to the medium income category followed by high annual family income category of project (27.8%) and non-project (13.0%) farmer participants. Surprisingly, there were no project farmers under low category, whereas 3.7 per cent of non-project farmers belonged to the low category. The average income of the participants (project 146.52 and non-project 113.37) was much higher than that of national average per capita income of the country i.e. 92.8 thousands. Identical results exhibited by *Haider (2010)*.

Impact of AWD on Rice Production : Impact of AWD technique on rice production has been discussed in this sub-section in terms of disease and insect infestation, yield difference and irrigation requirements.

Impact of AWD on disease infestation : Diseases are the very vital problems for rice production. It is generally assumed that higher the succulence of the rice crop, greater the occurrence of diseases. Results presented in Table 2 indicate that, occurrence of disease has no significant relationship with AWD technique but the frequency of disease occurrence in conventional technique (69.4%) was more than two times higher than that of AWD (33.6%). It also exhibited that, no disease occurrence in AWD practiced plot was 66.7 per cent in contrast with 29.6 per cent in farmers practiced plot (conventional technique).Therefore, it can be said that AWD technique had significant impact on the disease occurrence of the rice plant. *Chaboussou (2004)* reported alike results that AWD practiced plants were more resistant to insects and pests.

Impact of AWD on insect infestation : Insects are the one of the most severe enemies of rice production. In AWD technique there is less use of water for plant growth. Therefore, it is supposed to have higher resistant to any pest including insect. Results contained from Table 3mention that the nooccurrence of insect in AWD technique field is reported by higher number of participants (63.0%) which is almost half in case of conventional technique using participant farmers (33.3 per cent). It is also found that, there was a significant relationship between stem borer infestation and AWD

Table 2. Comparative intensity of disease infestation between AWD and farmers practice

Categories	AWD		Conventional		t-value	Significance (2-tailed)
	Participant (%)	Mean	Participant (%)	Mean		
No disease	66.7	0.667	29.6	0.296	4.366	0.000
Root knot	7.4	0.148	16.7	0.333	1.526	0.133^{NS}
Blast	13.0	0.389	20.4	0.611	1.272	0.209^{NS}
Sheath rot	5.6	0.222	14.8	0.593	1.695	0.096^{NS}
Sheath blight	9.3	0.463	18.5	0.926	1.299	0.200^{NS}
False smut	13.0	0.778	11.1	0.667	-0.299	0.766^{NS}

*=5 per cent Level of Significance, NS=Not significant

Table 3. Comparative intensity of insect infestation between AWD and Farmers practice

Categories	AWD technique		Conventionalt echnique) FP		t-value	Significance (2-tailed)
	Participant (%)	Mean	Participant (%)	Mean		
No insect	63.0	0.63	33.3	0.33	4.06	0.00
Stem borer	5.6	0.12	27.8	0.55	3.53	0.01*
Rice bug	7.4	0.22	16.7	0.50	1.70	0.10NS
Brown Plant Hopper	9.3	0.37	18.5	0.74	1.71	0.11 NS

*=5 per cent Level of significance NS= Not Significant

techniques, while others insects infestation presented insignificant results. Therefore, it can be concluded that, AWD technique is performed better to make the land less insect infestation from stem borer rather than conventional method in rice production. *Hinckley, (1963); Israel, (1969); Banerjee et al., (1973); Pathak and Dyck, (1973); Fernando, (1975) and Mochida* and *Suryana, (1975)* also showed analogous results.

Impact of AWD on yield : Yield is the most efficient and effective determinant of impact of any intervention on any crop and this case is very applicable in case of using AWD technique in rice production. Six rice cultivars viz. BR26, BRRI dhan28, BRRI dhan45, BRRI dhan 29, Nerica and Minikit were used in the project to determine the impact of AWD technique on rice production showed in Table 4.The t-test values for yield differences of all the cultivars used AWD and conventional technique were not significant. The overall average yield increase following AWD practice was about 5.96 per cent higher than the farmer's practice. Therefore, it can be implied that AWD technique has significant impact on rice yield, whereas analogous results demonstrated by *Faruki et al.,(2011); Hossain (2013); Cao*HYPERLINK\l "bookmark33"*et al., (2003*); *Anbumozhi et al. (1998), Uphoff, (2006)*; and *Cabangon et al., (2004).*

Impact of AWD on irrigation : AWD is a technique suggested to irrigate rice field when water is actually required in the root zone of rice plant for better growth and development. AWD technique could save irrigation requirement to a great extent (Table 5). The maximum water saving by AWD technique was found 23.01 per cent in case of BRRI dhan29 and Minikit. It can be concluded that, in all cases the less number of irrigation required for AWD method than farmers practice which reduces the production cost of rice. Irrigation is a vital part for rice production especially Boro rice cultivation in drought prone areas of Bangladesh.Information contained in Table 5indicated that in case of farmer practice, the frequency of irrigation water supply was significantly higher compared to AWD technique in all rice varieties.It is observed from Table 5 that AWD technique saves up to 23 per cent water use in rice production during Boro season. Therefore, AWD contributes to lessen cost of rice production. However, the AWD technique increases rice yields over the

Table 4. Comparative yield difference between AWD and farmers practice (FP)

Varieties	Yield Mean (ton/ha)		t-value	Significance (2-tailed)
	AWD	Conv-entional		
BRRI dhan29	6.28	5.92	11.22	0.00
BRRI dhan45	4.93	4.63	7.57	0.00
BRRI dhan28	5.78	5.46	7.86	0.00
BR26	5.91	5.60	8.59	0.00
Minikit	4.77	4.48	6.59	0.00
Nerica	4.57	4.34	6.16	0.00

*- 5 per cent Level of significance

Table 5. Comparison of irrigation water use between AWD technique and farmers' practice in six varieties and the extent of average water saving using AWD technique

Varieties	No. of installment (ton/ha)		Water saving (%) by AWD*
	AWD	Conventional	
BR26	15.2	19.3	20.44
BRRIdhan28	15	18.1	21.23
BRRIdhan29	20.3	26.2	23.01
BRRIdhan45	14.3	18.4	22.67
Nerica	14.2	17.1	22.49
Minikit	19.3	24.2	22.86

**Variation of irrigation cost with the variation of irrigation source*

Table 6. Comparison of average cost for irrigation between AWD and FP with different source of irrigation

Source of Irrigation	Participant project farmer using AWD technique		Participant non-project farmer not using AWD technique	
	Participant (%)	Av. Cost	Participant (%)	Av. Cost
Rented shallow tube well	18.5	9150	30	14007
Deep tube well operated by *Borendra* authority	33	10995	35	16410
Own shallow tube well	18.5	9408	9	14494
Public deep tube well	30	7441	26	9545
Total	100		100	

Table 7. Comparative average cost for irrigation between AWD and conventional techniques in different locations

Locations	Participant project farmer using AWD technique (Thoushand Taka)	Participant non-project farmer using conventional technique (Thoushand Taka)
Rangpur	9.5	13.2
Gaibandha	7.4	11.5
Naogaon	9.1	14.2
Joypurhat	8	8.3
Bogra	10	13.6
Chapai Nawabganj	13.1	21.6

farmers' practice. *Sattar et al., (2009); Belder et al., (2004); Husain et al., (2009); Guerra et al., (1998);* and *Bouman et al., (2001)* were found the incessant result.

There were four irrigation sources found in the study areas of six districts namely rented shallow tube well, deep tube well operated by *Borendra* authority, own shallow tube well and public deep tube well. Broadly, there were actually two irrigation sources namely shallow tube well and deep tube well. Shallow tube well may be own or rented and for the two cases irrigation cost was not same. However, deep tubes well operated by Borendra authority and public deep tube well were technically similar kind of irrigation source. In case of Naogaon and Chapai Nawabganj, it was called deep tube well operated by *Borendra* authority and for this study irrigation sources were classified into four categories.

From the Table 6, it can be explained that about two-third (63.0%) of participant project farmers were depended on public deep tube well and deep tube well operated by *Borendra* authority and more than one-third (37.0%) of them relied on rented and own shallow tube well for irrigation. However, two-third (65.0%) of the participant non-project farmers were depended on deep tube well operated by Borendra authority and rented shallow tube well and more than one-third (35.0%) of them relied on own shallow tube well and public deep tube well. Cost for public deep tube well based irrigation was lowest for both AWD and conventional. However, cost of irrigation by deep tube well operated by *Borendra* authority was highest in both AWD and conventional. All in all, average cost for irrigation was lower in AWD than conventional.

Variation of irrigation cost within the different locations : Irrigation cost plays a vital role in variation of the cost of rice production. It varies drastically; surprisingly it could be two or three times more from one district or region to another. This study was conducted on six different districts of Rangpur and Rajshahi divisions and variation of irrigation cost among different districts was very noticeable.

Results presented in Table 7 shows that average cost of irrigation was highest in Chapai Nawabganj for both AWD and conventional technique. Irrigation cost was lowest in Gaibandha districts following Joypurhat, Naogaon and Rangpur district in case of AWD technique. Contrastingly, irrigation cost was lowest in Joypurhat districts in case of conventional technique and there was a significant variation (t-value 3.852) of average cost of irrigation between AWD and conventional technique at all locations. The highest average cost of irrigation was in Chapai Nawabganj for both AWD and conventional technique because the district is considered as the most drought prone area of Bangladesh with lowest rainfall, highest temperature and deepest water table. Therefore, it requires highest number of irrigation in rice production in the district leading to highest average irrigation cost compare to

Table 8. Economic analysis of alternate wetting and drying and farmers' practice for rice production in one hectare land in the project areas during Boro 2012-2013 season

Item of cost	AWD technique	Farmers' practice
Land preparation	9600 BDT	9600 BDT
Seedling	11250	11250
Transplanting (additional 5 labor required for AWD pipe installation)	12750 (43 labor)	11250 (38 labor)
Irrigation	8952 BDT (15 installment)	13773 BDT (21 installment)
Weeding	9433 BDT (30 labor)	10596 BDT (35 labor)
Pesticide	3253 BDT	3402 BDT
Fertilizer	8000 BDT	12000 BDT
Harvesting	12000 BDT (40 labor)	12000 BDT (40 labor)
Threshing	6000 BDT (20 labor)	6000 BDT (20 labor)
Total production cost	81238	89871
Total yield (average)	5.37 ton	5.07 ton
Gross income	96660	91260
Benefit Cost Ratio	1.19	1.01

other districts. Alike findings were reported by FAO (2012).So, it can be remarked that, AWD technique saved significant amount of irrigation cost throughout the study areas.

Benefit Cost Ratio between AWD and Farmers' Practice (conventional): A benefit-cost ratio (BCR) is an indicator, used in the formal discipline of cost-benefit analysis that attempts to summarize the overall value for money of a project or proposal. In the present study, an attempt has been made to determine the amount of output obtained from investing a unit amount taka both from AWD and conventional techniques using in rice production. The BCR of alternate wetting and drying was found 1.19, which is considerably greater than that of farmers' practice (1.01) (Table 8).

From the above economic analysis we found that, cost for land preparation, seedling, harvesting and threshing were same for AWD and farmers practice. Otherwise, cost for irrigation, weeding, pesticide and fertilizer was higher in farmers practice than that of AWD technique. Although cost for transplanting was higher in AWD technique but total production cost was significantly lower than farmers practice and yield was also higher in AWD technique; finally BCR value of AWD technique was found 1.19 in contrast of 1.19 in case of farmers practice. The analysis also shows that by using AWD technique a farmer can save up to 5400BDT from one hectare of land of which 4821 BDT from irrigation cost. Regarding this, alternate wetting and drying provide some additional invisible benefits. This technique burns lesser fossil fuel leading to less emission of CO_2 and lifts lesser ground water which helps maintain stability of ground water table. Therefore, farmers can comfortably use alternate wetting and drying technique for sustainable rice production during Boro season, when scarcity of water is a common phenomenon in Bangladesh.

CONCLUSION

Socio-demographic characters of the participant farmers played a vital role to be selected as a project farmer. The overall average yield following AWD was 6.0 per cent higher than the farmers' practice and the irrigation water required for AWD practice was 22.0 per cent less than farmer practice (conventional technique). It implied that, AWD has a significant impact on rice yield and irrigation. The disease incidences and insect infestations were lower in AWD technique than the farmers' practice. As the farmers had given no exact specifications on their herbicide and insecticide input that's why the exact effect of AWD on weed and insect infestation could not revealed. So, further study should be conducted to determine the effect of AWD on weed infestation. Fixed-rate arrangements discourage farmers to adopt AWD technique since charges for irrigation are fixed amounts, settled prior to the season. Pump owners receive huge irrigation charges considering the savings of irrigation water in AWD technique. Therefore, government should impose AWD technique as compulsory for all farmers in Bangladesh. A national strategy of AWD dissemination could be formulated based on experiences exchanged at the National Agricultural Technology Coordination Committee (NATCC) which will provide an appropriate forum to start such a processes.

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