Growth responses to alternative irrigation water for drought season in paddy rice

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Abstract

This study was carried out to determine the suitable irrigation period and to assess the proper fertilization level with irrigation of alternative water during transplanting season in rice paddy for drought periods. Irrigation periods of alternative water as the discharge water from the municipal wastewater treatment (DMWT) were 10, 20, 30 days and continuous irrigation during rice cultivation after transplanting. Also, fertilization was applied with 3 levels such as amount of fertilization after soil test (FAST), 50% of fertilization after soil test (FAST50%) and non-fertilization (Non). It was observed that plant growth and yield characteristics at 20 days of alternative irrigation period with application of FAST50% were relatively similar to the control. For the surface water quality, it appeared that EC_i and SAR values of DMWT irrigation were twofold higher than those of groundwater irrigation regardless of fertilization levels. According to the irrigation periods, there were not significantly difference between 10 and 20 days, but EC_i and SAR values of surface water were highest at 30 day irrigation periods during initial rice growing stages. Overall, it might be considered that there is the possibility of irrigating DMWT with application of FAST 50% for 20 days of drought periods at rice transplanting season. Furthermore, efficiency rate of alternative irrigation water for 20 days of drought period was 32.7% relative to the total annual irrigation water for rice cultivation.

Media summary

There was environmental safety to irrigate DMWT and 50% of fertilizer application for 20 days of drought periods at rice transplanting season. Efficiency rate of alternative irrigation water for 20 days of drought period was 32.7%.

Keywords

Reuse water, Harvest index, SAR and surface water quality

Introduction

Rice (*Oryza sativa* L.) is widely cultivated among the Korea’s main food crops even if its demand is sufficient at certain rate than many other food crops. The demand of water resource has apparently increased because of the rapid economical growth, industrialization and the upgrading of living standard in Korea. On the other hand, the water resource is quite limited because it is difficult to develop the new water reservoir construction due to groundwater protection. In the status of wastewater reuse in United State, 18 states have adopted some form of regulations regarding the reuse of reclaimed water, 18 states had full-fledged guidelines or design standards and 14 states had nothing (U.S. EPA, 1992). In Cyprus, current total water use is 300Mm^3/yr, almost 80% used for irrigation, but the wastewater generated by the main cities, about 25Mm^3/yr, is planned to be collected and used for irrigation after tertiary treatment. This will reportedly allow irrigated agriculture to be expended by 8-10% while conserving an equivalent amount of water for other sectors (Papadopoulos, 1995). In Israel about 92% of wastewater is collected by municipal sewers, and subsequently is used 72% and 42% for irrigation and groundwater recharge, respectively (Angelakis et al., 1999). However, total discharge water from the municipal wastewater treatment plant is about 646,000 Mm^3/yr, and only 2.5% of reused water for agricultural irrigation in Korea (Environmental Management Corporation, 2001). For a while, it is frequent to meet agricultural water shortage during transplanting season in rice paddy. Shin *et al*. (2003) might be considered that there was limited possibility to irrigate the discharge water from municipal wastewater treatment plant to overcome drought injury of rice transplanting season in the pot experiment. Therefore, reuse of discharge water from municipal wastewater treatment plant is one of way to solve this problem. Although it has irrigated to paddy field during limited time, drought period, environmental assessment should be carried out to reduce the negative effect to rice plant and paddy field. Objectives of this study were to investigate the influence of plant growth and yield, and to evaluate the surface water quality as irrigated DMWT to alternative water resource during transplanting season for drought stress.

Methods

The variety used in the field experiment was daejin-byeo, and the selected soil was sandy loam that is ordinarily one of representative soils at rice paddy in Korea. Tank that a pipe serving as drainage outlet connected at the bottom of tank with mortar pump was fulfilled with the discharge water from municipal wastewater treatment plant (DMWT). Especially, the one pipeline serving the groundwater, and the other for DMWT was connected with cock and gauge at outlet of each plot for irrigation periods. Also, fertilization was applied with 3 levels such as amount of fertilization after soil test (FAST), 50% of fertilization after soil test (FAST50%) and non-fertilization (Non). The rice was transplanted with 10?15cm of planting distances at each plot (4?3m) in vinyl house. Irrigation periods were 10, 20, 30 days and continuous irrigation during rice cultivation after transplanting, and then there was irrigated with groundwater after designated periods. For growth responses of rice to alternative irrigation water, plant height and number of tillering were measured at 30 days after transplanting and harvest index was calculated by the following equation (Singh *et. al*., 1999): Harvest index = *(Grain yield/ Total bio-mass)?0.86* where factor 0.86 is used to convert grain yield with 14% moisture content on dry-weight basis. Surface water was sampled at 10, 20, 30, 60, and 90 days after transplanting, and filtered by using the membrane filter (0.45μm), and then kept at 4?C in the refrigerator for the analysis of water quality. The chemical characteristics of alternative irrigation water used and surface water were analyzed with standard methods (K.E.P.A., 2000). Sodium adsorption ratio (SAR) was calculated by the following equation using concentrations of Na^+, Ca^{2+} and Mg^{2+} per mM; SAR = $C_{Na}/ [(C_{Ca} + C_{Mg})/2)]^{1/2}$. The experimental design was split-split plot with 3 replications.

Results

For the chemical compositions of alternative water, it appeared that all parameters in DMWT were satisfied with reuse criteria for agricultural irrigation (Table 1). In plant growth responses, the plant height was increased with prolonging the irrigation periods of DMAT with application of FAST 50%, but it did not significantly difference among the treatments with FAST. The straw weight was decreased with prolonging the irrigation periods of DMAT regardless of fertilization levels, but its increasing rates with FAST were ranged from 12.5%-16.4% relative to its FAST 50%. Harvest index in FAST 50% was higher than its FAST, but it was not significantly difference among the irrigation periods (Table 2). For the surface water quality, it shown that EC_i and SAR values of DMWT irrigation were twofold higher than those of groundwater, but these were not significantly different with fertilization levels (Fig. 1). In respective to the fertilization levels, EC_i and SAR values of surface water were not significantly difference between 10 and 20 days of irrigation periods at initial rice growing stages (Fig. 2). In this case, efficiency rate of alternative irrigation water for 20 days of drought period was 32.7% (249.2 m^3/ha) relative to 761.1 m^3/ha of total annual irrigation water for rice cultivation.

Table 1. Chemical characteristics of discharge waters from municipal wastewater treatment plant and groundwater, and reused criteria for agricultural irrigation

Parameters	Units	Ground water	DMWT[b]	References (Angelakis *et al*., 1999)	
				Criteria	Nations

pH	-	6.2	6.9	6.5-8.5	Tunisia(1975)
EC_i	dS /m	0.23	0.78	〈3.0	〃
SS	mg/L	0.18	0.30	5, 15	U.S.EPA(1992), Israel(1978)
CODcr	〃	19.70	19.50	90.0	Tunisia(1999)
NH_4^+-N	〃	1.33	25.42	-	-
NO_3-N	〃	3.44	1.95	-	-
PO_4-P	〃	0.15	1.57	-	-
Cl^-	〃	24.12	77.85	2,000	Tunsia(1999)
SO_4^{2-}	〃	5.89	31.53	-	-
Mn^{2+}	〃	0.007	0.003	0.5	Tunsia(1999)
Ni^+	〃	0.006	0.005	0.2	〃
Zn^{2+}	〃	0.03	0.004	5	〃
SAR[a]	〃	0.87	2.87	〈10	Italy(1977)

[a] $SAR = C_{Na}/\sqrt{(C_{Ca}+C_{Mg})/2}$; [b]Discharge water from municipal wastewater treatment plant

Table 2. Plant responses to irrigation periods of alternative water with different fertilizer levels during rice cultivation periods.

Plant characteristics	FAST 50%			FAST			Control
	10 IP*	20 IP	30 IP	10 IP	20 IP	30 IP	
Plant height (cm)	52.9	56.7	59.4	62.7	60.8	63.4	55.0

No. of tiller	19.0	22.1	18.6	22.0	23.9	21.6	20.8
Straw weight (kg/10a)	2455.0	2333.1	2113.3	2808.3	2685.0	2528.3	2331.7
Grain yield (kg/10a)	686.7	658.3	643.3	553.3	590.0	571.7	621.7
Harvest index	0.22	0.22	0.23	0.17	0.18	0.18	0.21

*IP: Irrigation period

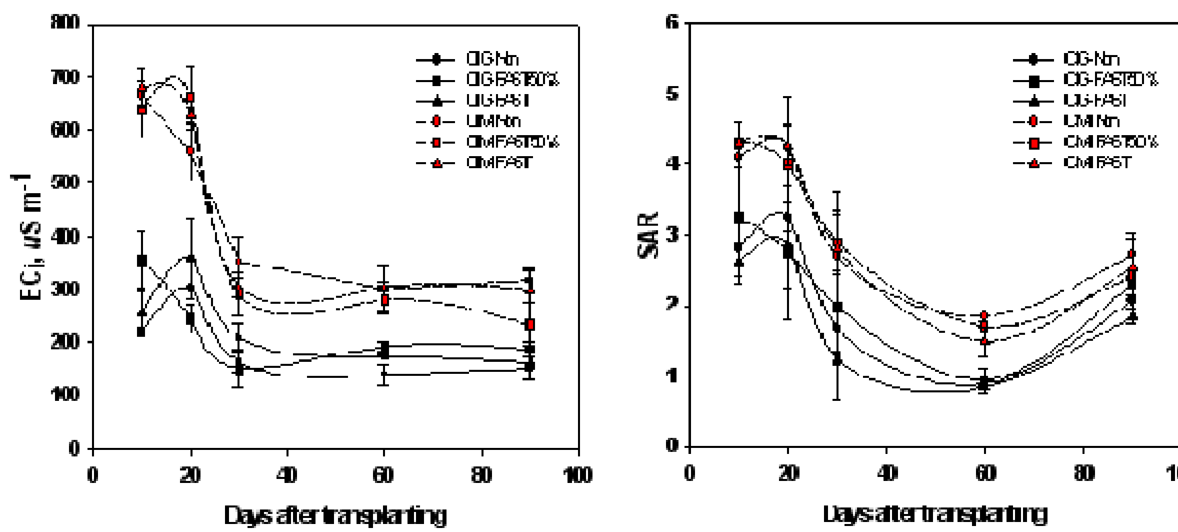

Figure 1. Changes of ECi and SAR of surface water to alternative irrigation waters with different fertilizer levels during rice cultivation periods. CIG; continuous irrigation of groundwater, CIM; continuous irrigation of discharge water from municipal wastewater treatment plant.

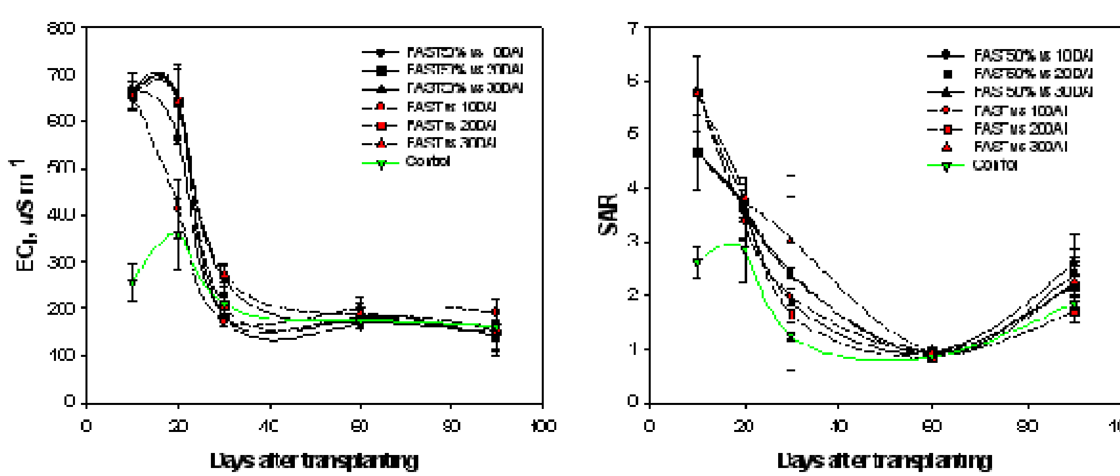

Figure 2. Changes of ECi and SAR of surface water to irrigation periods of DMWT with different fertilizer levels during rice cultivation periods. DAI; days after irrigation.

Conclusion

The discharge water from municipal wastewater treatment plant was potentially safe to irrigate for 20 days of drought period at transplanting season as compared to harvest index, SAR and EC_i values of surface water with groundwater through the rice cultivation period. In this case, efficiency rate of alternative irrigation water for 20 days of drought period was 32.7%.

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