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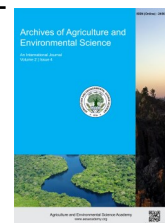


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ORIGINAL RESEARCH ARTICLE



Effect of source of irrigation water on yield performance of *Boro* rice

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ABSTRACT

Industrial wastewater is a major problem in Gazipur, Bangladesh which is very cheaply available in the surrounding area for crop production. An experiment was conducted at Farmer's Field of Gazipur district to study the effect of irrigation water quality on yield of *boro* rice. The study comprised three varieties viz., BR14, BRRI dhan28 and BRRI dhan29 and three sources of irrigation water viz. fresh water irrigation, mixed water (fresh + industrial wastewater) irrigation, industrial wastewater irrigation. The experiment was laid out in a split-plot design with three replications where irrigation water was assigned in the main plot and rice varieties in the subplot. BRRI dhan29 produced the tallest plant (85.25 cm), the highest number of total tillers hill^{-1} (19.77), effective tillers hill^{-1} (17.64), grains panicle⁻¹ (111.0), sterile spikelets panicle⁻¹ (44.29), 1000-grain weight (22.43 g), grain yield (4.56 t ha^{-1}) and straw yield (7.99 t ha^{-1}). On the other hand, plant height (74.50 cm), total tillers hill^{-1} (19.82), effective tillers hill^{-1} (17.53), grains panicle⁻¹ (131.7), sterile spikelets panicle⁻¹ (35.50), 1000-grain weight (25.83 g), grain yield (5.05 t ha^{-1}) were found highest when applied fresh water irrigation. The highest numbers of grains panicle⁻¹ (119.14), 1000-grain weight (25.10 g), grain (5.54 t ha^{-1}) and straw (7.93 t ha^{-1}) yield were obtained in BRRI dhan29 with fresh water irrigation. Therefore, BRRI dhan29 with fresh water irrigation would be safe to use. However, if fresh water irrigation is not possible, conjunctive use of fresh and wastewater can be used as irrigation for BRRI dhan29.

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INTRODUCTION

Rice is one of the most widely consumed grains of over half of the world's population and grown over 124 million hectares, and occupies almost one-fifth of the total world area under cereals (Sangeetha *et al.*, 2013; Statista, 2020). In Bangladesh, rice dominates over all other crops and covers 77% of the total cropped area and 92% peasants grow rice (Rikabder, 2004; BBS, 2018). Three major rice crops namely, *aus*, *aman* and *boro* constitute 100% of total rice production and grow in three different seasons. It is notable that the average yield of *boro* is the highest as a single crop (3.96 t ha^{-1}) and covers about 41.94% of total rice area (BBS, 2018). Therefore, *boro* rice is the most important

rice crops for Bangladesh with respect to its high yield and contribution to rice production.

Irrigation water quality and its impact on soil properties are important criteria for higher rice productivity. About 250 million hectares of agricultural land of the world is irrigated, which about 20% of total crop land area and producing about 40% of total crop. In Asia, more than 80% of the fresh water resources are used in agriculture and half of that is used for rice production (Khai and Yabe, 2012; Aryal *et al.*, 2015). For successful crop cultivation irrigation is practiced to meet the requirement of moisture in soils but poor quality of irrigation water, if applied for a long time, affects the crop growth directly and reduces the crop yield drastically. *Boro* rice is completely

dependent on irrigation water while it is cultivated in dry season in Bangladesh. In Bangladesh industrial sector is growing day by day specially garments sectors where lots of polluted waste water is releasing to the adjacent vast crop fields in an unplanned way. As the farmers of the adjacent area are getting this water cheaply, they used to intend this water to cultivate their *boro* crop. Unfortunately, scientific reports on this issue are scanty. Therefore, it is greatly needed to elucidate the effect of industrial waste water on *boro* rice production in Bangladesh (Begum et al., 2011).

The global water shortages and food security issues related to population explosion necessitate shifting fresh water away from agriculture to more pressing uses (Kumar et al., 2017). Therefore, search for new water resources for irrigation is required, among which is the re-use of wastewater for agricultural purposes. Wastewater irrigation has long been adopted in some developing and developed countries, due to its high fertility as well as due to lack of infrastructure and facilities for disposal of wastewater effluent (Ahaduzzaman et al., 2017). With this view in mind this research program was undertaken with rice as a test crop to evaluate the effect of industrial wastewater as irrigation on yield *boro* rice. This study also will give a direction to the farmers so that they can apply this knowledge for rice cultivation in *boro* season in the industrial areas of Bangladesh.

MATERIALS AND METHODS

Study area

The experiment was conducted at Farmer's Field, Kewa East Part village, Sreepur Upazilla, Gazipur district, Bangladesh. Geographically the experimental site is located at 24°09' N latitude and 90°26' E longitude at an elevation of 8.4 m above the sea level. The site belongs to the Shallow Red Brown Terrace soil (Brammer, 1971) under the Madhupur Tract Agro- ecological Zone (AEZ 28) (UNDP and FAO, 1988). The soil is silt clay loam in texture having pH 5.65 with poor fertility and impeded internal drainage. The climate and the locality are tropical in nature and is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in *kharif* season (April to September) and scanty rainfall associated with moderately low temperature (<15°C) during the *rabi* season (October to March).

Experimentation and crop husbandry

The experiment comprised three varieties viz. BR14 (V_1), BRRI dhan28 (V_2) and BRRI dhan29 (V_3), and three sources of irrigation water viz. fresh water irrigation (T_1), fresh water irrigation + industrial wastewater irrigation (T_2) and industrial wastewater irrigation (T_3). Fresh water irrigation source was the electric motor pump which supplied from household water. It maintains proper nutrient and balanced quality of water. On the other hand, industrial waste water source was a canal filled with water supplied from different surrounding industries such as Amantex

limited, Chittagong Denim Mills Ltd, and Fakhruddin Textile Mills Ltd. The experiment was laid out in a split-plot design with three replications. Irrigation water treatment was assigned in the main plot and rice varieties in the subplot. Each replication represented a block and each block was divided into 9-unit plots. Total number of unit plot was 27. The size of unit plot was 4.0 m × 2.5 m. The distance maintained between two-unit plots was 0.5 m and between blocks was 1.0 m. Healthy seeds of BR14, BRRI dhan28, BRRI dhan29 were used for this study. Seeds were immersed in water in bucket for 24 hours and then taken out of water and packed in the gunny bags for sprouting. The seeds sprouted after 72 hours. For raising seedlings, a piece of high land was selected. The land was prepared by puddling with a country plough then cleaned and leveled with ladder. After preparation of nursery bed, sprouted seeds were sown in the nursery bed and thirty-five days old seedlings were then transplanted in the main field with 3 seedlings hill⁻¹ having 20 cm × 20 cm spacing. The experimental land was prepared by tractor drawn disc plough. Fertilizers were applied to the plots uniformly at the 250, 110, 125, 7.5 and 50 kg ha⁻¹ urea, triple superphosphate, muriate of potash, zinc sulphate and gypsum, respectively (BRRI, 2010). The whole amount of triple superphosphate, muriate of potash and gypsum was applied at final land preparation. Fertilizers were applied before a day of transplanting. One third of Urea was applied at 15 days after transplanting (DAT) and the rest was applied in two equal splits at 30 DAT and 45 DAT. Intercultural operations were done for ensuring and maintaining the normal growth and development of the crops. Gap filling, weeding, irrigation, drainage, plant protection measures and bund repairing intercultural operations were done. When 90% of the grains became golden yellow, the crop was considered to be matured.

Collection of data

Five hills (excluding border hills and central 1.0 m × 1.0 m) were selected randomly from each experimental plot to record data on crop characters and yield contributing characters. An area of 1 m² was selected in the middle portion in each plot and harvested record the yields of grain and straw. The harvested crop of each plot was separately bundled, properly tagged and then brought to the clean threshing floor. The crop was threshed with a pedal thresher. Grains were then sun dried at 14% moisture level and cleaned. Straws also sun dried properly. Finally, straw and grain yield plot⁻¹ were recorded and converted to t ha⁻¹.

Statistical analysis

The collected data were compiled and tabulated in proper form and subjected to statistical analysis. Data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using a computer operated program namely, MSTAT-C (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of variety

The plant height at maturity was significant at 1% level of probability (Table 1). BRR1 dhan29 produced tallest plant (85.25 cm) than BRR1 dhan28 (75.53cm) and BR14 (75.14cm). These differences are mostly due to the genetic variation among the varieties. These results are consistent to those of Anjuman (2012) who recorded variable plant height among varieties. Variety exerted significant influence on number of total tillers hill⁻¹ (Table 1) at 5% level of probability. The results showed that highest number of total tillers hill⁻¹ (19.83), effective tillers hill⁻¹ (17.64) was produced by BRR1 dhan28 whereas the lowest values of respective tillers were found in BR14. The reduction of number of tillers in BR14 was due to tiller mortality in the vegetative stages. The probable reason of these results might be due to different genetic makeup of these varieties which are influence by heredity. Among the varieties, BRR1 dhan29 produced the highest number (111.0) of grains panicle⁻¹ and the lowest one (93.0) was recorded in BR14. Number of grains panicle⁻¹ differed significantly due to variety was reported elsewhere (Islam et al. 2013; Jisan et al., 2014; Chowdhury et al., 2016). Variety differed significantly in respect of number of sterile spikelets panicle⁻¹ at 1% level of probability (Table 1). The result showed that the higher number of sterile spikelets panicle⁻¹ (49.33) was produced by BRR1 dhan28 than BRR1 dhan29 (44.29) and BR14 (38.65). Varietal differences regarding the number of sterile spikelets panicle⁻¹ might be due to their differences in genetic constituents (Tyeb et al., 2013; Chowdhury et al., 2016).

The highest 1000-grain weight (26.33 g) was obtained in BR14 than BRR1 dhan28 (22.60 g) and BRR1 dhan29 (22.43 g). This confirms the report of Islam et al., 2013 and Sarkar et al., 2014 who reported the variable effect of variety on 1000-seed weight. Variety had significant effect on grain yield at 5% level of probability (Table 1). The results indicated that BRR1 dhan29 produced the highest grain yield (4.56 t ha⁻¹) than BRR1 dhan28 (4.01) and BR14 (3.77 t ha⁻¹). The probable reason of the different grain yields due to the different yield parameters (tillers hill⁻¹, grains panicle⁻¹, 1000-grain weight etc.) influenced by the genetic make-up of the variety. Grain yield differences due to varieties were recorded by Anjuman (2012) who observed variable grain yield among varieties. (Table 1). BRR1 dhan28 produced the higher straw yield (8.14 t ha⁻¹) than BR14 (8.07 t ha⁻¹) and BRR1 dhan29 (7.99 t ha⁻¹). The probable reason of the different straw yield due to the different yield parameters which was mainly influenced by the genetic make-up of the variety. The results are similar with Kirttania (2013); Jisan et al. (2014) who found different straw yield among the varieties. Variety differed no significant in respect of biological yield. Variety showed significant effect at 1% level of probability on harvest index (Table 1). The highest values were found from BRR1 dhan29 (36.33%) and the lowest values was found from BR14 (31.84%).

Table 1. Effect of variety on yield and yield contributing characters of boro rice.

Variety	Plant height (cm)	Number of total tillers hill ⁻¹	Number of effective tillers hill ⁻¹	Number of non-effective tillers hill ⁻¹	Number of grains panicle ⁻¹	Number of sterile spikelets panicle ⁻¹	1000-grain weight (g)	Grain yield (tha ⁻¹)	Straw yield (tha ⁻¹)	Biological yield (tha ⁻¹)	Harvest index (%)
BR14	75.14b	17.23b	14.64b	2.59b	93.0c	38.65b	26.33a	3.77b	8.07	11.84	31.84b
BRR1 dhan28	75.53b	19.83a	16.19a	3.64a	99.3b	49.33a	22.60b	4.01b	8.14	12.15	33.00b
BRR1 dhan29	85.25a	19.77a	17.64a	2.12b	111.0a	44.29ab	22.43b	4.56a	7.99	12.55	36.33a
Level of significance	**	*	*	*	**	**	*	*	NS	NS	**
Sx	1.27	0.98	0.62	0.77	1.53	0.09	1.44	0.19	1.01	0.33	0.52
CV (%)	7.12	8.66	7.23	5.76	9.41	7.34	6.33	7.87	8.11	3.23	7.78

In a column figures with similar letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

Table 2. Effect of irrigation water quality on yield and yield contributing characters of *boro* rice.

Treatment	Plant height (cm)	Number of total tillers hill ⁻¹	Number of effective tillers hill ⁻¹	Number of non-effective tillers hill ⁻¹	Number of grain panicle ⁻¹	Number of Sterile spikelets panicle ⁻¹	1000-grain weight (g)	Grain yield (tha ⁻¹)	Straw yield (tha ⁻¹)	Biological yield (tha ⁻¹)	Harvest index (%)
T ₁	74.50b	19.82	17.53a	2.29	131.7a	35.50c	25.83a	5.05a	7.66	12.71a	39.73a
T ₂	79.43a	18.20	15.30b	2.90	104.7b	42.15b	23.87b	3.91b	8.28	12.19a	32.02b
T ₃	78.95a	18.81	15.64b	3.17	70.8c	54.62a	21.67b	3.01c	7.60	10.61b	28.38bc
Level of significance	*	NS	*	NS	**	**	*	**	NS	*	**
Sx	1.20	0.17	0.18	0.08	0.32	1.48	0.33	0.31	0.07	0.052	0.18
CV (%)	7.12	8.66	7.23	5.76	9.41	7.34	6.33	7.86	8.12	3.23	7.78

In a column figures with similar letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; T₁ = Fresh water irrigation, T₂ = Mixed water (Fresh + industrial wastewater) irrigation and T₃ = industrial wastewater irrigation.

Effect of source of irrigation water

Irrigation water source had significant effect on yield and yield contributing characters of *boro* rice (Table 2). The tallest plant (79.43 cm) was obtained from mixed (fresh + industrial wastewater) application whereas the shortest plant (74.50 cm) was obtained from fresh water application. The highest number of effective tillers hill⁻¹ (17.53) was produced by fresh water irrigation application and the lowest number of effective tillers hill⁻¹ (15.30) was obtained from mixed (fresh + industrial wastewater) irrigation application. The highest number of grains (131.7) was produced by fresh water irrigation application and the lowest one (70.8) was obtained from industrial wastewater irrigation application. Irrigation water quality had significant effect on the 1000-grain weight and grain yield (Table 2). The highest 1000-weight (25.83 g), grain yield (5.05 t ha⁻¹) was found when fresh water applied while lowest 1000-grain weight (21.67 g), grain yield (3.01 t ha⁻¹) was obtained from industrial wastewater irrigation application. Balanced nutritional values in fresh water may help to maintain a good health of soil which helps to gain good grain yield. On the other hand, waste water contains heavy metals which reduce soil health resulting low yield of crops (Afrad et al., 2020). The highest straw yield (8.28 tha⁻¹) was produced by mixed (fresh + industrial wastewater) irrigation application and the lowest straw yield (7.60 tha⁻¹) was obtained from industrial wastewater irrigation application. The highest biological yield (12.71), harvest index (39.73%) was produced by fresh water irrigation application and the lowest biological yield (10.61); harvest index (28.38%) was obtained from industrial wastewater irrigation application. The quality of irrigation water directly hampers the soil quality resulting variances among varietal performances and their yield contributing characters (Kirttania, 2013).

Interaction effect

Plant height was significantly affected by the interaction of variety and irrigation water quality. The tallest plant height (86.29 cm) was obtained from BRR1 dhan29 with fresh water irrigation application whereas the smallest plant height (74.44cm) was obtained from BRR1 dhan28 with mixed (fresh + industrial wastewater) irrigation application (Table 3). Combinedly variety and irrigation water quality had no significant effect on total tillers hill⁻¹ (Table 3). But apparently the highest number of total tillers hill⁻¹ (20.67) was obtained from BRR1 dhan28 with fresh water irrigation combination and the lowest number of tillers hill⁻¹ (16.10) was obtained from BR14 with mixed (fresh + industrial wastewater) irrigation application. The highest number of effective tillers hill⁻¹ (19.00) was obtained from BRR1 dhan29 with fresh water irrigation combination and the lowest number of effective tillers hill⁻¹ (13.53) was obtained from BR14 × mixed (fresh + industrial wastewater) irrigation application (Figure 1).

Interaction of variety and irrigation water quality had significant effect on non-effective tillers hill⁻¹ at 5% level of probability (Figure 2). The highest number of non-effective tillers hill⁻¹ (3.93) was obtained from BRR1 dhan28 with industrial

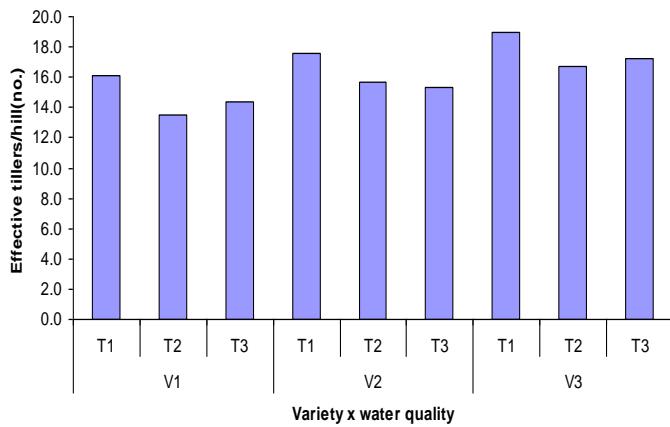


Figure 1. Interaction effect of variety and irrigation water quality on effective tillers of boro rice. V₁= BR14, V₂=BRRI dhan28 and V₃= BRRI dhan29; T₁= Fresh water irrigation, T₂= Mixed (Fresh + industrial wastewater) irrigation and T₃= industrial wastewater irrigation.

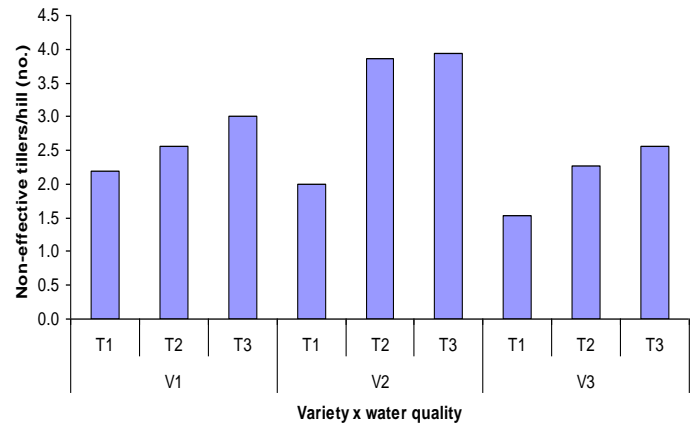


Figure 2. Interaction effect of variety and irrigation water quality on non-effective tillers of boro rice.

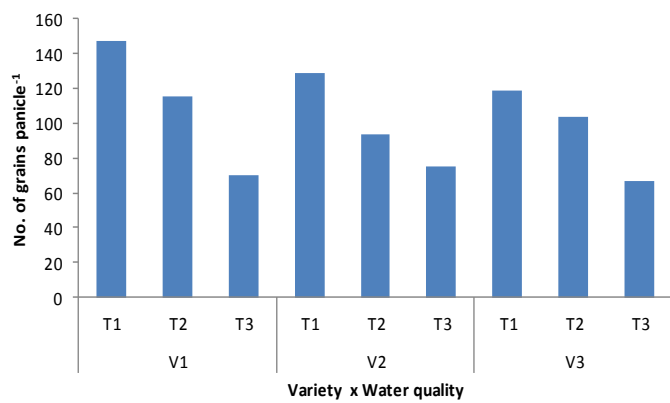


Figure 3. Interaction effect of variety and irrigation water quality on number of grains panicle⁻¹ of boro rice.

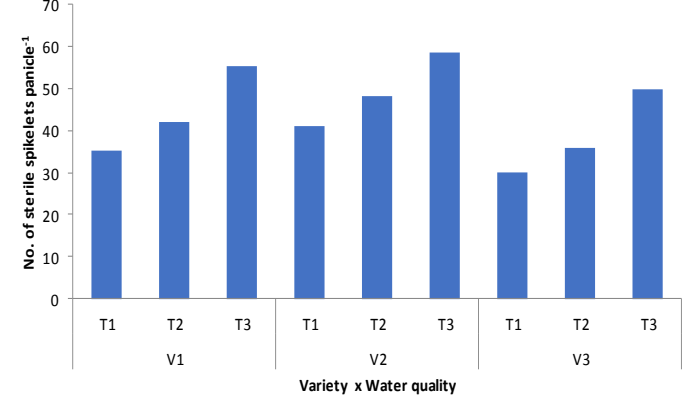


Figure 4. Interaction effect of variety and irrigation water quality on number of sterile spikelets panicle⁻¹ of boro rice.

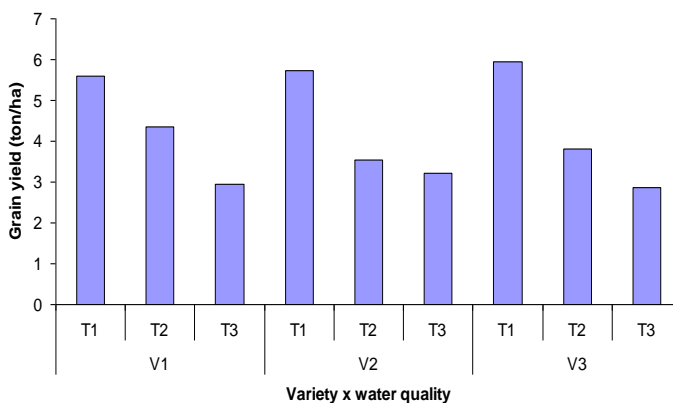


Figure 5. Interaction effect of variety and irrigation water quality on grain yield of boro rice.

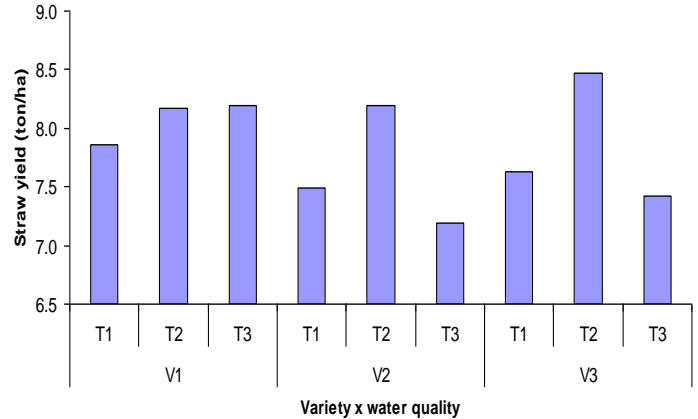


Figure 6. Interaction effect of variety and irrigation water quality on straw yield of boro rice.

Table 3. Interaction effect of variety and irrigation water quality on yield and yield contributing characters of *boro* rice.

Variety x Treatment		Plant height (cm)	Number of total tillers hill ⁻¹	1000-grain weight (g)	Biological yield (tha ⁻¹)	Harvest index (%)
V ₁	T ₁	75.93c	18.27	28.20a	12.95ab	39.31ab
	T ₂	74.93c	16.10	26.30ab	12.52b	34.74b
	T ₃	74.56c	17.33	24.50b	11.13c	26.42cd
V ₂	T ₁	76.08c	20.67	24.20b	13.22ab	39.56ab
	T ₂	76.08c	19.57	23.20bc	11.74bc	30.24c
	T ₃	74.44c	19.27	20.40d	10.40de	30.87bc
V ₃	T ₁	86.29a	20.53	25.10b	13.47a	41.13a
	T ₂	85.85a	18.93	22.10cd	12.29b	31.08bc
	T ₃	83.40b	19.83	20.10d	10.28e	27.82cd
Level of significance		**	NS	**	NS	**
Sx		1.44	1.57	1.23	0.91	0.41
CV (%)		7.12	8.66	6.33	3.23	7.78

In a column figures with similar letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant; V₁= BR14, V₂=BRR1 dhan28 and V₃= BRR1 dhan29; T₁= Fresh water irrigation, T₂= Mixed water (Fresh + industrial wastewater) irrigation and T₃= industrial wastewater irrigation

wastewater irrigation combination and the lowest number of non-effective tillers hill⁻¹ (1.53) was obtained from BRR1 dhan29 with fresh water irrigation application.

Interaction of variety and quality irrigation water significantly affected the number of grains panicle⁻¹ (Figure 3). Results showed that the highest number of grains (147.0) was obtained from BR14 with fresh water irrigation combination and the lowest grain (66.90) was obtained from BRR1 dhan29 with industrial wastewater irrigation combination. Interaction of variety and irrigation water quality significantly affected the number of sterile spikelets panicle⁻¹ (Figure 4). Results showed that, the highest number of sterile spikelets panicle⁻¹ (49.94) was obtained from BRR1 dhan29 with industrial wastewater irrigation combination and the lowest number of sterile spikelets panicle⁻¹ (30.00) was obtained from BRR1 dhan29 with fresh water irrigation combination. Interaction of variety and irrigation water quality had significant effect at 1% level of probability of the weight of 1000-grain. The results showed that, the highest 1000 grain (28.20 g) was obtained from BR14 with fresh water irrigation combination and the lowest 1000-grain (20.10g) was obtained from BRR1 dhan29 with industrial wastewater irrigation combination (Table 3). Interaction of variety and irrigation water quality significantly affected grain yield. The highest grain yield (5.54 tha⁻¹) was obtained from BRR1 dhan29 with fresh water irrigation combination and the lowest grain yield (2.86 tha⁻¹) was obtained from BRR1 dhan29 with industrial wastewater irrigation combination (Figure 5). Interaction of variety and irrigation water quality had no significant effect on the straw and biological yields of rice (Figure 6). Interaction of variety and irrigation water quality had significantly affected for the harvest index at 5% level of the harvest index (Table 3). The results showed that, the highest value (41.13%) was obtained from BRR1 dhan29 with fresh water irrigation combination and the lowest value (26.42%) was obtained from BR14 with industrial wastewater irrigation combination.

Conclusion

Among the varieties, BRR1 dhan29 produced highest grain yield when fresh water was used as irrigation. Industrial waste water reduced the yield and yield associated traits of BRR1 dhan29. Therefore, it may be recommended that fresh water irrigation would be safe to use for BRR1 dhan29 rice production. However, if fresh water is not available, combined application of fresh and industrial waste water can be applied as irrigation water.

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