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GROWTH AND YIELD OF WHEAT UNDER IRRIGATION BY SUGAR MILL'S WASTEWATER

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ABSTRACT

The possibility of using sugar mill's wastewater/effluent in irrigation was evaluated by investigating the effects of wastewater on growth and yield of wheat (*Triticum aestivum cv. Prodip*). The experiment was conducted at North Bengal Sugar Mill site in Natore during December 2011 to March 2012. Three irrigation treatments (I_1: irrigation with fresh/tubewell water, I_2: irrigation with a mixture of fresh and wastewater at 1:1 ratio and I_3: irrigation with wastewater) under a main factor and three fertilizer treatments (F_0: no application of fertilizer, F_1: half dose fertilizer and F_2: full dose fertilizer) under a sub factor were evaluated. The experiment was laid out in a split-plot design with three replications of the treatments. Wheat was grown with three irrigations totaling 14 cm applied at 4, 26 and 43 days after sowing (DAS). Important growth and yield data of the crop were recorded. The highest grain yield of 1.829 t/ha was obtained under mixed water irrigation and the lowest grain yield of 1.469 t/ha was obtained under wastewater irrigation. The three irrigation treatments, however, provided statistically similar (p = 0.05) grain yield. For the interaction between irrigation and fertilizers, mixed water irrigation and full dose fertilizer application (I_2F_2) provided significantly higher grain yield (2.757 t/ha) than all other treatment combinations. The second highest yield, produced under freshwater irrigation and full dose fertilizer (I_1F_2), was statistically similar to the yield under wastewater irrigation and full dose fertilizer (I_3F_2). Results of this experiment thus exposed good prospects of irrigating wheat by sugar mills' wastewater.

Key Words: Wastewater, Irrigation, Wheat

INTRODUCTION

Water resources are becoming scarce because of over-population stress, industrialization and urbanization. Therefore, it is a need of the time to seek alternative sources of irrigation water to ensure sustainability of the available resources (Thawale *et al*., 2006). Raw or partially treated wastewater has become an alternate source of irrigation that is being applied to almost 20 million hectares of agricultural land in 50 countries of the world (Scott *et al*., 2004; Mahmood and Maqbool, 2006). FAO (1992) reported that the use of wastewater in agriculture could be an important consideration when its disposal is planned in arid and

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semi-arid regions. Al Khamisia *et al*. (2012) stated that with the increasing scarcity of freshwater for agriculture, the need to use of reclaimed water from sewage treatment plants in agriculture has increased. They also explored that irrigation with reclaimed water will prevent its disposal to the sea and minimize stress on fresh groundwater zones. Adequate nutrient availability, particularly nitrogen, to fulfill crop requirements from wastewater has encouraged farmers to use such water in irrigation. Raw wastewater being rich in nutrients becomes quickly available to the crops at a low price (Clemett and Ensink, 2006). Farmers prefer untreated wastewater because it is perceived as more dependable for irrigation because of its quick availability at low cost and its rich nutrient status. A properly planned use of wastewater not only takes advantages of the nutrients contained in it to grow crops but also alleviates surface water pollution problems and conserves the valuable water resources.

The annual production of wheat in Bangladesh is 0.90 million tons that is cultivated in 0.38 million hectares of land with an average yield of 2.39 t/ha (BBS, 2011). During the growing period of wheat (December to March), wastewater from sugar mills becomes readily available. So, there may be a good possibility to irrigate wheat with sugar mill's wastewater. A large amount of effluent from thirteen sugar mills in Bangladesh is discharged on land or into water courses. This effluent is characterized by high BOD, COD, sodium and other dissolved solids as well as micro-nutrients, and often heavy metals. The disposal of wastewater from the sugar cane industry creates several environmental problems. But, the use of this water for irrigation can offer a potential solution to the problems. Before any formal attempt for a sustainable irrigation with sugar mills' wastewater in Bangladesh, the quality of the wastewater as well as its impacts on growth and yield of crops needs to be evaluated. This study was therefore planned to address this objective.

MATERIALS AND METHODS

An experiment was conducted by cultivating wheat (*Triticum aestivum cv. Prodip*) under irrigation by sugar mill's wastewater during December 2011 to March 2012 at the site of North Bengal Sugar Mill (NBSM), Natore, Bangladesh (24.1833°N latitude and 88.9750°E longitude). The soil of the experimental field belongs to the Low Ganges River Floodplain (BARC, 2005) with bulk density, porosity, field capacity and saturated hydraulic conductivity of 1.44 g/cm3, 63.17%, 46.71% and 0.20 cm/h, respectively. During the growing season of wheat, there was only 22.352 mm rainfall.

Two factors – irrigation as the main factor and fertilizer as the sub factor (both factors with three treatments) – were evaluated in the experiment. The irrigation treatments were – I_1: irrigation with fresh/tubewell water, I_2: irrigation with mixed water (fresh water: wastewater = 1 : 1) and I_3: irrigation with wastewater (raw wastewater). The fertilizer treatments were – F_0: no application of fertilizer, F_1: half dose fertilizer and F_2: full dose fertilizer. The experiment was laid out in a split-plot design with three replications of the treatments.

Two-thirds of urea (133 kg/ha) and full doses of the other fertilizers – Triple Super Phosphate (160 kg/ha), Muriate of Potash (160 kg/ha), Gypsum (120 kg/ha) and Borax (3 kg/ha) – were applied to the experimental plots (size: 3 m × 2 m) as basal dose during last ploughing. The rest of urea (67 kg/ha) was top dressed after 20 DAS. The wheat seeds (120 kg/ha) were sown in line with a spacing of 20 cm on 7 December 2011. Weeds were controlled by uprooting at 24 DAS and insect pests were controlled by spraying Vitavax-200 at 31 DAS.

Three irrigations – the first (3 cm) at 4 DAS, second (5 cm) at 26 DAS and third (6 cm) at 43 DAS – were applied to the plots. The first irrigation was applied to facilitate germination since the soil was relatively dry. Table 1 shows some important quality parameters of wastewater of the North Bengal Sugar mill and freshwater in that area along with the FAO and Bangladesh standards of water quality for irrigation.

Table 1. Some important quality parameters of wastewater of the North Bengal Sugar mill and freshwater in the area along with the FAO and Bangladesh standards for irrigation

Location	EC dS/m	pH	NO_3-N (mg/l)	NO_2-N (mg/l)	NH_3-N (mg/l)	P (mg/l)	Mn (mg/l)	Fe (mg/l)	B (mg/l)	BOD (mg/l)	COD (mg/l)	Temp. °C
WW at mill gate	1.03	6.60	15.00	0.229	0.57	5.2	0.7	0.43	0.49	291*	677*	39
WW at 6 km downstream	0.78	6.83	24.13	0.292	0.32	5.7	0.3	0.37	0.51	183*	196*	19±1
FW at 6 km downstream	0.72	7.62	2.26	0.064	1.05	0.9	0.5	0.36	0.14	-	-	19±1
FAO standard	0.70	6.5–8.0	10.0	-	-	-	0.2	3.0	2.0	-	-	-
Bangladesh standard	1.2	6–9	-	-	-	15	5.0	1–2	2.0	10	-	20–30

Source: Adapted from Tabriz *et al*. (2011); * The values are approximate since it took 7–8 hours to carry the samples to Mymensingh and start measurement

The volumetric water contents of the soil at 0−10 and 10−20 cm profiles were measured with a digital moisture meter both at sowing and harvest. At sowing, water content was 24.5 and 45.0% at 0−10 and 10−20 cm profile, respectively. At harvest, it was 12.7 and 25% at 0−10 and 10−20 cm profile, respectively. The wheat became mature at 109 DAS. In the middle portion of each plot, a harvest area of 1 m × 1 m was selected and the crop was harvested by cutting the plants at ground level. The harvested crop of each plot was bundled separately and tagged. The data on plant population (plants per square meter), plant height at harvest, number of tillers per plant and weight of 1000 grains (dried at 12% moisture content) were recorded. Grain yield, straw yield, biological yield, harvest index and water use efficiency (WUE) for different treatments/treatment combinations were calculated. The WUE was calculated by

$$WUE = \frac{Y}{WU} \quad \text{(1)}$$

Where WUE is seasonal crop-water use in the field (cm) and Y is grain yield (kg/ha). The crop water use was calculated by

$$WU = IR + ER + \sum_{i=1}^{n} = \frac{M_s - M_h}{100} D_i \text{ ......} \quad (2)$$

Where IR is total irrigation water applied (cm), ER is seasonal effective rainfall (cm), M_s is soil moisture content (% volume) at sowing, M_h is soil moisture content (% volume) at harvest and D_i is depth of root zone layer (average 60 cm for wheat). The effective rainfall was calculated by

$$ER = \frac{P_{total}(125 - 0.2P_{total})}{125} \quad [\text{for } P_{total} < 250 \text{ mm}] \text{ ......} \quad (3)$$

and

$$ER = 125 + 0.1P_{total} \quad [\text{for } P_{total} < 250 \text{ mm}] \text{ ......} \quad (4)$$

Where, P_{total} is the total rainfall (mm) during the wheat growing period.

RESULTS AND DISCUSSION

Effect of irrigation on growth and yield

The irrigation treatments employed different degrees of influence on various crop attributes; some attributes differed significantly while others differed insignificantly. The tallest plant (80.12 cm) was obtained with mixed water irrigation (I_2). The mean plant height increased by 2.94% in treatment I_2 compared to the control treatment, I_1. Wastewater contributed increasing the number of tillers per plant; the highest number of tillers per plant (2.23) was obtained with I_3. Both the plant height and number of tillers per plant were, however, statistically similar (p=0.05) under the irrigation treatments (Table 2). The highest 1000-grain weight of 53.90 g was obtained with I_2 and the lowest grain weight of 50.02 g was obtained with I_1. The 1000-grain weight increased by 7.75 and 1.95% in I_2 and I_3, respectively compared to the control. Irrigation with mixed water significantly augmented the grain weight of wheat compared to irrigation with fresh water.

Effect of irrigation on yield and water use efficiency

Treatment I_2 produced the highest grain yield of 1.829 t/ha and I_3 produced the lowest grain yield of 1.469 t/ha (Table 2). The grain yield increased by 19.23% in I_2 but decreased by 4.23% in I_3 compared to I_1 implying that (raw) wastewater imposed negative impacts on grain yield. The yields under the irrigation treatments were, however, statistically similar. The higher number of tillers/plant with relatively heavier grains appeared to have contributed to the higher yields in the plots irrigated with mixed water. This result is consistent with the findings of Ghanbari *et al*. (2007). The straw yield under the three irrigation treatments ranged from 1.927 to 2.408 t/ha (Table 2). I_2 produced the highest yield and I_1 produced the lowest yield; both yields were statistically similar. The straw yield increased by 24.96 and 5.39 % in treatment I_2 and I_3 compared to I_1. Raw wastewater exerted some negative impacts on straw yield compared to mixed water. Wastewater contributed increasing the biological yield of wheat in the fashion it contributed to grain and straw yields. Treatment I_2 produced the highest biological yield of 4.237 t/ha and I_1 produced the lowest of 3.461 t/ha. There was, however, no significant difference of this yield among the treatments. As compared in Table 3, wastewater irrigation significantly reduced the harvest index (HI) of wheat. The observed HI implies that wastewater contributed more in producing straw yield than in producing grain yield.

Table 2. Plant height, number of tillers per plant, weight of 1000 grains, and grain, straw and biological yields of wheat under three irrigation treatments

Treatment	Plant height (cm)	No. of tillers/plant	Wt. of 1000 grains (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
I_1	77.83^{A}	1.94^{A}	50.02^{B}	1.534^{A}	1.927^{A}	3.461^{A}
I_2	80.12^{A}	2.11^{A}	53.90^{A}	1.829^{A}	2.408^{A}	4.237^{A}
I_3	74.48^{A}	2.23^{A}	51.00^{B}	1.469^{A}	2.031^{A}	3.500^{A}
CV (%)	4.12	10.20	0.70	10.05	7.88	7.39
$LSD_{0.05}$	7.62	0.36	1.34	0.384	0.497	0.879

Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by Duncan's Multiple Range Test

Table 3. Harvest index (HI) and water use efficiency for grain (WUE_g) and biomass (WUE_b) production of wheat under different irrigation treatments

Treatment	HI (%)	WUE_g (kg/ha/cm)	WUE_b (kg/ha/cm)
I_1	43.49^{A}	65.68^{A}	148.2^{A}
I_2	42.89^{AB}	78.29^{A}	181.4^{A}
I_3	41.74^{B}	62.88^{A}	149.8^{A}
CV (%)	6.59	10.05	7.39
$LSD_{0.05}$	1.59	16.42	37.62

Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by Duncan's Multiple Range Test

Water use efficiency that demonstrates the productivity of water in producing crop yields did not differ significantly among the three irrigation treatments in case of grain and biomass production (Table 3). The water use efficiencies for grain (WUE_g) and biomass (WUE_b) production were obtained highest under I_2. The lowest WUE_g (62.88 kg/ha/cm) was obtained under I_3 and the lowest WUE_b (148.2 kg/ha/cm) was obtained under I_1. WUE_b increased by 22.40 and 1.07% in I_2 and I_3, respectively compared to the control. Since I_2 provided the highest grain yield, the water use efficiency was higher under I_2 than the control treatment.

Interaction effects of irrigation and fertilizer on growth and yield

The interaction effect of irrigation and fertilizer on the plant height of wheat was significant under most treatment combinations (Table 4). The tallest plant of 90.20 cm was obtained under I_2F_2 and the shortest plant of 65.63 cm was obtained under I_3F_0. The number of tillers per plant did not differ significantly except the treatment combination I_1F_1 (Table 4). The highest number of tillers per plant (2.33) was obtained under I_3F_1 and the lowest number of tillers per plant (1.78) was obtained under I_1F_1. The number of tillers per plant increased by 13.65% in I_3F_1 compared to that in I_1F_0. Also, this plant attribute increased by 17.08% in I_3F_1 compared to that in I_2F_0. The mean 1000-grain weight differed significantly under most combinations of irrigation and fertilizer treatments (Table 4). The highest 1000-grain weight of 55.71 g was obtained under I_2F_2 and the lowest of 48.82 g was obtained under I_1F_0. The 1000-grain weight increased significantly in all treatment combinations compared to that in I_1F_0, implying that wastewater, either raw or mixed with freshwater, always contributed positively in grain production.

Table 4. Plant height, number of tillers per plant, weight of 1000 grains, and grain, straw and biological yields of wheat under the interaction of three irrigation treatments and three fertilizer doses

Treatment Combination	Plant height (cm)	No. of tillers/plant	Wt. of 1000 grains (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
I_1F_0	71.10^{FG}	2.05^{AB}	48.82^{F}	0.763^{E}	1.207^{E}	1.970^{E}
I_1F_1	77.30^{CDE}	1.78^{B}	50.07^{E}	1.650^{CD}	1.907^{D}	3.557^{A}
I_1F_2	85.10^{AB}	2.00^{AB}	51.16^{D}	2.190^{B}	2.667^{B}	4.857^{B}
I_2F_0	71.77^{EF}	1.99^{AB}	52.53^{C}	1.047^{E}	1.477^{E}	2.523^{D}
I_2F_1	78.40^{CD}	2.08^{AB}	53.45^{B}	1.683^{C}	2.293^{C}	3.977^{C}
I_2F_2	90.20^{A}	2.27^{A}	55.71^{A}	2.757^{A}	3.453^{A}	6.210^{A}
I_3F_0	65.63^{G}	2.29^{A}	49.68^{E}	0.890^{E}	1.197^{E}	2.087^{DE}
I_3F_1	74.93^{DEF}	2.33^{A}	50.99^{D}	1.367^{D}	2.120^{CD}	3.487^{C}
I_3F_2	82.87^{BC}	2.06^{AB}	52.33^{C}	2.150^{B}	2.777^{B}	4.927^{B}
CV (%)	4.12	10.20	0.70	10.05	7.88	7.39
$LSD_{0.05}$	5.67	0.381	0.64	0.287	0.298	0.490

Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by Duncan's Multiple Range Test

Interaction effects of irrigation and fertilizer on yield and water use efficiency

The interaction effects of irrigation and fertilizer on the grain yield, straw yield and biological yield were statistically significant in most treatment combinations compared to I_1F_0 (Table 4). The treatment combination I_2F_2 produced the highest grain yield of 2.757 t/ha, highest straw yield of 3.453 t/ha and highest biological yield of 6.210 t/ha. I_1F_0 produced the lowest grain yield of 0.763 t/ha. The grain yield increased by 261.20% under I_2F_2 compared to that under I_1F_0. I_3F_2 produced significantly lower grain yield than I_2F_2, implying that raw wastewater retarded grain production of wheat to some extent. Wastewater, due to its considerable contribution to nutrients, augmented the grain yield of wheat under both fertility treatments (F_1 and F_2). Papadopoulos (1988) and Ghanbari *et al.* (2007) also reported similar results. I_3F_0 produced the lowest straw yield of 1.197 t/ha that was similar to the straw yield under I_1F_0. The straw yield increased by 186.08% under I_2F_2 compared to that under I_1F_0. I_1F_0 also produced the lowest biological yield of 1.970 t/ha. The biological yield increased by 215.23% under I_2F_2 compared to that under I_1F_0 exposing tremendous contributions of fertilizer and wastewater on the biological yield of wheat.

As compared in Table 5, the harvest index (HI) of wheat differed insignificantly, but the water use efficiency, for grain and biomass production, differed significantly among the combinations of irrigation treatments and fertilizer doses. The highest water use efficiency for grain production, WUE_g (118 kg/ha/cm), was obtained under I_2F_2 and the lowest WUE_g (32.67 kg/ha/cm) was obtained under I_1F_0. WUE_g increased by 261.18% under I_2F_2 compared to that under I_1F_0. The treatment combination I_2F_2 provided significantly higher WUE_g than other treatment combinations. The highest WUE_b (265.8 kg/ha/cm), was obtained under I_2F_2 and the lowest WUE_b (84.33 kg/ha/cm) under I_1F_0. WUE_b increased by 215.2% under I_2F_2 compared to that under I_1F_0. These results imply that water was most effectively utilized under mixed water irrigation and half dose fertilizer application.

Table 5. Harvest index (HI) and water use efficiency for grain production (WUE_g) and biomass production (WUE_b) of wheat under the interaction of three irrigation treatments and three fertilizer doses

Treatment combination	HI (%)	WUE_g (kg/ha/cm)	WUE_b (kg/ha/cm)
I_1F_0	39.93^{B}	32.67^{E}	84.33^{E}
I_1F_1	46.34^{A}	70.63^{CD}	152.3^{C}
I_1F_2	45.20^{A}	93.75^{B}	207.9^{B}
I_2F_0	41.92^{AB}	44.80^{E}	108.0^{D}
I_2F_1	42.36^{AB}	72.06^{C}	170.2^{C}
I_2F_2	44.41^{AB}	118.0^{A}	265.8^{A}
I_3F_0	42.50^{AB}	38.10^{E}	89.3^{DE}
I_3F_1	39.06^{B}	58.50^{D}	149.3^{C}
I_3F_2	43.65^{AB}	92.03^{B}	210.9^{B}
CV (%)	6.59	10.05	7.39
$LSD_{0.05}$	5.006	12.32	21.0

Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by Duncan's Multiple Range Test

CONCLUSIONS

Mixed water irrigation produced the highest grain, straw and biological yields. The 1000-grain weight and water use efficiencies for grain and biomass production were also obtained maximum for mixed water irrigation. Due to the interaction effects of irrigation and fertilizer on the crop, the grain, straw and biological yields and water use efficiency for grain production were obtained maximum under mixed water irrigation with full dose fertilizer application. On the other hand, the lowest grain, straw and biological yields and water use efficiency for grain production were obtained under fresh water irrigation with no application of fertilizer. So, wastewater mixed with fresh water contributed some nutrients, which helped increasing the yield and water use efficiency of wheat. It is, therefore, concluded that sugar mill's wastewater, when mixed with fresh water at 1:1 ratio, has good potential to be used for irrigating wheat.

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