

Original Research Paper

Irrigation water management of some salt tolerant rice cultivars for higher yield

SALT STRESS IS ONE OF THE MOST IMPORTANT ABIOTIC STRESSES THAT ADVERSELY AFFECT CROP PRODUCTIVITY AND CAUSES SIGNIFICANT CROP LOSS WORLDWIDE. THE OBJECTIVE OF THIS FIELD STUDY WAS TO INVESTIGATE THE EFFECT OF DIFFERENT IRRIGATION REGIMES AND AMELIORATIVE ON THE YIELD PERFORMANCE OF SOME RICE LINES/CULTIVARS IN SALT AFFECTED AREA OF BANGLADESH. IRRIGATION TREATMENTS WERE COMPRISED OF : = CONTINUOUS SATURATION + GYPSUM APPLICATION AT FLOWERING STAGE (T_1), CONTINUOUS PONDING WITH 2 CM + GYPSUM APPLICATION AT FLOWERING STAGE (T_2), CONTINUOUS PONDING WITH 5 CM + GYPSUM APPLICATION AT FLOWERING STAGE (T_3), AWD LOWERING WITH 5CM (T_4), AWD LOWERING WITH 10 CM (T_5). THE MUTANT/VARIETY TESTED WERE: V_1 = RC-222, V_2 = RC-228, V_3 = BINADHAN-8, AND V_4 = BINADHAN-10. THE INTERACTION RESULTS REVEALED SIGNIFICANT EFFECT ON YIELD ATTRIBUTING CHARACTERS AS WELL AS ON GRAIN YIELD. THE HIGHEST GRAIN YIELD (5.83 T/HA) WAS OBSERVED IN CONTINUOUS PONDING BY 2 CM COUPLED WITH GYPSUM AT FLOWERING STAGE, FOLLOWED BY CONTINUOUS SATURATION CONDITION PLUS GYPSUM, WITH BINADHAN-8. CONSIDERING THE GRAIN YIELD AND IRRIGATION WATER USED, BINADHAN-8 CAN BE CULTIVATED UNDER CONTINUOUS PONDING BY 2 CM CONDITION COUPLED WITH GYPSUM APPLICATION AT FLOWERING STAGE.

Keywords: Irrigation, saline water, gypsum, rice productivity

1. INTRODUCTION

The most important cereal crop in the world is rice, yielding one-third of the total carbohydrate source. Three billion people consider rice as their stable food, accounting for 50–80% of their daily calorie intake. Rice is a salt-sensitive monocot (Darwish *et al.*, 2009; Shereen *et al.*, 2005). Salinity is a limiting environmental factor for rice production, and is becoming more prevalent as the intensity of agriculture increases. Around the world, 100 million ha, or 5% of arable land, is adversely affected by high salt concentrations, which reduce crop growth and yield (Gunes *et al.*, 2007). Salt and drought stresses have toxic effects on plants and lead to metabolic changes, like loss of chloroplast activity, decreased photosynthetic rate and increased photorespiration rate which then lead to an increased reactive oxygen species production (Teixeira & Pereira 2007; Hoshida *et al.*, 2000).

About 53 % of net cultivable land of coastal region of Bangladesh is affected by different degrees of salinity (SRDI, 2016). Agricultural land use in these areas is very poor compared to the country's average cropping intensity of 191 % (BBS, 2011; Haque, 2006). Water is the main natural resource for crop production which is also affected by salinity during

winter/dry season. Salinity in the river system of the southwest coastal region increases steadily from December through February, reaching maximum in the late March and early April (EGIS, 2001).

In salt-affected soil, there are many salt contaminants, especially NaCl which readily dissolves in water to yield the toxic ions, sodium ion (Na^+) and chloride ion (Cl^-). Also, the water available in the salt-contaminated soil is restricted, inducing osmotic stress (Castillo *et al.*, 2007; Pagter *et al.*, 2009; Siringam *et al.*, 2011). Salinity and sodicity can reduce plant growth and alter ionic relations by ionic and osmotic effects and oxidative stress (Eraslan *et al.*, 2007; Tarakcioglu & Inal 2002). Salinity inhibits plant growth in three principle ways: by ion toxicity (mainly of Na^+ and Cl^-), osmotic stress, and nutritional disruption (Ali, 2011; Caines & Shennan, 1999). A combination of these factors may also occur (Ashraf & Harris 2004; Marschner, 1995). All of these cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels and at the molecular level (Munns, 2002; Tester and Davenport 2003; Winicov, 1998). Many enzymatic activities of plants are adversely affected by high Na^+ concentration (Maathuis & Amtmann 1999). Salt tolerance is related to exclusion of Na^+ ion and distribution of almost uniform concentration of this ion in all leaves (Ashraf & O'Leary 1995; Haq *et al.*, 2009). Accumulation of toxic levels of NaCl in the cytoplasm must therefore be avoided.

Plant adaptations to salinity include sequestration of salt ions in vacuoles and accumulation of 'compatible compounds', such as sugars, proline and glycinebetaine in the cytoplasm to balance the osmotic pressure (Hopkins, 1999; Jampeetong & Brix 2009). Some researchers suggested that application of gypsum, plantation of leguminous crops, selection of more salt-tolerant crops, harvesting rainwater, exploring suitable locations for tube-wells, might be the possible management options (Akanda *et al.*, 2014; Khanom and Salehin, 2012; Haque, 2006). Besides, crop planting on raised-bed and mulching is used as a technique for decrease of salinity (Kamar *et al.* 2015; Pang *et al.*, 2010; Dong *et al.*, 2008, 2009; Karlberg *et al.*, 2007; Beecher *et al.*, 1998). Previously, many researchers have reported substantial increases in crop yields as a result of proper irrigation and management technique (Kamar *et al.*, 2015; Wang *et al.*, 2015).

Rezaei *et al.* (2012) studied the effects of salinity stress as well as water stress on rice (in a pot experiment) at Rice Research Institute of Iran. Five water salinity levels: fresh water ($\text{EC} = 1 \text{ dS m}^{-1}$), 2, 4, 6 and 8 dS m^{-1} and five irrigation regimes: continues flooding, Alternative Wetting and Drying (AWD), intermittent irrigation at 100, 90 and 80 percent of field capacity (FC) were considered as irrigation treatments. The results showed severe effects of water and salinity stresses on rice yield and yield components. Fresh water produced the highest yield, $18.57 \text{ gm pot}^{-1}$, whereas, the yield in salinity levels of 2, 4, 6 and 8 dS.m^{-1} were 13.78, 5.78, 3.61 and 0.74 gm pot^{-1} , respectively, with the yield losses of 25, 70, 80 and 97%, respectively. Intermittent irrigation at FC produced the highest yield. The high levels of salts in irrigation water can restrict or even scupper the rice cultivation, also by the presence of some elements in toxic concentrations (Fraga *et al.*, 2010; Silva, 2004). Asch & Wopereis (2001) studied the effect of field-grown irrigated rice cultivars to varying levels of floodwater salinity and concluded that use of salinity tolerant cultivars, drainage if floodwater $\text{EC} > 2 \text{ dS.m}^{-1}$ at critical growth stages, and early sowing in the WS to avoid periods of low air humidity during the crop cycle, are ways to increase rice productivity.

Crop yield response to salinity depends on crop sensitivity/resistivity to salinity, soil-water regime (which is modified by irrigation amounts and frequency) and also on salinity of irrigation water. The objective of this study was to investigate the effect of different irrigation regimes and ameliorative on the yield performance of some rice lines/cultivars in salt affected area of Bangladesh.

2. MATERIAL AND METHODS

2.1 Location and experimental treatments

The experiment was conducted at farmer's field of Debhata village, Satkhira District (22°43' N, 89°05' E), during Boro season (January-May) of 2013 to determine the optimum water requirement and water productivity of salt tolerant rice mutants/varieties in saline area.

The experimental design was RCBD with split plot having three replications. Irrigation treatments were: T₁ = Continuous saturation + Excess gypsum application (half of the recommended basal dose) at flowering stage,

T₂ = Continuous ponding with 2 cm + Excess gypsum application at flowering stage,

T₃ = Continuous ponding with 5 cm + Excess gypsum application at flowering stage,

T₄ = AWD lowering with 5cm (AWD = Alternate wetting and drying),

T₅ = AWD lowering with 10 cm.

The Mutant/variety tested were:

V₁= Rc-222

V₂= Rc-228

V₃= Binadhan-8

V₄= Binadhan-10

Forty-five days rice seedlings were transplanted on 31st January 2013. The recommended fertilizers were: Urea, TSP, MP, Gypsum, and Zinc at the rate of 217, 110, 70, 45, and 4.5 kg/ha; respectively. Treatments were started 15 days after transplanting. All the mutants/ varieties were harvested on 11th May 2013. At the harvest time, yield and yield attributing characters were collected. Other necessary data (e.g. amount of water applied at each irrigation, EC of plot water and EC of irrigation water) were recorded.

2.3 Irrigation Water Productivity

Irrigation water productivity (IWP) was calculated as:

$$IWP = \frac{Y_{\text{grain}}}{I} \dots\dots\dots (1)$$

Where I is the irrigation amount.

2.3 Analysis of experimental data

The analysis of variance technique (ANOVA) was carried out on the data for each parameter as applicable to the design. The significance of the treatment effect was determined using F-test, and to determine the significant difference among the means of the treatments, least significant difference (LSD) were estimated at 5% probability level.

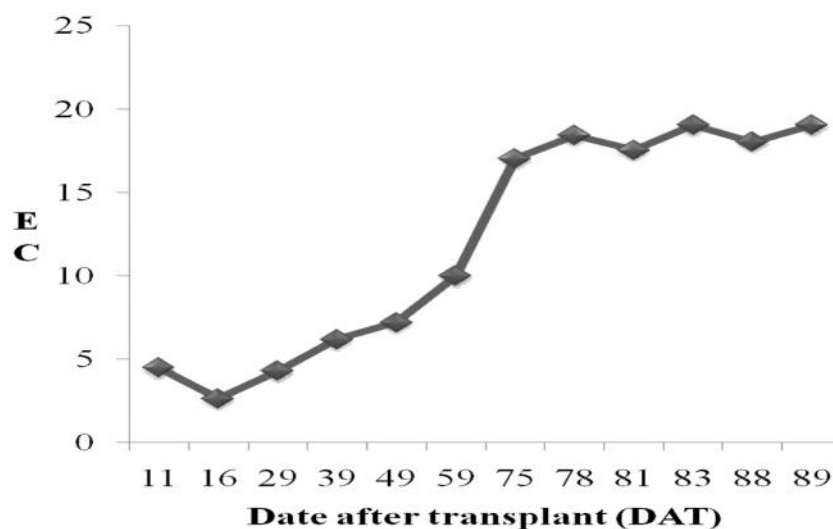
3. RESULTS AND DISCUSSION

[(Detailed instruction about this section is given below. 3.1 Plot-water salinity

Irrigation water salinity varied from 2.19 to 10.8. Plot water salinity varied from 2.65 to 19.05 dS m⁻¹ during the crop period (Fig. 1). Irrigation was applied by 80 cm, and 90 cm, 101cm, 69 cm and 66 cm in T₁, T₂, T₃, T₄ and T₅ treatment,

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125 Fig. 1. EC (dS/m) of plot-water during the rice growing period

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127 3.2 Yield attributes and grain yield

128 The mean effects of different irrigation treatments and cultivars on different yield attributes and grain yield are presented
129 in Table.1. The irrigation treatments showed significant effect on yield attributing characters as well as on grain yield. The
130 highest grain yield (5.83 t/ha) was observed in T1 treatment (continuous saturation + gypsum at flowering stage) followed
131 by T2 (continuous ponding by 2 cm + gypsum). The treatment T1 and T2 produced statistically identical yield.

132 In case of mean varietal effects, Binadhan-8 (V3) produced the highest grain yield (5.55 t ha⁻¹) followed by Binadhan-10
133 (V4) (5.20 t ha⁻¹), but the yields are statistically similar.

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135 Table 1. Effect of irrigation and varieties on yield and yield attributing characters of rice at Satkhira.

Treatment	Plant height (cm)	No of hill/plant (nos.)	Panicle length (cm)	No of seeds/ panicle (nos.)	1000 seed wt. (gm)	Grain yield (t. ha ⁻¹)
T ₁	89.15	12.34	26.35	90.98	21.34	5.83 a
T ₂	89.90	14.55	27.23	97.01	21.64	5.12 ab
T ₃	85.22	13.47	25.68	84.53	20.94	4.71 b
T ₄	84.08	13.83	25.33	75.38	20.04	4.13 b
T ₅	81.25	14.83	25.90	75.22	19.19	2.96 c
LSD _{0.05}	3.81	1.56	0.73	16.62	1.58	0.99
V ₁	73.78	15.09	24.07	77.54	18.98	3.98
V ₂	92.32	14.39	26.55	61.44	21.53	3.47
V ₃	88.64	12.49	26.85	104.65	20.70	5.55
V ₄	88.93	13.24	26.91	94.85	21.31	5.20
LSD _{0.05}	2.21	0.92	0.72	9.03	1.19	0.73

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137 3.3 Interaction effects of irrigation treatments and cultivars

Interaction effects of irrigation treatments and varieties are presented in Table 2. The interactions are significant for all yield attributes and grain yield. The combination T2V3, that is, the variety Binadhan-8 under 'continuous ponding by 2 cm plus gypsum application' produced the highest grain yield followed by T1V3 (that is, the variety Binadhan-8 under 'continuous saturation plus gypsum application'), but they are statistically similar. The third highest grain yield was obtained in combination T1V4, that is, the variety Binadhan-10 under 'continuous saturation plus gypsum application'. The results revealed that drought stress along with salinity stress, have more detrimental effect on grain yield for all cultivars.

Khan et al. (1992) reported that gypsum and Zinc application significantly reduced the adverse effects of salinity and resulted in the production of the maximum number of tillers and in the tallest plant height. The combination of gypsum (160 kg/ha) and Zn (5 kg/ha) produced a grain yield about 30, 8, and 20% higher than that of the control at 0.6, 8, and 16 mS/cm salinity, respectively. Hussain et al. (2000) obtained highest yield of rice (2.5 t/ha) with 100% gypsum requirement along with double soil ripping. In our case, we obtained highest yield of Binadhan-8 under continuous ponding by 2 cm plus gypsum application at flowering stage. Application of less amount of water (compared to 5cm ponding) resulted in lower accumulation of total salt during growing period, and thus may have less adverse effect on yield.

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Table 2. Interaction effect of treatment and varieties on yield and yield attributing characters of rice at Sathkhira.

Treatment	Plant height (cm)	No of hill/plant (nos.)	Panicle length (cm)	No of seeds/panicle (nos.)	1000 seed wt. (gm)	Seed yield (t ha ⁻¹)
T ₁ V ₁	76.53	14.20	24.20	84.73	19.69	5.33
T ₁ V ₂	95.80	13.07	27.27	69.00	22.89	5.33
T ₁ V ₃	91.13	11.50	26.87	113.20	22.05	6.50
T ₁ V ₄	93.13	10.60	27.07	97.00	20.74	6.17
T ₂ V ₁	77.13	17.33	24.27	91.73	19.76	3.83
T ₂ V ₂	94.80	14.60	28.60	79.50	21.52	4.00
T ₂ V ₃	93.93	13.33	28.53	105.07	22.29	6.83
T ₂ V ₄	93.73	12.93	27.53	111.73	22.89	5.83
T ₃ V ₁	71.60	13.93	23.93	79.73	20.26	4.00
T ₃ V ₂	93.00	14.00	25.30	55.50	20.27	4.00
T ₃ V ₃	88.93	13.10	26.13	100.73	20.85	5.50
T ₃ V ₄	87.33	12.80	27.33	102.13	22.38	5.33
T ₄ V ₁	74.13	14.47	24.27	73.87	17.84	3.50
T ₄ V ₂	90.10	13.90	25.30	48.70	20.79	3.00
T ₄ V ₃	85.40	11.60	25.87	99.33	19.56	4.67
T ₄ V ₄	86.67	15.33	25.87	79.60	21.98	5.33
T ₅ V ₁	96.50	15.50	23.70	57.65	17.35	3.25
T ₅ V ₂	87.90	16.40	26.30	54.50	22.16	1.00
T ₅ V ₃	83.80	12.87	26.87	104.93	18.78	4.25
T ₅ V ₄	83.80	14.53	26.73	83.80	18.49	3.33

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3.4 Comparative irrigation water savings and yield reductions

Table 3 shows the total irrigation water requirement and comparative water savings under different treatments. The treatment T3 required the highest amount (101 cm) followed by T2 (90 cm). Compared to T3, the treatment T5 saved the highest amount, but the yield in low (Table 1, Table 2).

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Table 3. Comparative irrigation water savings and irrigation water productivity under different treatments

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Treatment	Irrigation water (cm)	Irrigation water saved compared to T ₃ (cm)	% Irrigation water savings	Irrigation water productivity (kg.ha ⁻¹ .cm ⁻¹)
T ₁	80	21	20.8	72.9
T ₂	90	11	10.9	56.9
T ₃	101	-	-	46.6
T ₄	69	32	31.7	59.9
T ₅	66	35	34.7	44.8

Considering the grain yield and irrigation water used, Binadhan-8 can be cultivated under continuous saturation condition coupled with gypsum application at flowering stage.

4. CONCLUSION

The results of our study revealed that continuous ponding by 2 cm with gypsum application at flowering stage produced the highest yield. Binadhan-8 produced higher yield than Binadhan-10.

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