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ALTERNATE WETTING AND DRYING IRRIGATION SYSTEM ON GROWTH AND YIELD OF HYBRID BORO RICE

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ABSTRACT

Nasir A, Shahriar S, Rupa WS, Mehraj H, Jamal Uddin AFM (2014) Alternate wetting and drying irrigation system on growth and yield of hybrid boro rice. *J. Soil Nature* 7(2), 28-35.

An experiment was conducted at Farm of Sher-e-Bangla Agricultural University, Bangladesh from December 2011 to April 2012 to study the influence of AWD irrigation system on growth and yield of boro rice (HIRA HYBRID dhan2). The experiment consisted nine levels of irrigations (coded from T_1-T_9) were used. Maximum number of total tillers (26.7/hill), number of effective tillers (21.5/hill), panicle length (31.5 cm), number of grains (215.5/panicle), 1000-grains weight (24.0 g), grain yield (7.8 t/ha) and straw yield (7.5 t/ha) were found from T_3 (Start irrigation when water table in the porous tube at 10 cm). Maximum concentrations of grain N (1.20%), P (0.38%), K (0.39%) and S (0.10%) were recorded from T_3; similarly maximum concentrations of straw N (0.69%), P (0.20%), K (1.87%) and S (0.10%) were also from T_3. Maximum pH (5.9), organic matter (1.26%) were recorded from T_1 treatment and total N (0.075%), available P (19.89 mg/kg soil), exchangeable K (0.12 meq/100g soil) and available S (14.66 mg/kg soil) were recorded from T_3. T_6 (Start irrigation after 7 days disappearance of water) treatment was found as the worst in terms of most of the parameters.

Key words: *Boro rice, AWD, growth and yield*

INTRODUCTION

Rice (*Oryza sativa*) is a cereal crop under Gramineae family. Boro rice is an irrigation depending crop and it needs huge irrigation water. Due to scarcity of freshwater resources available for irrigated agriculture, in future it will be necessary to produce more food with less water. Alternate Wetting and Drying (AWD) irrigation is a promising method in irrigated rice cultivation with dual benefits of water saving and environment saving, while maintaining rice yields at least at the same level (Yang *et al.* 2009). However, many factors play a role in determining the success or failure of AWD irrigation. Some of these factors can be influenced such as irrigation infrastructure and irrigation management capacity while others cannot be such as rainfall and soil conditions (Rajendran *et al*. 1995). The increased productivity of water is likely to be the critical factor that will make farmers and officials adopt AWD irrigation in water-scarce areas. AWD irrigation is one method of managing the water so that water will not be wasted but it will aid the root growth, facilitate higher nutrient uptake and increase land and water productivity (Sarkar 2001). But it is necessary to know that when irrigation will be started under AWD system. Considering the present situation the present study was undertaken to study the performance of AWD irrigation method for hybrid boro rice production.

MATERIALS AND METHODS

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to April 2012 to study the effect of alternate wetting and drying irrigation system on the growth and yield of hybrid boro rice. HIRA HYBRID dhan2 (from China) was used in this experiment. Experiment consisted nine treatments *viz*. T_1: Continuous submergence (1 to 7 cm standing water); T_2: Start irrigation when water table in the porous tube (it was 30 cm long plastic pipe having a diameter of 15 cm with many holes on all sides of the basal half) at 15cm; T_3: Start irrigation when water table in the porous tube at 10cm; T_4: Start irrigation when water table in the porous tube at 5cm; T_5: Start irrigation when disappearance of water by naked eyes; T_6: Start irrigation after 7 days disappearance of water; T_7: Start irrigation after 5 days disappearance of water; T_8: Start irrigation after 3 days disappearance of water and T_9: Start irrigation after 1 days disappearance of water using Randomized Complete Block Design with three replication. The unit plot size was 3.5 m × 2.5 m and the plots were separated through raising soil bund up to 25 cm from the soil level. The blocks were separated by one meter drains. In each sub-plot a 30 cm diameter and 40 cm long PVC pipe was installed in the centre of the sub-plot (Plate 1 and 2). Seedlings were transplanted on 12 January, 2012 in well puddled plot maintaining 20 cm × 15 cm spacing. The sources of nitrogen, phosphorus, potassium, sulphur and zinc were urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc oxide, respectively (BARC 2007). Urea was applied in 3 equal splits: one third was applied at basal before transplanting, one third at active tillering stage (30 DAT i.e., days after transplanting) and the remaining one third was applied at 5 days before panicle initiation stage (55 DAT).

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The initial soil sample was analyzed for particle size distribution, particle density, bulk density, pH, organic carbon, total nitrogen, available P and exchangeable K which were given below:

Physical and chemical properties of the initial soils sample

Physical properties	Value	Chemical properties	Value
Sand (%)	29.04	Soil pH	5.8
Silt (%)	41.8	Organic Carbon (%)	0.75
Clay (%)	29.16	Total N (%)	0.045
Texture	Silty clay loam	Available P (mg/kg soil)	19.85
Porosity (%)	44.5	Exchangeable K (meq/100 g soil)	0.08
Bulk density (g/cc)	1.48	Available S (mg/kg)	14.4
Particle density (g/cc)	2.52		

Plate 1.Water at 15 cm depth in porous tube

Plate 2. Field in flooded condition

IRRI 2013

Data were collected on plant height, number of tillers/hill, length of panicle (cm), number of grains/panicle, filled grains/ panicle, 1000 grains weight (g), grain yield and straw yield. Particle size analyses of soil was done by hydrometer method (Black 1965) and the textural class was determined by plotting the values for percent sand, percent silt and percent clay to the Marshall's Textural Triangular Coordinate following the USDA system.

Particle density of soil was determined by volumetric flask method (Black 1965) following the formula:

Particle density (Pd) = (Weight of soil solid/Volume of soil solid) g/cc

Bulk density of soil was determined by core sampler method following the formula:

Bulk density (Bd) = Weight of oven dry soil ÷ Volume of soil (pore + solid) g/cc

Soil pH was measured by glass electrode pH meter using soil water suspension of 1:2.5 as described by Jackson (1962).

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). Oxidize the organic matter with excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. Content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.* 1982).

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro Kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160^0C and added 2 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*. 1982). Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10N-NaOH solutions was added in container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink (Jackson 1973).

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where, T = Sample titration (ml) value of standard H_2SO_4; B = Blank titration (ml) value of standard H_2SO_4; N = Strength of H_2SO_4; S = Sample weight in gram

Available phosphorus was extracted from the soil with 0.5 M NaHC03 at pH 8.5. The phosphorus in the extract was then determined by developing the blue color by ascorbic acid reduction of phospo-molybdate complex and measuring the color calorimetrically at 660 nm (Olsen *et al.* 1954). Exchangeable K of soil was determined by 1N ammonium acetate (pH 7.0) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*. 1982). Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*. 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

Collection and preparation of plant samples

Grains and straw samples were collected after threshing for N, P, K and S analysis. The plant samples were dried in an oven at 65^0C for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S. The grains and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows:

Digestion of plant samples with sulphuric acid for N analysis: For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro Kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^0C and added 2 ml 30% H_2O_2 then heating was continued at 360^0C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

Digestion of plant samples with nitric-perchloric acid for P, K and S analysis: A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest by using following methods.

Determination of P, K and S from plant samples

Phosphorus: Plant samples (grains and straw) were digested by diacid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.* 1954). Phosphorus in the digest was determined by using 1 ml for grains sample and 2 ml for straw sample from 100 ml digest by developing blue color with reduction of phospomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*. 1982).

Potassium: 10 ml of digest sample for the grains and 5 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

Sulphur: The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals (Page *et al*. 1982). The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter 1984).

Collected data were statistically analyzed using the MSTAT-C computer package program and mean differences were adjusted by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at 5% level of significance.

RESULTS AND DISCUSSION

Plant height: Tallest plant was found from T_3 (89.5 cm) which was statistically similar with T_4 (89.3 cm) while shortest from T_6 (80.3 cm) (Table 1). Thakur *et al*. (2011) observed that system of rice intensification practices with alternate wetting and drying improve rice plants height.

Number of tiller: Maximum number of tillers was found from T_3 (26.7/hill) which was statistically similar with T_1 (26.5/hill) while minimum from T_6 (21.7/hill) (Table 1). Singh and Pandey (1972) observed that tiller production was greatest under continuous submergence and decreased with decreasing soil moisture.

Number of Effective tiller: Maximum number of effective tillers was found from T_3 (21.5/hill) which was statistically identical with T_4 (21.4/hill) while minimum from T_6 (18.7/plant) (Table 1). Gani *et al*. (2002) reported that intermittent (alternate wet and drying) irrigation consistently performed better than continuously flooded irrigation, that it is produced more effective tillers, leaf area and biomass.

Non-effective tiller: Maximum number of non-effective tiller was found from T_6 (3.8/hill) which was statistically identical with T_1 (3.6/hill) and T_5 (3.5/hill) whereas minimum from T_3 (3.0/hill) which was statistically identical with T_4, T_7 and T_9 (3.2/hill) (Table 1).

Panicle length: Panicle length showed significant variation among the treatments. Longest panicle was found from T_3 and T_4 (31.5 cm) while shortest from T_6 (29.7 cm) (Table 1).

Table 1. Response of different levels of irrigations on different characteristics of rice

Irrigations	Plant height (cm)	Number of tillers/hill	No. of effective tillers/hill	No. of non-effective tillers/hill	Panicle length (cm)
T_1	87.3 b	26.5 a	20.7 b	3.6 ab	30.5 bc
T_2	85.1 c	23.8 c	20.5 c	3.4 bcd	30.3 cd
T_3	89.5 a	26.7 a	21.5 a	3.0 e	31.5 a
T_4	89.3 a	24.2 b	21.4 a	3.2 de	31.5 a
T_5	84.8 d	23.6 c	20.5 c	3.5 abc	30.8 bc
T_6	80.3 g	21.7 d	18.7 g	3.8 a	29.7 e
T_7	83.1 ef	21.9 d	19.3 f	3.2 de	29.9 de
T_8	82.7 fg	22.1 d	19.6 e	3.7 b	30.0 de
T_9	83.5 ef	23.6 c	20.3 d	3.2 de	30.1 de
LSD0.05	0.2	0.1	0.1	0.1	0.1
CV (%)	0.5	1.1	0.5	4.7	0.7

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Number of grains/panicle: Maximum number of grains was found from T_3 (215.5/panicle) followed by T_4 (212.1/panicle) while minimum from T_6 (175.4/panicle) (Table 2). Reddy and Hokkeri (1979) found no effect of continuous and phasic submergence on the number of grains per panicle and 1000 grains weight.

Number of unfilled grain/panicle: Minimum number of unfilled grain was found from T_3 (8.6/panicle) whereas maximum from T_6 (15.2/panicle) (Table 2).

1000-grains weight: Maximum weight of 1000-grains was found from T_3 (24.0 g) followed by T_4 (23.1 g) while minimum from T_5 and T_6 (20.4 g) (Table 2). Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algae) on rice yield. The result indicated that water regimes affected 1000 grains yield of rice significantly.

Grain yield: Maximum grain yield was found from T_3 (7.80 t/ha) followed by T_4 (7.20 t/ha), T_5 (7.18 t/ha) and T_1 (7.17 t/ha) whereas minimum from T6 (6.30 t/ha) (Table 2). McHugh *et al*. (2002) observed highest yield of rice grain was obtained in case of alternate wetting and drying system than non flooded and continuously flooded irrigation. AWD can improve yield (Zhang *et al.* 2010) by increasing proportion of tillers that are productive, reducing the angle of the topmost leaves thus allowing more light to penetrate the canopy and modifying shoot and root activity, implying altered root-to-shoot signaling of phytohormones such as abscisic acid (ABA) and cytokinins (Yang and Zhang, 2010). Increased grain yield due to reduction of nonproductive tillers by encouraging early tillering (Yang and Zhang, 2010) an increased percentage of filled grains (Zhang *et al.* 2010) and increased individual grain weight (Matsuo and Mochizuki, 2009; Zhang *et al.* 2010). Remobilization of carbohydrates from stems to grain (Yang and Zhang, 2010) could represent another important mechanism of improving grain filling under AWD treatments. Although root signals (such as plant hormones) can influence grain yield independently of leaf water relations (Westgate *et al.* 1996; Zhang *et al.* 2010), relatively little is known about the mechanistic basis of this response. The highly dynamic soil environment during AWD (decreased soil oxygen concentrations during flooding and decreased matric potential during drying) will produce dramatic fluctuations in the root synthesis of chemical signals and their transport to the shoot. Flooding seems to increase shoot ACC status, and decrease shoot ABA and cytokinins status (Else *et al.* 2009) while soil drying increases shoot ABA (and possibly ACC) status and decreases shoot cytokinin status (Kudoyarova *et al.* 2007; Belimov *et al.* 2009). AWD increased macro and micro nutrient availability and uptake also increase the concentration of essential dietary micronutrients in the grain (Price *et al.* 2013). N_2O emissions tend to increase because of increased nitrification and denitrification activities, with soil conditions constantly changing between anaerobic and aerobic, and related changes in redox potential by alternate wetting and drying (Sander *et al.* 2011). Alternate wetting and drying therefore generates multiple benefits related to reducing water use, reducing methane emissions (mitigation) and increasing productivity (Bouman *et al.* 2007) by producing heavier and bigger grains, more tillers, fewer insect pests and diseases (Palis *et al.* 2004). Alternate drying and wetting of the fields allows for good aeration of the soil and better root growth thereby increasing rice yield and water use efficiency (Uphoff 2006). For conventional crop management, AWD is applied instead of continuous flooding, which is the standard irrigation method. Although water productivity is increased, yields associated with AWD can either be maintained or decreased compared to continuous flooding. In 31 field experiments analyzed by Bouman and Tuong (2001), 92% of the AWD treatments resulted in yield reductions varying from 0% to 70% compared with those of the flooded control plots. Yao *et al.* (2012) testing "super hybrid" variety and a "water-saving and drought-resistant" variety found water saving of 24%-38% with AWD compared to continuously flooded plots, but no significant difference in yield between the two treatments. In contrast, under the SRI system, reducing irrigation water application, done through the AWD method, is one of the main principles of SRI. AWD is co-responsible for saving water and increasing yields. Other studies, which reported water productivity improvements from 32-100%, with associated yield increases of 5-51% (Zhao *et al.* 2009; Zhao *et al.* 2010; Chandrapala *et al.* 2010; Geethalakshmi *et al.* 2011; Ndiiri *et al.* 2012).

Straw yield: Maximum straw yield was found from T_3 (7.52 t/ha) followed by T_1 (7.33 t/ha) and T_4 (7.32 t/ha) whereas minimum from T_6 (6.06 t/ha) (Table 2). Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algae) on rice yield. The result indicated that water regimes affected straw yield of rice significantly.

Table 2. Response of different levels of irrigations on different yield characteristics of rice

Treatments	No. of grains per panicle	No. of unfilled grains/panicle	1000 grains weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1	209.0 c	11.7 f	22.1 c	7.17 b	7.33 b
T_2	203.7 d	12.1 e	21.5 c	7.07 c	7.26 c
T_3	215.5 a	8.6 h	24.0 a	7.80 a	7.52 a
T_4	212.1 b	10.8 g	23.1 b	7.20 b	7.32 b
T_5	199.0 e	12.2 e	20.4 d	7.18 b	7.26 c
T_6	175.4 i	15.2 a	20.4 d	6.30 f	6.06 f
T_7	185.8 h	14.4 b	21.6 c	0.28 e	6.52 e
T_8	188.9 g	13.5 c	21.3 c	6.54 e	7.09 d
T_9	189.9 f	13.2 d	21.3 c	6.97 d	7.09 d
LSD0.05	0.2	0.1	0.3	0.03	0.02
CV (%)	0.2	0.6	2.2	0.81	0.44

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NPKS concentration in grains and straw

Maximum N concentration in rice grain (1.20%) and straw (0.69%) was found from T_3 whereas minimum from T_6 (0.96% in grain and 0.51% in straw). Maximum P concentration in rice grain (0.38%) and straw (0.20%) was found from T_3 while minimum from T_6 (0.29% in grain and 0.10% in straw). Maximum K concentration in rice grain (0.39%) and straw (1.87%) was found from T_3 whereas minimum from T_6 (0.25% in grain and 1.32% in straw). Maximum S concentration in rice grain and straw (0.10%) was found from T_3. On the other hand minimum S concentration in grain was found from T_6 (0.06%) and minimum S concentration in rice straw was found from T_6, T_7, T_8 (0.07%) (Table 3).

Table 3. Effect of different levels of irrigation on NPKS concentration of boro rice grains and straw[X]

Treatments	Concentration (%) in grains				Concentration (%) in straw			
	N	P	K	S	N	P	K	S
T_1	1.16 c	0.36 b	0.36 c	0.09 b	0.60 d	0.16 c	1.70 c	0.08 c
T_2	1.13 e	0.33 d	0.35 d	0.08 c	0.62 c	0.14 d	1.58 d	0.08 c
T_3	1.20 a	0.38 a	0.39 a	0.10 a	0.69 a	0.20 a	1.87 a	0.10 a
T_4	1.19 b	0.36 b	0.38 b	0.09 b	0.66 b	0.19 b	1.75 b	0.09 b
T_5	1.14 d	0.34 c	0.36 c	0.08 c	0.66 b	0.16 c	1.55 e	0.08 c
T_6	0.96 h	0.29 g	0.25 g	0.06 e	0.51 h	0.10 g	1.32 i	0.07 d
T_7	1.09 g	0.30 f	0.29 f	0.07 d	0.54 f	0.12 f	1.47 h	0.07 d
T_8	1.12 f	0.32 e	0.34 e	0.08 c	0.57 e	0.12 f	1.51 g	0.07 d
T_9	1.13 e	0.33 d	0.36 c	0.08 c	0.53 g	0.13 e	1.54 f	0.08 c
LSD0.05	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
CV (%)	0.300	1.03	0.42	5.6	0.2	0.88	0.52	11.3

[X]In a column figures having similar letter(s) do not differ significantly where as figures with dissimilar letter(s) differ significantly as per DMRT

pH, organic matter and NPKS status of post harvest soil

Maximum pH and organic matter of post harvest soil was found from T_1 (5.9 and 1.26%) where plot was kept continuous submergence with 1 to 7 cm standing water while minimum from T_6 (5.4 and 1.05%) where irrigation was started after 7 days disappearance of water (Table 4). Total nitrogen content of post harvest soil was found from T_3 (0.075%) (start irrigation when water table in the porous tube at 10 cm) while minimum from T_6 (0.061%) which was statistically similar with T_7 (0.062%) (Table 4). Maximum available phosphorus content of post harvest soil was found from T_3 (19.89 mg/kg soil) while minimum from T_6 (13.27 mg/kg soil). Maximum exchangeable potassium content of post harvest soil was found from T_3 (0.12 meq/100g soil) while minimum from T_6 (0.04 meq/100g soil). Maximum available sulphur content of post harvest soil was recorded from T_3 while minimum from T_6 (10.08 mg/kg soil) (Table 4).

Table 4. Effect of different levels of irrigation on the pH, organic matter and NPKS content in post harvest soil

Treatments	pH		Organic matter (%)		Total N (%)		Available P (mg/kg soil)	Exchangeable K (meq/100g soil)	Available S (mg/kg soil)	
T_1	5.9	a	1.26	a	0.071	b	19.21	0.09	14.37	c
T_2	5.7	c	1.15	g	0.066	d	17.36	0.07	12.03	f
T_3	5.8	b	1.16	f	0.075	a	19.89	0.12	14.66	a
T_4	5.6	d	1.19	d	0.072	b	19.78	0.11	14.50	b
T_5	5.5	e	1.23	b	0.069	c	16.46	0.07	13.20	d
T_6	5.4	f	1.05	i	0.061	f	13.27	0.04	10.08	i
T_7	5.7	c	1.11	h	0.062	f	14.43	0.05	11.58	h
T_8	5.6	d	1.18	e	0.063	ef	14.16	0.07	11.85	g
T_9	5.7	c	1.20	c	0.064	e	16.02	0.08	12.35	e
LSD0.05	0.002		0.004		0.001		NS	NS	0.04	
CV (%)	0.03		0.540		5.25		0.84	0.02	0.49	

In a column figures having similar letter(s) do not differ significantly where as figures with dissimilar letter(s) differ significantly as per DMRT

CONCLUSION

From the above discussion it can be concluded that alternate wetting and drying irrigation had significant effect on yield and yield contributing characters of boro rice. Irrigating field when water table in porous tube at 10 cm is most favorable for improving yield and yield contributing characters of HIRA HYBRID dhan2 in Boro season.

REFERENCES

BARC (Bangladesh Agricultural Research Council) (2007) Fertilizer Recommendation Guide, 2007. BARC, Soils Pub. No.14. 2007. Farmgate, Dhaka: 25-128.

Belimov AA, Dodd IC, Hontzeas N, Theobald JC, Safronova VI, Davies WJ (2009) Rhizosphere bacteria containing 1-aminocyclopropane-1-carboxylate deaminase increase yield of plants grown in drying soil via both local and systemic hormone signalling. *New Phytol.* 181, 413–423.

Black CA (1965) Methods of Soil Analysis. Part I and II Amer. Soc. Agron. Inc. Pub. Madison, Wisconsin, USA.

Bouman BAM, Lampayan RM, Tuong TP (2007) Water management in irrigated rice: coping with water scarcity. Los Baños (Philippines): International Rice Research Institute. p. 54.

Bouman BAM, Tuong TP (2001) Field water management to save water and increase its productivity in irrigated lowland rice. Agricultural Water Management 49, 11-30.

Chandrapala ANG, Yakadri M, Mahender Kumar R, Bhupal Raj G (2010) Productivity and economics of rice (*Oryza sativa*)-maize (*Zea mays*) as influenced by methods of crop establishment, Zn and S application in rice. *Indian Journal of Agronomy* 55(3), 171-176.

Else MA, Janowiak F, Atkinson CJ, Jackson MB (2009) Root signals and stomatal closure in relation to photosynthesis, chlorophyll a fluorescence and adventitious rooting of flooded tomato plants. *Ann. Bot.* 103, 313–323.

Gani A, Rahman A, Dahono, Rustam, Hengsdijk H (2002) Synopsis of water management experiments in Indonesia. *Water wise rice production*, IRRI. 29-38.

Geethalakshmi V, Ramesh T, Palamuthirsolai A, Lakshmanan (2011) Agronomic evaluation of rice cultivation systems for water and grain productivity. *Archives of Agronomy and Soil Science* 57(2), 159-166.

Gomez KA, Gomez AA (1984) Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hunter AH (1984) Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

IRRI (2013) Nutrient Manager for Rice. Los Baños, Philippines: International Rice Research Institute (IRRI). (Available from: http://webapps.irri.org/ph/rcm)

Jackson ML (1962) Soil Chemical Analysis. Constable and Co. Ltd London, First Print.

Jackson ML (1973) Soil chemical analysis. Prentice-Hall of India, Pvt. Ltd.. pp. 326-338.

Kudoyarova GR, Vysotskaya LB, Cherkozyanova A, Dodd IC (2007) Effect of partial rootzone drying on the concentration of zeatin-type cytokinins in tomato (*Solanum lycopersicum* L.) xylem sap and leaves. *J. Exp. Bot.* 58, 161–168.

Matsuo N, Mochizuki T (2009) Growth and yield of six rice cultivars under three water-saving cultivations. *Plant Prod. Sci.* 12, 514–525.

Ndiiri JA, Mati BM, Home PG, Odongo B, Uphoff N (2012) Comparison of water savings of paddy rice Under System Of Rice Intensification (SRI) growing rice In Mwea, Kenya. *International Journal of Current Research and Review* 4(6), 63-73.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U. S. Dept. Agric. Circ., p. 929.

Page AL, Miller RH, Keeney DR (1982) Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. pp. 403-430.

Palis FG, Cenas PA, Bouman BAM, Lampayan RM, Lactaoen AT, Norte TM, Vicmudo VR, Hossain M, Castillo GT (2004) A farmer participatory approach in the adaptation and adoption of controlled irrigation for saving water: a case study in Canarem, Victoria, Tarlac, Philippines. *Philipp. J. Crop Sci.* 29(3), 3-12.

Patel JR (2000) Effect of water regimes, variety and blue-green algae on rice (*Oryza sativa*). *Indian J. Agron.* 45(1), 103-106.

Price AH, Norton GJ, Salt DE, Ebenhoeh O, Meharg AA, Meharg C, Islam MR, Sarma RN, Dasgupta T, Ismail AM, McNally KL, Zhang H, Dodd IC, Davies WJ (2013) Alternate wetting and drying irrigation for rice in Bangladesh: Is it sustainable and has plant breeding something to offer? *Food and Energy Security* 2(2), 120–129.

Rajendran R, Reuben R, Purush S, Veerapatran R (1995) Prospects and problems of intermittent irrigation for control of vector breeding in rice fields in southern India. *Annals of Tropical Medicine and Parasitology*. 89, 541-549.

Reddy SR, Hokkeri SB (1979) Soil, water and weed management for direct seeded rice grown on irrigated soils in north western India. *Ind. J. Agric. Sci.* 49(6), 427-433.

Sander PM, Klein N, Stein K, Wings O (2011) Sauropod bone histology and its implications for sauropod biology. In: Klein, N., Remes, K., Gee, C.T. & Sander, P.M. (eds.): Biology of the sauropod dinosaurs: understanding the life of giants. Indiana University Press (Bloomington): 276-302.

Sarkar S (2001) Effect of water stress on growth, productivity and water expense efficiency of summer rice. *Indian J. Agril. Sci.* 71(3), 153-158.

Singh P, Pandey HK (1972) Tillering potentiality and yield of rice varieties under different levels of soil moisture and nitrogen. *Riso.* 21(3), 201-207.

Thakur, Amod K, Rath S, Patil DU, Kumar A (2011) Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance. *Paddy and water Environment.* 9, 13-24.

Uphoff N (2006) "The System of Rice Intensification (SRI) as a methodology for reducing water requirements in irrigated rice production. Paper for International Dialogue on Rice and Water: Exploring Options for Food Security and Sustainable Environments" held at IRRI, 7-8 March 2006, Los Banos, Philippines.

Walkley A, Black DR (1935) An examination of the digestion method for determining soil organic matter and proposed modification of the chronic acid titration method. *Soil Sci*. 37, 29-38.

Westgate ME, Passioura JB, Munns R (1996) Water status and ABA content of floral organs in drought-stressed wheat. *Aust. J. Plant Physiol.* 23, 763–772.

Yang J, Dongfen H, Hua D, Guilu T, Jianhua Z (2009) Alternate wetting and moderate soil drying increases grain yield and reduces cadmium accumulation in rice grains. *Journal of the Science of Food and Agriculture*. 89(10), 1728-1736.

Yang JC, Zhang JH (2010) Crop management techniques to enhance harvest index in rice. *J. Exp. Bot.* 61, 3177–3189.

Yao F, Huang J, Cui K, Nie L, Xiang J, Liu X, Wu W, Chen M, Peng S (2012) Agronomic performance of high-yielding rice variety grown under alternate wetting and drying irrigation. *Field Crops Research* 126, 16-22.

Zhang H, Chen T, Wang Z, Yang J, Zhang J (2010) Involvement of cytokinins in the grain filling of rice under alternate wetting and drying irrigation. *J. Exp. Bot.* 61, 3719–3733.

Zhao L, Wu L, Li Y, Sarkar A, Zhu D, Uphoff N (2010) Comparisons of yield, water use efficiency, and soil microbial biomass as affected by the System of Rice Intensification. *Communications in Soil Science and Plant Analysis* 41(1), 1-12.

Zhao L, Wu L, Li Y, Xinghua L, Zhu D, Uphoff N (2009) Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates. *Experimental Agriculture* 45, 275-286.