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Responses of Rice (*Oryza sativa* L.) Yield and Percolation Water Qualities to Alternative Irrigation Waters

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ABSTRACT : Objective of this study was to investigate the influences of harvest index and percolation water quality as irrigated the discharge waters from an industrial and a municipal wastewater treatment plants and seawater (1:5 seawater: tap water) as alternative water resources during tillering stage for drought stress. There were four different treatments such as the discharge water from an industrial (textile dyeing manufacture plant) wastewater treatment plant (DIWT),discharge water from the municipal wastewater treatment plant (DMWT), seawater (1:5) and groundwater as a control. For the initial chemical compositions of alternative waters, it appeared that higher concentrations of COD, Mn^{2+}, and Ni^{+} in DIWT were observed than reused criteria of other country for irrigation, and concentrations of EC_i, Cl and SO_4in seawater were higher than that for irrigation. Harvest index was not significantly different between DIWT and DMWT with different irrigation periods in two soil types, but that of seawater (1:5) is decreased with irrigation periods in clay loam soil and not different between 10 days and 20 days of irrigation periods in sandy loam soil. For percolation water qualities, values of sodium adsorption ratio (SAR) are increased with prolonging the irrigation periods of seawater (1:5) and DIWT, but those of DMWT were almost constant through the cultivation periods regardless of the irrigation period in both soil types. EC_i of percolation waters is eventually increased with prolonging days after irrigation regardless of irrigation periods in both soil types. Therefore, it might be concluded that there was potentially safe to irrigate the discharge water from municipal wastewater treatment plant relative to harvest index, SAR and EC_i values of the ground water through the rice cultivation period at tillering stage for drought period.

Key words: alternative irrigation waters, percolation water quality, harvest index, sodium adsorption ratio.

INTRODUCTION

Rapid industrial development has increased competition for the scarce water resources. Rapid growth in the demand for high quality water coupled with natural shortage and continuous restrictions in supply have accelerated the alternative sources. Thus, irrigated agriculture faces the cha- llenge of using less water, in many cases of poorer quality, to provide food and fiber for an expanding population. In regions with limited natural water sources, treated wastewater from primarily urban sewage can be utilized for agriculture, industry, recreation and recharge of aquifers[1-3]. Most importantly, effluent application for irrigation simultaneously solves water shortage and wastewater disposal problems. The issue of wastewater is of crucial importance in small and isolated communities in which the treatment of sewage needs fundamental attention for quality control[4]. Wastewater treatment and improvement are required both to minimize the health and environmental risks and to evaluate the utilization of wastewater as a solution to water shortage problems. There are alternative irrigation resources such as discharge waters from industrial and municipal wastewater treatment plant. However, wastewater is oftenassociated with environmental risks. Therefore, its acceptability to replace other water resources for irrigation is highly dependent on environmental impacts entailed. Water and nutrients belong to the most important growth factors for all

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green plants. In general, both fertilization and irrigation are costly for the farmer, but could also create problems for the society in a long term perspective. This due to the fact that water as well as many of the nutrients involved are scare natural resources.

In the other hand, the water resource is difficult to develop economically due to groundwater pollution and the difficulty of new reservoir construction. Hence, 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[5]. However, there is not sufficient for irrigation water at tillering stage in rice paddy when the drought is sometimes occurred. Therefore, how to reclaim and reuse thewater is an efficient way to solve this problem. Among the wastewaters, the discharge waters from industrial and municipal wastewater treatment plants are most valuable for alternative irrigation water during drought period because it has large volume and less contaminated. Although it has irrigated in rice paddy for only drought period, the potential must be evaluated for the reuse with rice cultivation safely.

Objective of this study was to investigate the influences of harvest index and percolation water quality as irrigated DMWT, DIWT and seawater (1:5) as alternative water resources during tillering stage for drought stress.

MATERIALS AND METHODS

The variety of rice used in this experiment was Ilmi-byeo. The selected soils were sandy loam and clay loam that are ordinarily representativesoils at rice paddy in Korea. The collected soils from the field are dried and passed through 4 mm sieve, and Wagner pot (1/2,000 a) was fulfilledwith approximately 12.8 kg/pot (dry basis).

Amount of fertilizer was based on soil test for chemical properties to the soil before experiment. Chemical properties of soil used are presented in Table 1.

It was applied with 3.2-4.8-1.5 kg/10a ($N-P_2O_5-K_2O$) in sandy loam soil and 3.3-3.0-1.6 kg/10a ($N-P_2O_5-K_2O$) in clay loam soil as the basal application amount of fertilizer at 3 days before transplanting, respectively. At the vegetative stage, top dressing

Table 1. Chemical properties of soils before experiment

Soil types	pH	O.M (g/kg)	Av.P_2O_5 (mg/kg)	Av.SiO_2 (mg/kg)	Ex. Cation ($cmol^+$/kg) Ca	Mg	K	Na	CEC ($cmol^+$/kg)
Clay loam	5.9	1.9	52.52	118.26	2.21	0.32	0.14	0.27	6.96
Sandy loam	6.1	2.4	116.1	128.55	1.27	0.2	0.11	0.13	5.43

of fertilizer had not applied due to the appearance of salinity in the pot. Rice was transplanted with three plants at each plot in vinyl house, and each ceramic cup (ø 0.5 mm) was installed at 10 cm of soil depth for the collection of percolationwater. Rice was grown with irrigation of ground water until the tillering stage. For inducing the initial wilting points, there is stopped to irrigate the ground water until 186 kPa of soil moisture content in sandy loam soil and until its 40 kPa in clay loam soil. Treatments of alternative irrigation waters are consisted with DIWT, DMWT, seawater (1:5) and groundwater as the control. Irrigation periods were then irrigated for 10, 20, 30 days and whole cultivation period at tillering stage, and there was irrigated with ground water after designated periods.

For the effect of yield, harvest index was calculated by the following equation[6].

$$\text{Harvest index} = (\textit{Grain yield/ Total bio-mass}) \times 0.86$$

Where factor 0.86 was used to convert grain yield with 14% moisture content on dryweight basis. Forty ml of percolation water at each pot was collected at 10, 20, 30 and 60 days after irrigation of alternative water and filtered by using the membrane filter (0.45 μm), and then kept at 4℃ in the refrigerator for the analysis of percolation water quality.

The chemical characteristics of different irrigation waters used and percolation water were analyzed with standard methods[7]. The pH values were determined by using an Orion Research EA-940 pH meter, electric conductivity with EC meter(Y.S.I model-30), COD_{Cr} with $K_2Cr_2O_7$ method, NH_4-N with Indophenol method, NO_3-N, PO_4-P, Cl^- and $SO_4^{2-}$with using IC(Ion Chromato graphy, Dionex-300), cations as Na^+, Ca^{2+} and Mg^{2+} with using ICP-AES(Inductively Coupled Plasme-Atomic Emission Spectrometry, GBC INTERGRA XMP).

Sodium adsorption ratio (SAR) was calculated by the following equation using concentrations of the cations as Na^+, Ca^{2+} and Mg^{2+} in $mmol_c$/L

$$SAR = C_{Na} / [(C_{Ca} + C_{Mg})/2)]^{1/2}$$

This experiment was conducted with randomized complete design with 5 replications.

Data were subjected to an analysis of variance and standard deviation is calculated to compare the treatments.

RESULTS AND DISCUSSION

Chemical compositions of alternative irrigation water

Chemical compositions of alternative irrigation water are necessary to evaluate its suitability for irrigation. Water analysis of alternative irrigation waters irrigated at tillering stage and reuse criteria of wastewater for irrigation are described in Table 2. For the initial chemical compositions of alternative water, it appeared that higher concentrations of COD, Mn^{2+}, and Ni^{+} in DIWT were observed than the reused criteria of other country for irrigation, and concentrations of EC_i, Cl and SO_4 inseawater were higher than that for irrigation. Especially, SAR values of alternative irrigation waters were exceeded the reused criteria of irrigation water quality. According to classification of water by EC_i value, DIWT was slightly saline, ranged from 0.7 to 2.0 dS/mand DMWT was non-saline as lower than 0.7 dS/m, but seawater was brine as higher than 45 dS/m of electrical conductivity[8].

However, it may be not suitable for irrigation water quality by considering some of chemical components, but it is necessary for alternative irrigation water to consider the irrigation water during drought periods in rice paddy, limitedly.

Influence of rice yield to alternative irrigation waters

The alternative irrigation water may affect the harvest index that is dependent on the irrigation water resources, periods and soil types. Influences of harvest index to alternative irrigation waters and irrigation periods with two soil types were presented in Fig. 1. For soil types, harvest indexes are ranged from 0 to 0.08 for seawater (1:5), from 0.32 to 0.38 for DIWT and from 0.3 to 0.36 for DMWT as compared to the control, 0.35, in clay loam soil, but from 0 to 0.16 for seawater (1:5), from 0.32 to 0.38 for DIWT and from 0.25 to 0.36 for DMWT as compared to the control, 0.34, in sandy loam soil regardless of irrigation periods.

Harvest index was not significantly different between DIWT and DMWT with different irrigation periods in two soil types, but that of seawater (1:5) was decreased with irrigation periods in clay loam soil and not different between 10 days and 20 days of irrigation periods in sandy loam soil. Furthermore, it was observed that rice plant grown under the continuous seawater (1:5) irrigation was almost withering, and then it could not obtain

Table 2. Chemical characteristics of alternative irrigation waters irrigated for drought periods at tillering stage and reused criteria of wastewater for irrigation (adopted from Angelakis et al[9])

Parameters	Ground-water	DIWT	DMWT	Seawater	References	
					Criteria	Nations
pH	8.13	7.30	7.61	8.31	6.5~8.5	Tunisia (1975)
EC_i(dS/m)	0.19	1.81	0.64	49.00	〈3.0	〃
SS	ND	3.00	2.13	0.33	5, 15	U.S.EPA(1992), Israel (1978)
COD	17.92	109.40	28.80	ND	90.0	Tunisia (1999)
NH_4-N	0.05	29.66	0.55	1.61	-	-
NO_3-N	1.96	4.70	14.52	1.11	-	-
PO_4-P	0.01	0.40	3.48	0.01	-	-
Cl	43.48	306.60	66.60	11986.10	2,000	Tunisia (1999)
SO_4	26.50	169.70	45.00	3076.70	-	-
Al	ND	0.06	0.18	0.25	-	-
Mn	ND	0.84	0.01	0.01	0.5	Tunsia(1999)
Ni	ND	1.63	0.03	0.03	0.2	〃
Zn	ND	2.1	0.17	1.86	5	〃
SAR[b)]	5.03	97.85	19.37	31.64	〈10	Italy (1977)

[a)]All units in mg/Lunless otherwise specified except for pH.
[b)]$SAR = C_{Na}/ [(C_{Ca} + C_{Mg})/2]^{1/2}$.

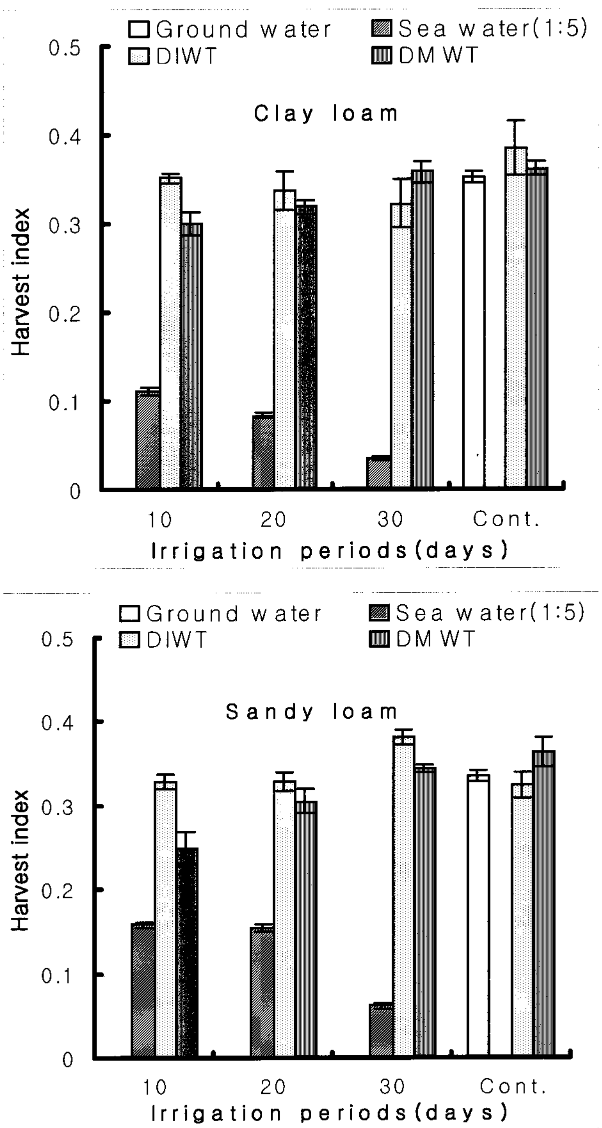

Fig. 1. Influences of harvest index to alternative irrigation waters and different irrigation periods with selected soil types. DIWT, discharge water from industrial wastewater treatment plant; DMWT, discharge water from municipal wastewater treatment plant; I, represent the standard deviation of each variable.

the grain yield in both soil types.

Percolation water quality

A classification of the quality of irrigation water, widely used for more than 20 years, was developed by the riverside Salinity laboratory[10]. The waters were classified according to their electrical conductivity (EC_i) and sodium adsorption ratio (SAR).

Changes of SAR in soil water at 10 cm depth, rooting zone, over 60 days after tillering stage to alternative irrigation waters and irrigation periods with two soil types are shown in Fig. 2. SAR values are increased with prolonging the irrigation periods of seawater (1:5) and DIWT, but those of DMWT were almost constant through the cultivation periods regardless of the irrigation period in both soil types. Ayers and Westcot[11] indicated that specific ion toxicity for surface irrigation at higher than 9 of SAR value is severely restricted to use for the sensitive crops. However, there was not an agreement with results of irrigation with DIWT and DMWT except for irrigation of seawater (1:5) in this study. It might be considered that this is attributed to crop sensitivity of salinity.

Changes of electrical conductivities with the percolation water to alternative irrigation waters and different irrigation periods in two soil types are shown in Fig. 3. Within 30 days of irrigation, average EC_i of percolation water was 16.0 dS/m for seawater (1:5), 1.1 dS/m for DIMT and 0.8 dS/m for DMWT as compared to 0.6 dS/m of the control in clay loam soil. In sandy loam soil, it was 13.2 dS/m for seawater (1:5), 1.2 dS/m for DIMT and 0.6 dS/m for DMWT as compared to 0.4 dS/m for the control. EC_i of percolation waters is eventually increased with prolonging days after irrigation regardless of irrigation periods in both soil types. This tendency might be attributed to less uptake of plant and accumulate of sodium in soil at the end of vegetative growth.

Over all, it might be concluded that there was potentially safe to irrigate the discharge water from municipal wastewater treatment plant relative to harvest index, SAR and EC_i values of the ground water through the rice cultivation period at drought period of tillering stage.

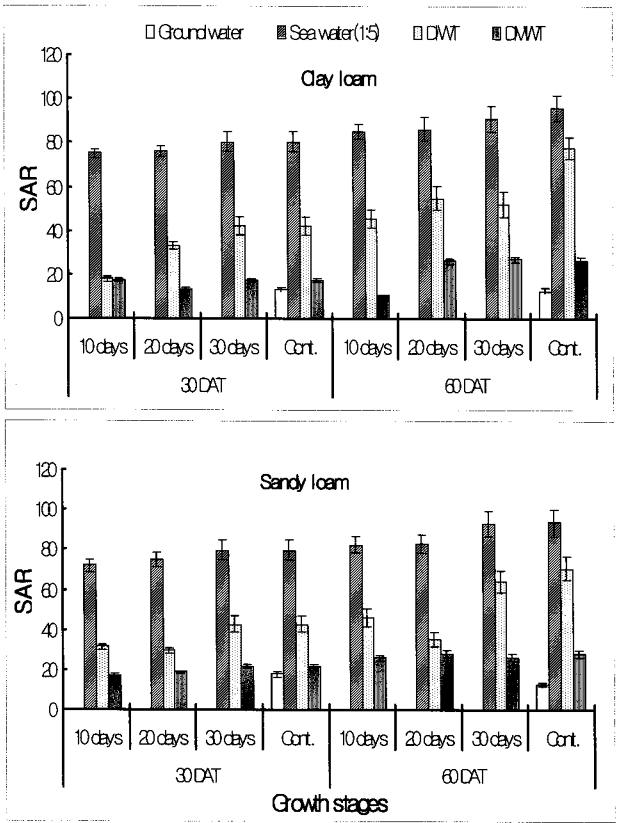

Fig. 2. Changes of SAR in soil water at 10 cm of soil depth over 60 days after tillering stageto alternative irrigation waters and irrigation periods with selected soil types. DAT, days after treatment; DIWT, discharge water from industrial wastewater treatment plant; DMWT, discharge water from municipal wastewater treatment plant; I, represent the standard deviation of each variable.

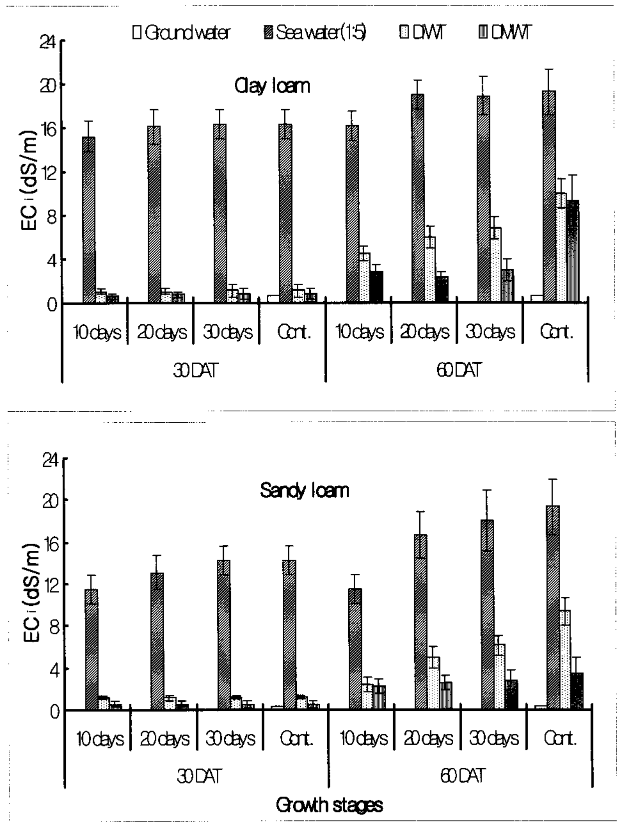

Fig. 3. Changes of EC_i in soil water at 10 cm of soil depth at 60 days after tillering stage to alternative irrigation waters and irrigation periods with selected soil types. DAT, days after treatment; DIWT, discharge water from industrial wastewater treatment plant; DMWT, discharge water from municipal wastewater treatment plant; I, represent the standard deviation of each variable.

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