Journal of Crop and Weed, 10(2):24-30(2014)

Sustaining productivity in *boro* (winter) season using minimal water through dry direct seeding of rice

M. M. RAHMAN AND M. M. MASOOD

Dept. of Agronomy,
Bangladesh Agricultural University
Mymensingh-2202, Bangladesh

Received: 29-07-2014, Revised: 27-09-2014, Accepted: 02-10-2014

ABSTRACT

The sustainability of rice productivity in Bangladesh is likely to face major threat due to water shortage during boro (winter season). The conventional transplanted boro rice requires huge amount of irrigation water due to wastage of various means. It is an imperative task that water saving production technology is needed to replace the conventional system for sustaining boro rice production in the country ensuring food security. Keeping with this in view, a field experiment was conducted during two consecutive boro seasons of 2009-10 and 2010-11 on two rice varieties viz. V_1 - BRRI dhan28 and V_2 - BRRI dhan29 in farmers field under three different systems viz. T_1 - puddle transplanted conventional irrigated, T_2 - puddle transplanted alternate wetting and drying irrigated and T_3 - dry direct seeded systems at four locations of Bangladesh viz. Sundarban in Sadar of Dinajpur, Norkona in Modhupur of Tangail, Narandia in Purbadhala of Netrokona and Bijoynagar in Godagari of Rajshahi, respectively. At each location, the experiment used a split-plot design with four disperse location allocating systems in the main plot and variety as sub-plot.The result revealed that the rice yield and economic return for both the varieties were highest in dry direct seeded system. The number of irrigation required for puddle transplanted conventional system were 14-19, while those for dry direct seeded field and puddle transplanted alternate wetting and drying fields were 6-9 and 11-15, respectively. The puddle transplanted alternate wetting and drying field and dry direct seeded fields used about 24% and 58% less irrigation water than the puddle transplanted conventional irrigated field. The study concluded that dry direct seeding could be practiced for boro rice cultivation to get higher yield using 58% less irrigation water.

***Keywords*:** Alternate wetting and drying, boro rice, dry direct seeding, economics, puddle transplanting

Rice (*Oryza sativa* L.) contributes about 95% of the food grains consumed in Bangladesh. The production of rice in the country was 9.77 million tons from 9.2 million hectares of land in 1971-72. The rice production has been increased by 3.4 folds over the four decades (Rahman and Masood, 2012). The agricultural land of Bangladesh is being reducing by about 1.0% per annum. The population of the country is increasing and the food requirement will be 55.0 million tons by 2050 against the present requirement of 33.0 million tons. The *Boro*, *Aman* and *Aus* crops contributed 55.50, 38.81 and 5.69%, respectively to total rice production (33.54 million tons) in 2010-11 and thus, boro rice is the major contributor to the food production in Bangladesh.

The *Aman* – Fallow – *Boro* rice is the major cropping pattern of Bangladesh. *Aman* rice is cultivated in puddle transplanted system under rainfed condition. On the other hand, *boro* rice is also cultivated using puddled transplanted system but with full irrigation. About 3000 to 5000 liters of water is required to produce one kilogram of rice. At present, the scarcity of irrigation water from both surface and underground sources is now looming and the situation will be continued to be aggravated in future. Under this situation, there is a need of developing water saving rice production technology to sustain *boro* rice production to ensure food security in the country.

The dry direct seeded rice production (D-DSR) technology can help sustain rice production using about 50-60% less water in *boro* season (Choudhury *et al*., 2007; Bhushan *et al*., 2007; Mandal *et al*., 2009; Rahman and Masood, 2012). The D-DSR system is a labour saving and cost-effective technology (Khade *et al.*, 1993) which can give higher yield than the puddled transplanted conventional irrigated rice (PTR-CI). Under the present climate change scenario, the sustainability of *boro* rice production is dependent mainly on a suitable water saving technology and the dry direct seeding could be the most potential option. The dry direct seeding system is a new technology for *boro* rice in Bangladesh. Therefore, the yield performance of *boro* rice varieties under dry direct seeding system compared with the conventional puddle transplanted and alternate wetting and drying systems needs to be evaluated under different agro-ecological conditions. Research report in this regard is highly scarce in Bangladesh. Therefore, keeping with this in view the present study was initiated with the aim of comparing yield performance, cost-effectiveness and water saving efficacy of dry direct seeded rice (D-DSR) in *boro* season compared with PTR-CI and PTR-AWD technology in farmers' field.

Email: rahmanag63@ yahoo.com

MATERIALS AND METHODS

The experiment was conducted in farmers' field at four locations *viz.* Sunderban block under Sadar upazilla of Dinajpur, Narandia block under Purbadhala upazilla of Netrokona, Narokona block under Modhupur upazilla of Tangail and Bijoynagar block under Godagari upazilla of Rajshahi district of Bangladesh during two consecutive *boro* seasons of 2009-10 and 2010-11. The field trial was conducted in a split-plot design involving three systems of cultivation *viz.* T_1 - Puddle transplanted conventional irrigation (PTR-CI), T_2-Puddle transplanted alternate wetting and drying (PTR-AWD) and T_3 - Dry direct seeded system (D-DSR) as main-plot and two rice varieties viz. V_1 - BRRI dhan28 (long duration, 155-160 days) and V_2 - BRRI dhan28 (short duration, 134-140 days) considered as sub-plot system in four disperse locations treated as replication of the experiment. The unit plot size was 10 decimal and therefore, the land area under the study at each location was 240 decimal. The land was prepared by dry cultivation for dry direct seeding system while puddling was done for PTR-CI and PTR-AWD.

In case of dry direct seeded system, seed was sown directly on dry cultivated land on 8, 15 and 17 December 2009 respectively for Dinajpur, Netrokona and Tangail sites in 2009-10 while that was done on 8, 26 and 23 December 2010, respectively in 2010-11. The seeding in Rajshahi was done on 19 and 17 February in 2009-10 and 2010-11, respectively. The transplanting was done during last week of January 2010 and during February 2011 in 2009-2010 and 2010-11, respectively. Sowing done at 25 cm x 15 cm spacing using 4-5 seeds at each spot in the furrows. Before sowing the seed was primed by soaking in water at room temperature for 30 hours and then incubated for another 30-35 hours until the seed was about to sprout. In case of PTR-CI and PTR-AWD systems, seedling was raised in the seed bed. Before seeding in the bed, seeds were soaked in water for 72 hours and then incubated for 48 hours. Sowing of seed in the seed bed was done concurrently during the sowing on the main field for dry direct seeding system. After 40 days 30 days old seedlings were transplanted at a spacing of 25 cm x 15 cm allocating 3 seedlings per hill respectively in 2009-10 and 2010-11. At each location, fertilizers were applied at the recommended rates (BARC, 2005). The rates of Urea-Triple Super Phosphate-Muriate of Potash-Gypsum-Zinc sulphate were 212-50-70-45-3, 217-70-116-45-3, 212-60-90-45-3 and 212-100-120-115-3 kg ha^{-1} for Dinajpur, Netrokona, Tangail and Rajshahi, respectively. All the fertilizers (except urea) at the recommended rate and cowdung @ 5 tones ha^{-1} were applied during final land preparation. Urea was applied in four equal installments *i.e.* at final land preparation, at 45-50, 60-65 and 75-80 days after sowing for dry direct seeded system while that was applied in three installments *i.e.* at 20-25, 40-45 and 55-60 days after transplanting in case of CTR and AWD system.

Irrigation was applied by deep tube well operated with electricity in Dinajpur and Rajshahi while by shallow tube well operated with diesel at Netrokona and Tangail. The number of irrigation required for each system at each location was recorded and the amount of irrigation was measured by volumetric method. The dry direct seeded crop required four hand weeding at 25, 45, 60 and 70 DAS, while that for PTR-CI and PTR-AWD were done at 30, 50 and 65 DAT.

All the collaborating and participating farmers are the members of the ICM/IPM clubs/FFSs. So, the plots of the trials were carefully observed regularly to control disease and insect-pest attack. The crops in seedlings stage in all the systems were suffered with cold injury but they were successfully recovered by applying Ridomil Gold @ 4 kg ha^{-1}. The crop under PTR-CI and PTR-AWD were infested by sheath blast, leaf roller, stem borer, rice bug etc. The infestation was successfully controlled by using ICM/IPM technology. In Rajshahi, the situation was something different. The first sown crop was totally damaged because of irrigation failure as the deep tube well went out of order for a long time in 2009-10. On the other hand, the crop damage both in D-DSR and PTR seedbed was evident due to severe cold injury in 2010-11. So, the second crop reached the flowering stage when there were no rice fields around. For this, there was a high infestation of grass hopper, rice bug, leaf roller and other insects which caused a severe damage to the crops. All kinds of measures were taken to control the infestation but it gave a partial control only.

The crop was harvested from central 2.5 m x 4.0 m area of each plot at maturity (when more than 80% grains became golden yellow in colour) and threshed by beating on wooden platform. Yield parameters and grain yield were recorded and were recorded analyzed as per Gomez and Gomez (1984) using M-STAT software.

RESULTS AND DISCUSSION

Yield attributes and yield

The highest grain yield was obtained from BRRI dhan29 with dry direct seeded system of cultivation (D-DSR). The yield of BRRI dhan29 with D-DSR at Dinajpur, Netrokona, Tangail and Rajshahi sites were 7.67, 8.34, 8.62 and 5.16 t ha^{-1}, respectively and the lowest grain yield was found with BRRI dhan28 from puddle transplanted conventional irrigated field (PTR-CI) which were were 6.45, 6.12, 6.27 and 4.49 t ha^{-1}, respectively at Dinajpur, Netrokona, Tangail and Rajshahi sites (Tables 1-4). It was also found that the yield of BRRI dhan28 and BRRI dhan29 were the highest in D-DSR and the lowest in PTR-CI for all the locations under the study. The yield improvement in D-DSR could be mainly attributed to the improvement of number panicle m^{-2} than PTR-CI and PTR-AWD system (Tables 1-4). The present result supports the result of Yadav *et al.* (2011). In contrast, Choudhury *et al*. (2007), Ladha *et al*. (2009) and walia *et al.* (2014) reported lower yield of D-DSR compared with PTR. The variable performance of D-DSR relative to PTR could be related to many factors including soil properties (which primarily affect nutrient and water availability to the plants), water management and weed management.

Irrigation water saving

The crop was grown under full irrigation and water was applied following free flood irrigation system. The amount of water applied in each system every time was measured through volumetric method for BRRI dhan29. Then the amount irrigated was converted into millimeter (mm). The water applied in all locations ranged between 1235-1407 mm in PTR-CI and 545 to 630 mm in D-DSR system. Across the locations, PTR-CI and D-DSR required 16-19 and 7-8 irrigations, respectively. The irrigation frequency for PTR-AWD was between 12 and 13 times (Table 5).

Table 1: Effect of system of cultivation on yield attributes and grain yield of rice varieties during *boro* at farmers' field in Dinajpur

Treatment	Panicle m^{-2}			Grains $panicle^{-1}$			Test weight (g)			Grain yield (t ha^{-1})		
	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
BRRI dhan28												
PTR-CI	294.75	299	289	84.98	91	86	24.34	23.72	24.03	5.61	6.45	6.03
PTR-AWD	346.50	352	342	91.70	91	91	23.15	21.86	21.33	5.95	6.75	6.35
DDSR	394.75	310	305	86.95	95	91	22.62	22.87	23.01	6.70	7.57	7.13
BRRI dhan29												
PTR-CI	353.00	369	358	86.30	98	100	20.80	20.60	20.43	6.21	7.05	6.63
PTR-AWD	383.75	346	350	97.43	91	86	20.27	23.95	23.28	6.67	7.47	7.07
DDSR	460.75	408	417	91.15	94	95	20.12	21.02	20.57	7.27	8.07	7.67
SEm (±)	**12.53**	**15.34**	**12.88**	**4.18**	**4.58**	**2.77**	**0.61**	**0.47**	**0.47**	**0.22**	**0.21**	**0.20**
LSD(0.05)	**28.34**	**34.70**	**38.81**	**9.45**	**2.99**	**8.39**	**1.37**	**1.08**	**1.4**	**0.48**	**0.68**	**0.49**

Table 2: Effect of system of cultivation on yield attributes and grain yield of rice varieties during *boro* at farmers' field in Netrokona

Treatment	Panicle m^{-2}			Grains $spike^{-1}$			Test weight (g)			Grain yield (t ha^{-1})		
	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
PTR-CI	303.00	299	298	88.60	87	87	22.99	24.49	23.39	5.89	6.35	6.12
PTR-AWD	307.25	366	334	88.05	95	101	24.14	21.21	22.13	6.23	6.57	6.4
DDSR	354.00	337	304	86.40	87	86	23.40	23.38	24.05	6.70	6.64	6.67
BRRI dhan29												
PTR-CI	323.25	413	367	100.23	94	99	22.10	20.29	21.58	6.91	8.06	7.48
PTR-AWD	357.00	382	337	98.28	86	84	21.98	22.54	23.46	7.36	8.37	7.86
DDSR	383.25	461	376	100.50	93	102	21.33	20.08	21.40	7.88	8.80	8.34
Sem (±)	**3.28**	**5.17**	**4.16**	**3.14**	**3.71**	**1.33**	**0.17**	**0.25**	**0.23**	**0.11**	**0.35**	**0.28**
LSD(0.05)	**7.48**	**11.7**	**12.52**	**7.10**	**8.40**	**3.39**	**0.38**	**0.57**	**0.69**	**0.25**	**1.13**	**0.69**

Table 3: Effect of system of cultivation on yield attributes and grain yield of rice varieties during *boro* at farmers' field in Tangail

Treatment	Panicle m^{-2}			Grains $spike^{-1}$			Test weight (g)			Grain yield (t ha^{-1})		
	2009-10	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**
BRRI dhan28												
PTR-CI	291.75	299	295	87.28	87	85	24.93	24.49	24.71	6.13	6.41	6.27
PTR-AWD	317.25	366	373	87.43	95	98	23.28	21.21	21.14	6.48	6.90	6.69
DDSR	386.50	337	327	85.38	87	85	22.29	23.38	23.33	6.75	7.50	7.125
BRRI dhan29												
PTR-CI	378.50	413	415	96.78	94	98	21.07	20.29	20.21	6.84	7.56	7.2
PTR-AWD	416.00	382	384	96.40	86	83	20.13	22.54	22.41	7.22	7.92	7.57
DDSR	476.25	461	469	92.68	93	95	19.34	20.08	19.71	8.28	8.62	8.45
Sem (±)	**15.65**	**10.62**	**12.16**	**3.87**	**3.27**	**1.69**	**0.29**	**0.26**	**0.36**	**0.21**	**0.11**	**0.17**
LSD(0.05)	**35.41**	**34.0**	**36.67**	**8.76**	**7.38**	**5.08**	**0.95**	**0.58**	**1.01**	**0.72**	**0.36**	**0.42**

PTR-CI = Puddle transplanted conventional irrigation, PTR-AWD = Puddle transplanted alternate wetting and drying, D-DSR = Dry direct seeded rice

The water savings for PTR-AWD were 21.8-23.6 and 22.0-26.0% in 2009-10 and 2010-11, respectively. The water savings for D-DSR were 55.87, 57.62, 57.30, and 55.26% for D-DSR respectively in Dinajpur, Netrokona, Tangail and Rajshahi locations while these values for PTR-AWD were 22.67, 25.54, 24.20 and 24.72%, respectively over the PTR-CI system. The water savings in these trials were mostly due to reduction in irrigation frequency in D-DSR system compared with PTR-AWD system (Table 5).

The irrigation in *Boro* season requires huge number of diesel and electrically operated STWs (shallow- tube wells) and DTWs_(deep-tube wells). The daily total electricity and diesel consumption during *Boro* season for irrigation is 1000 mega watt and 10 million litres. The cultivation of *Boro* rice using D-DSR system could save 50% irrigation water which means that there will be a save of 50% power for operating irrigation equipments. The saving of 50% electricity and diesel will lead to the saving of cost for irrigation worth around BDT 300 billion every year.

Table 4: Effect of system of cultivation on yield attributes and grain yield of rice varieties during *boro* at farmers' field in Rajshahi

Treatment	Panicle m^{-2}			Grains $spike^{-1}$			Test weight (g)			Grain yield (t ha^{-1})		
	2009-10	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**
BRRI dhan28												
PTR-CI	272.50	362	317	65.70	66.72	64	21.40	22.13	21.77	3.68	5.30	4.49
PTR-AWD	238.75	381	312	66.80	70.35	71	21.88	19.89	19.65	3.70	5.77	4.735
DDSR	294.00	376	307	67.85	69.32	66	21.73	22.15	22.02	3.83	5.45	4.64
BRRI dhan29												
PTR-CI	243.25	391	363	69.42	70.72	72	19.42	19.33	19.20	3.90	5.35	4.625
PTR-AWD	336.50	348	321	70.62	70.95	67	19.08	22.05	21.89	4.04	5.33	4.685
DDSR	276.75	427	352	73.10	74.32	75	18.74	19.18	18.96	4.23	6.09	5.16
SEm (±)	**8.38**	**14.73**	**10.76**	**1.86**	**3.05**	**1.93**	**030**	**0.32**	**0.28**	**0.02**	**0.14**	**0.14**
LSD(0.05)	**26.82**	**33.32**	**32.43**	**4.20**	**6.89**	**5.8**	**0.97**	**1.08**	**0.84**	**.036**	**0.45**	**0.34**

Table 5: Amount and frequency of irrigation water applied in systems of rice cultivation for BRRI dhan29 in farmers' field at four locations of Bangladesh

	Dinajpur			Tangail			Rajshahi			Netrokona		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Amount of Irrigation (mm)												
PTR-CI	1250	1220	1235	1420	1390	1405	1440	1375	1407.5	1380	1310	1345
PTR-AWD	960	950	955	1110	1020	1065	1100	1020	1060	1075	980	1027.5
DDSR	590	500	545	650	550	600	700	560	630	620	520	570
Frequency of irrigation												
PTR-CI	17	14	15.5	19	18	18.5	17	16	16.5	18	16	17
PTR-AWD	13	11	12	15	11	13	12	12	12	13	12	12.5
DDSR	8	6	7	9	7	8	9	7	8	8	8	8

PTR-CI = Puddle transplanted conventional irrigation, PTR-AWD = Puddle transplanted alternate wetting and drying, D-DSR = Dry direct seeded rice

Economic benefit

The highest cost of production for both variety BRRI dhan28 and BRRI dhan29 was found with conventional transplanting (PTR-CI) and the lowest was with dry direct seeding (D-DSR) system. In case of net return from rice cultivation it was found that the highest net return for BRRI dhan28 was found from D-DSR system while the lowest from conventional transplanting. For example, in Dinajpur site, the production cost of BRRI dhan29 under D-DSR system was Tk. 48835.00 while that for conventional system was Tk. 53585.00. That means was a saving of Tk. 4750.00 and Tk. 3750.00 from D-DSR compared with conventional system and AWD technique, respectively. The return from BRRI dhan 29 rice cultivation in D-DSR was Tk148380.00 and that in conventional system was Tk. 123305.00. The net returns for aerobic, AWD and conventional systems for BRRI dhan29 in Dinajpur were Tk. 80390.00, 66415.00 and 57815.00, respectively. The economic analysis shows that cultivation of BRRI dhan29 under aerobic system could give Tk. 22575.00 more benefit than conventional system. Cultivation of BRRI dhan29 in *boro* season under aerobic system could give Tk. 17675.00, 28825.00 and 9045.00 advantages over conventional system in Netrokona, Tangail and Rajshahi sites, respectively (Table 6).

In Dinajpur site, the production cost of BRRI dhan29 under aerobic system was Tk. 52110.00 while that for conventional system was Tk. 54285.00. That means was a saving of Tk. 2175.00 and Tk. 975.00 from aerobic system compared with conventional system and AWD technique, respectively. The return from BRRI dhan29 rice cultivation in D-DSR system was Tk. 124100.00 and that in conventional system was Tk. 105400.00. The net returns for aerobic, AWD and conventional systems for BRRI dhan29 in Dinajpur were Tk. 80390.00, 66415.00 and 57815.00, respectively (Table 6). The economic analysis shows that cultivation of BRRI dhan29 under D-DSR system could give Tk. 29825.00 more benefit than conventional system. Cultivation of BRRI dhan29 in boro season under D-DSR system could give Tk. 16675.00, 29780.00 and 15548.00 advantages over conventional system in Netrokona, Tangail and Rajshahi sites, respectively.

The result of both the seasons at four locations showed that the production cost was the highest with puddle transplanted conventional irrigated plots while that was the lowest with dry direct seeded system for both the varieties. The net return was highest with the DDSR and lowest in the puddle transplanted conventional irrigated fields for both the varieties in both the seasons. On an average, cost saving in D-DSR system was about 9.5% compared with puddle transplanted conventional irrigated rice. This observation was found at par with *Sidhu et.al.* (2014)

The present study showed that over two seasons, the new dry directed seeded system produced highest benefit to rice production. The high benefit was achieved due to decrease of production cost in term of planting and irrigation although weed management cost was higher. Dry direct seeding saves 56 % irrigation water while AWD saves only 24% compared with conventional transplanted rice. Economic analysis revealed that dry direct seeding requires least input cost while gives highest economic benefit among different rice cultivation systems for both rice varieties BRRI dhan29 and BRRI dhan45. Dry direct seeding appeared to be as the most efficient water saving rice production system.

Table 6: Cost and return (BDT) of rice cultivation under different systems at farmers' field in four locations of Bangladesh

	Dinajpur			Tangail			Rajshahi			Netrokona		
Systems	**2009-10**	**2010-11**	**Mean**	**2009-10**	**2010-11**	**Mean**	**2009-10**	**2010-11**	**Mean**	**2009-10**	**2010-11**	**Mean**
BRRI dhan28					**Total cost (BDT)**							
PTR-CI	53785	51885	52835	55535	54485	55010	52845	50585	51715	54085	54385	54235
PTR-AWD	52885	51485	52185	52885	52485	52685	50185	49885	50035	52885	52985	52935
DDSR	51610	44410	48010	51210	44660	47935	49860	42760	46310	52610	45360	48985
					Total return (BDT)							
PTR-CI	101500	123260	112380	110600	122740	116670	67400	101690	84545	105200	121410	113305
PTR-AWD	108000	129560	118780	115800	131850	123825	67300	110560	88930	119800	125770	122785
DDSR	123500	143710	133605	121300	143370	132335	69100	104420	86760	124300	126940	125620
					Net benefit (BDT)							
PTR-CI	47715	71375	59545	55065	68255	61660	14555	51105	32830	51115	67025	59070
PTR-AWD	55115	78075	66595	52915	79365	66140	17115	60675	38895	66915	72785	69850
DDSR	71890	99300	85595	70090	98710	84400	19240	61660	40450	71690	81580	76635
BRRI dhan29					**Total cost (BDT)**							
PTR-CI	54285	52885	53585	56035	55585	55810	54705	51585	53145	54585	55235	54910
PTR-AWD	53085	52085	52585	54285	53785	54035	52085	50385	51235	53585	53735	53660
DDSR	52110	45560	48835	52210	45260	48735	51260	43435	47347	53110	46060	49585
					Total return (BDT)							
PTR-CI	112100	134510	123305	123200	144450	133825	70900	102650	86775	124800	143960	134380
PTR-AWD	119500	142570	131035	130300	151360	140830	72800	102200	87500	132100	147330	139715
DDSR	132500	164260	148380	148200	164860	156530	76500	116550	96525	141000	150460	145730
					Net benefit (BDT)							
PTR-CI	57815	81625	69720	67165	88865	78015	16195	51065	33630	70215	88725	79470
PTR-AWD	66415	90485	78450	76015	97575	86795	20715	51815	36265	78515	93595	86055
DDSR	80390	118700	99545	95990	119600	107795	25240	73115	49178	87890	104400	96145

PTR-CI = Puddle transplanted conventional irrigation, PTR-AWD = Puddle transplanted alternate wetting and drying, D-DSR = Dry direct seeded rice, Cost for different items was calculated based on the market value. 1 USD = 78 BDT

REFERENCES

BARC. 2005. *Fertilizer Recommendation Guide-2005.* Bangladesh Agricultural Research Council (BARC), Farmgate, New Airport Road, Dhaka-1215. pp.60-65.

Bhushan, L., Ladha, J. K., Gupta, R. K., Singh, S. Triol-Padre, A., Saharawat, Y. S., Gathala, M. and Pathak, H. 2007. Saving of water and labour in a rice-wheat system with no-tillage and direct seeding technologies. *Agron. J.*, **99**: 1288-96.

Choudhury, B.U., Bouman, B.A.M. and Singh, A.K. 2007. Yield and water productivity of rice-wheat on raised beds-results from a field experiment at New Delhi, India. *Field Crops Res.*, **100**: 229-39.

Khade, V. N., Patil, B. D., Khanvilkar, S. A. and Chavan, L. S. 1993. Effect of seeding rates and level of nitrogen on yield of direct seeded (Rahu) summer rice in *Konkan. J. Maharastra Agric. Univ.*, **18**: 32-35.

Ladha, J. K., Kumar, V., Alam, M. Sharma, S., Gathala, M., Chandna, P. and Balaubramanian, V. 2009. Integrated crop and resource management technology for enhanced productivity, profitability and sustainability of rice-wheat system in South Asia. In. *Integrated Crop and Resource Management in the Rice-Wheat System of South Asia.* (Ladha, J. K., Yadvinder-Singh, Erestein, O., Hardy, B. Eds.).

Sidhu, A.S., Kaooner, R. and Verina, A. 2014 on from assessment of direct seeded rice production system under central Punjab conditions. *J. Crop Weed*,**10**: 56-60. *Los Banos, Philippines: International Rice Research Institute*, pp. 69-108.

Mandal, S. N., Regmi, A. P., Ladha, J. K. and Tuong, T. P. 2009. Crop establishment, tillage, and water management effects on crop and water productivity in rice-wheat rotation in Nepal. In. *Integrated Crop and Resource Management in the Rice-Wheat System of South Asia.* (Ladha, J. K., Y. V. Singh, Erestein, O., Hardy, B. Eds. Los Banos, Philippines: International Rice Research Institute. pp. 239-60.

Rahman, M. M. and Masood, M. M. 2012. *Aerobic System: A Potential Water Saving Boro Rice Production Technology.* Department of Agronomy, Bangladesh Agricultural University, Mymensingh. pp. 1-16.

Yadav, S., Humphreys, E., Kukal, S.S., Gill, G. and Rangarajan, R.2011. 2011. Effect of water management on dry seeded and puddle transplanted rice. *Field Crop Res.*, **120**: 123-32.

Walia, U.S., Walia, S.S., Sidhu, A.S. and Nayar, S. 2014. Productivity of direct seeded rice in relation to different dates of sowing and varities in Central Punjab. *J. Crop Weed*, **10:** 126-29.