Asian Journal of Advances in Agricultural Research

3(4): 1-7, 2017; Article no.AJAAR.35860
ISSN: 2456-8864

Irrigation Water Management of Some Salt Tolerant Rice Cultivars for Higher Yield

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJAAR/2017/35860
Editor(s):
(1) Tancredo Souza, Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal.
Reviewers:
(1) Kürşat Çavuşoğlu, Süleyman Demirel University, Turkey.
(2) Blas Lotina Hennsen, Universidad Nacional Autónoma de México, Mexico.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/22073

Original Research Article

Received 31st July 2017
Accepted 6th September 2017
Published 28th November 2017

ABSTRACT

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 lines/varieties 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 saturation condition couple with gypsum application at flowering stage.

Keywords: Irrigation; saline water; gypsum; rice productivity.

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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 [1,2]. 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 [3]. 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 [4,5].

About 53% of net cultivable land of coastal region of Bangladesh is affected by different degrees of salinity [6]. Agricultural land use in these areas is very poor compared to the country's average cropping intensity of 191 % [7,8]. 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 [9].

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 [10,11,12]. Salinity and sodicity can reduce plant growth and alter ionic relations by ionic and osmotic effects and oxidative stress [13,14]. Salinity inhibits plant growth in three principle ways: by ion toxicity (mainly of Na^+ and Cl^-), osmotic stress, and nutritional disruption [15,16]. A combination of these factors may also occur [17,18,15]. All of these cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels and at the molecular level [19,20,21]. Many enzymatic activities of plants are adversely affected by high Na^+ concentration [22]. Salt tolerance is related to exclusion of Na^+ ion and distribution of almost uniform concentration of this ion in all leaves [23,24]. 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 [25,26]. 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 [27,28,8,15]. Besides, crop planting on raised-bed and mulching is used as a technique for decrease of salinity [29,30,31,32]. Previously, many researchers have reported substantial increases in crop yields as a result of proper irrigation and management technique [29,33].

Rezaei et al. [34] 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 (EC = 1 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 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. 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 [35,36]. Asch & Wopereis [37] 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 EC >2 $dS.m^{-1}$ 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. MATERIALS 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°5″ E), during Boro season (January-May) of 2013 to determine the optimum irrigation management strategy of some salt tolerant rice lines/varieties in saline area.

The experimental design was RCB with split plot having three replications. Irrigation treatments were:

- T_1 = Continuous saturation + Excess gypsum application (half of the recommended basal dose) at flowering stage,
- T_2 = Continuous ponding with 2 cm + Excess gypsum application at flowering stage,
- T_3 = Continuous ponding with 5 cm + Excess gypsum application at flowering stage,
- T_4 = AWD lowering by 5 cm (AWD = Alternate wetting and drying),
- T_5 = AWD lowering by 10 cm.

The lines/varieties tested were:

- V_1= RC-222
- V_2= RC-228
- V_3= Binadhan-8
- V_4= 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 lines/ 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.

2.2 Irrigation Water Productivity

Irrigation water productivity (IWP) was calculated as:

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

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

3.1 Plot-water Salinity

Irrigation water salinity varied from 2.19 to 10.8 dS m^{-1}. 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, 90 cm, 101cm, 69 cm and 66 cm in T1, T2, T3, T4 and T5 treatment, respectively.

3.2 Yield Attributes and Grain Yield

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

In case of mean varietal effects, Binadhan-8 (V3) produced the highest grain yield (5.55 t ha1) followed by Binadhan-10 (V4) (5.20 t ha1), but the yields are statistically similar.

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

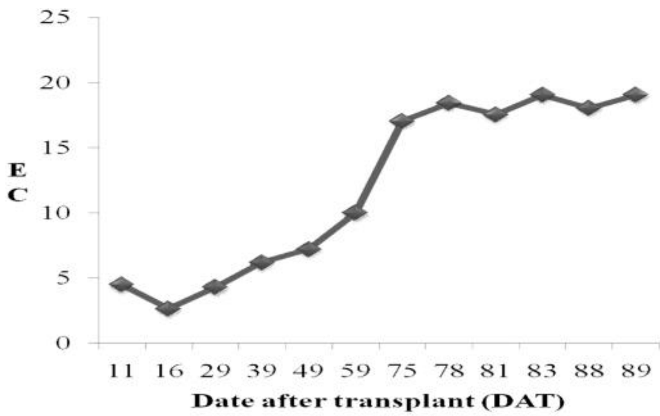

Fig. 1. EC (dS/m) of plot-water during the rice growing period

Table 1. Mean 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

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 also revealed that drought stress along with salinity stress, have more detrimental effect on grain yield for all cultivars. Rezaei et al. [34] also noted severe effects of water and salinity stresses on rice yield and yield components.

Khan et al. [38] 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 dS/cm salinity, respectively. Hussain et al. [39] 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 (keeping saturation or 2 cm ponding, compared to 5 cm ponding) resulted in lower accumulation of total salt during growing period, and thus may have less adverse effect on growth and yield, resulting higher yield in T1 and T2 treatments in our study.

3.4 Comparative Irrigation Water Savings and Yield Reductions

Table 3 shows the total irrigation water requirement and comparative water savings

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_1V_1	76.53	14.20	24.20	84.73	19.69	5.33
T_1V_2	95.80	13.07	27.27	69.00	22.89	5.33
T_1V_3	91.13	11.50	26.87	113.20	22.05	6.50
T_1V_4	93.13	10.60	27.07	97.00	20.74	6.17
T_2V_1	77.13	17.33	24.27	91.73	19.76	3.83
T_2V_2	94.80	14.60	28.60	79.50	21.52	4.00
T_2V_3	93.93	13.33	28.53	105.07	22.29	6.83
T_2V_4	93.73	12.93	27.53	111.73	22.89	5.83
T_3V_1	71.60	13.93	23.93	79.73	20.26	4.00
T_3V_2	93.00	14.00	25.30	55.50	20.27	4.00
T_3V_3	88.93	13.10	26.13	100.73	2085	5.50
T_3V_4	87.33	12.80	27.33	102.13	22.38	5.33
T_4V_1	74.13	14.47	24.27	73.87	17.84	3.50
T_4V_2	90.10	13.90	25.30	48.70	20.79	3.00
T_4V_3	85.40	11.60	25.87	99.33	19.56	4.67
T_4V_4	86.67	15.33	25.87	79.60	21.98	5.33
T_5V_1	96.50	15.50	23.70	57.65	17.35	3.25
T_5V_2	87.90	16.40	26.30	54.50	22.16	1.00
T_5V_3	83.80	12.87	26.87	104.93	18.78	4.25
T_5V_4	83.80	14.53	26.73	83.80	18.49	3.33

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

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

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).

3.5 Discussion

Gypsum has ameliorative effect to reduce the EC of soil [38], thus facilitating crop growth environment, and resulting in higher yield. Secondly, higher saline irrigation amount resulted in higher salt accumulation, thus impeding crop growth, and finally reduced yield. These two factors attributed to higher yield in T_1 and T_2 treatments (in T_1V_3 and T_2V_3). Zeng et al. [40] also found highly significant negative correlation between water depth and seedling stand, and also between water depth and grain yield. The cultivar V_3 produced the highest yield under both T_1 and T_2 treatments.

4. CONCLUSION

The results of our study revealed that considering the grain yield and irrigation water used, Binadhan-8 can be cultivated under continuous saturation condition coupled with gypsum application at flowering stage.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/22073