Agricultural Water Management 138 (2014) 17–25

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Assessment of growth and yield components of rice irrigated with reclaimed wastewater

Kiwoong Jung[a], Taeil Jang[b,*], Hanseok Jeong[c], Seongwoo Park[c,d]

[a] Korea District Heating Corporation, Sejong-si 339-001, Republic of Korea
[b] Department of Rural Construction Engineering, Chonbuk National University, Jeonbuk 561-756, Republic of Korea
[c] Department of Rural Systems Engineering, Seoul National University, Seoul 151-921, Republic of Korea
[d] Research Institute for Agriculture and Life Sciences, Seoul National University, Seoul 151-921, Republic of Korea

ARTICLE INFO

Article history:
Received 5 August 2013
Received in revised form 26 February 2014
Accepted 26 February 2014
Available online 19 March 2014

Keywords:
Reuse
Water quality
Soil
Nutrient
HSD

ABSTRACT

The objective of this study is to assess the growth and yield components of rice irrigated with reclaimed domestic wastewater. The experimental plots consisted of four blocks of each of the three irrigation water treatments: groundwater, untreated wastewater, and reclaimed wastewater. Randomized complete block design was applied to the experimental plots (5 m × 5 m). Soil and water quality were monitored during a five cropping period. Crop height and tiller number data were analyzed from 2005 to 2009 according to growth stage. Analysis of variance (ANOVA) and honestly significant difference (HSD) post-hoc tests were applied to compare the rice components and yields from the treatments with the control plot. The wastewater and reclaimed wastewater irrigation plots were significantly higher than groundwater in clum length, panicle number, and rice yield. The total nutrients supplied with irrigation water were highly correlated with rice yield data, suggesting that the higher rice yield from reclaimed wastewater resulted from nutrient supply. The heavy metal contents in the milled rice that was cultivated with the reclaimed wastewater did not show significant differences from rice irrigated with groundwater. Reclaimed wastewater irrigation plots were significantly higher than groundwater irrigation plots in the contents of protein and milled head rice ratio, which had levels similar to or in the middle of conventional rice and brand rice. This study shows that reclaimed wastewater irrigation did not have adverse environmental impacts on the agricultural ecosystem, although long-term monitoring is needed to fully understand its relationships.

1. Introduction

Many countries are suffering from limited and contaminated water problems. Korea has similar issues due to population growth, urbanization, economic development, etc. Irrigation of agricultural fields using treated wastewater is being extensively practiced in countries faced with water shortage problems, such as Mediterranean countries (Belaid et al., 2012). A recent national survey on the future Korean water supply and demand reported that the country can expect a shortage of over 0.44 billion m^3 of water by 2030 (MLTM, 2006). In addition, rice is the most widely cultivated crop in Korea and rice production requires large amounts of water; agricultural irrigation is allocated upwards of 62% of the total annual water use in Korea (Jang et al., 2012).

Wastewater is a valuable source of plant nutrients and organic matter, which are needed to maintain fertility and productivity levels of soil (Meli et al., 2002; Rusan et al., 2007) and wastewater reuse with proper management can improve growth and productivity (Bedbabis et al., 2010). However, it is important to understand and control the risks involving aspects of health, productivity, and soils due to widespread usage and potentially deleterious effects of wastewater irrigation (Pedrero et al., 2010). Although treated wastewater generally displays low concentrations of metals, the long-term use of this wastewater often results in the build-up of metal content in soils (Mireles et al., 2004; Rattan et al., 2005; Solis et al., 2005). The extent of the metal content increase in irrigated soils depends on both the period and rate of wastewater application (Rattan et al., 2005; Solis et al., 2005; Nayek et al., 2010). Therefore, good management, taking into account the nutrient content of wastewater, soil, and crops, is essential for the safe and effective reuse of wastewater for irrigation (Hamilton et al., 2007; Rusan et al., 2007).

Reclaimed wastewater can be an alternative water resource for supplementary irrigation in areas that suffer from water shortages or unsatisfactory water quality since agricultural irrigation

* Corresponding author. Tel.: +82 632702518; fax: +82 632702517.
E-mail address: tjang@jbnu.ac.kr (T. Jang).

http://dx.doi.org/10.1016/j.agwat.2014.02.017

water is not usually required to meet same high standards of water quality as drinking water (Kang et al., 2007; Jang et al., 2010, 2013). Wastewater can provide an important quantity of nutrients, especially nitrogen and phosphorus, which can increase soil fertility, benefit plant growth and crop production, and reduce the quantity of commercial fertilizers needed, thus increasing farmers' economic benefits (Papadopoulos and Savvides, 2003). For this reason, guidelines for reclaimed wastewater irrigation have been developed and the Ministry of Environment finally adopted a set of guidelines for paddy fields in Korea (MOE, 2005). As a result, more data (i.e., water quality, soil, crop, etc.) are becoming available, and these data help clarify potential human health problems and assess the environmental effects associated with reclaimed wastewater irrigation of paddy fields. However, few reports of practical wastewater reuse for rice paddies have been presented (Kang et al., 2007; Jang et al., 2010, 2012, 2013), even though case studies for upland crop irrigated with treated wastewater have been reported in many countries (e.g., Jang et al., 2012).

The goal of this study was to assess the effects of reclaimed wastewater irrigation on the growth, yield and yield components, and heavy metal contents for five growing seasons in rice ecosystems. To do so, three treatment plots were monitored: two rice plots, one irrigated with untreated wastewater and one with reclaimed wastewater, and a control treatment consisting of a rice plot irrigated with groundwater. This study is part of a general field survey using statistical analysis aimed at evaluating the crop growth, metal contents in the soil and plants, and the relationship between irrigation quality and yield of rice irrigated with reclaimed wastewater. The effects of treated wastewater on environmental pollution, plant growth, and crop production are rarely studied in field conditions (Pedrero et al., 2012) and thus, this kind of study is scarce.

2. Materials and methods

2.1. Study area and experimental design

The experimental plots were located in the Byoung-gem district (E 37°12′32′′, N 127°01′18′′) near the domestic wastewater treatment plant (WTP) in Suwon, Gyeonggi-do, Korea (Fig. 1). The construction of the Suwon domestic WTP, an activated sludge aeration plant, was completed in 1996 and the secondary treatment plant was completed in 2004. A randomized complete block design with split plot arrangements was used with three treatments and four replicates on 5 m × 5 m plots (Fig. 1). The three treatments indicate the different irrigation water used for plots: groundwater (TR#1), untreated wastewater (TR#2), and reclaimed wastewater (TR#3). The reclamation system for wastewater included the LCHE-WRT filter system (Maeng et al., 2006), a UV treatment unit, and pipelines supplying irrigation water from the wastewater effluents. A monitoring system was designed to analyze the environmental effects (Fig. 1) and Jang et al., 2012 provided a detailed description of the experimental site. The irrigation water levels were controlled to be 1–10 cm by farmer according to rice growth stage.

2.2. Crop management

For this experiment, one-month-old rice seedlings (*Oryza sativa cv. Chucheongbyeo*) were transplanted into the study plots in May and harvested in October during a 5-year period from 2005 to 2009. Fertilizers are typically applied three times, during the pre-plant, tilling, and panicle growing stages, but for our experiment, they were applied only one time during the pre-plant stage (N:P:K = 55:45:40 kg ha^{-1}) based on high-nutrient-concentration irrigation. Insecticides were sprayed in June of every year to exterminate rice water weevils (*Lissorhptrus oryzophillus Kuschel*) and weeds were controlled manually.

2.3. Weather and soil data

Primary weather data for the experimental plots were obtained from the Suwon National Meteorological Station, which is located approximately 7 km north of the study site. Rainfall was monitored using a tipping bucket rain gauge at the site and inflow was measured using a water gauge at the outlet of each plot (Jang et al., 2012). These monitoring results were used to calculate mass balance with water quality concentrations to evaluate the relationship

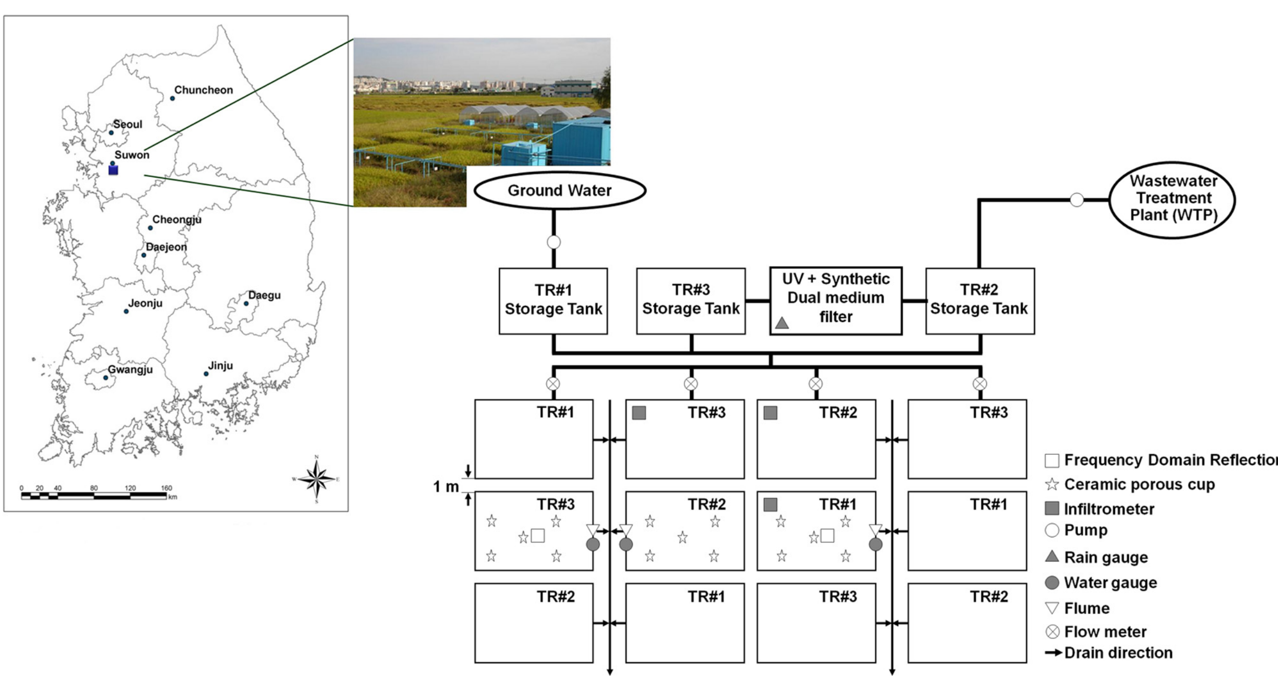

Fig. 1. Location and schematic representation of the study site and field experiments, including the wastewater reclamation and irrigation system and water sampling gauges (Jang et al., 2012).