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Influence of drip irrigation by reclaimed water on the dynamic change of the nitrogen element in soil and tomato yield and quality

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ABSTRACT

This paper carries out an analysis of the influence of the dynamic change pattern of soil in every crop growth period and irrigation by reclaimed water on yield and quality of fruit and vegetables comparative to drip irrigation by groundwater under the condition of drip irrigation by reclaimed water based on a field experiment. The results show the variation of peak value of concentration of NH_4^+—N in topsoil is: drip irrigation by reclaimed water > drip irrigation by 50% reclaimed water > drip irrigation by groundwater, the concentration of NH_4^+-N is higher at the depth of 0–40 cm with almost no accumulation of NH_4^+-N below the depth of 40 cm NO_3-N presence in soil slightly increases across the entire growth period with irrigation by reclaimed water. Irrigation by reclaimed water increases tomato yield and irrigation water use efficiency, and has an improved taste index indicated by an improved soluble sugar and titratable acidity content of the fruit without any obvious adverse influence on the nutritive indexes such as Vc soluble solid. The shortening of the irrigation period and increase in buried depth of drip irrigation tape are to promote an increase in tomato yield and irrigation water use efficiency to carry out drip irrigation by reclaimed water under the condition of having a shorter irrigation period and a greater depth of drip irrigation tape and to yield a higher rate of water conservation.

1. Introduction

Reclaimed water irrigation reduces serious nonpoint source pollution as a result of waste water irrigation and provides important nutrients for plant growth and promotes plant growth and development and increases yield, however, the excessive nutrients, poisonous chemical substances and pathogens in reclaimed water flow into ecological systems in the environment and result in environmental pollution to a certain extent of which may jeopardize the environment and human health (Ivanov et al., 2013; Velvizhi and Venkata Mohan, 2012). Drip irrigation is able to adjust soil moisture and nutrients based on the characteristics of irrigation time, irrigation quantity, soil infiltration range and height control point as well as physical properties (Shibao et al., 2016a; ShibaoLu et al., 2015a; Shibao et al., 2016b), root system distribution and water consumption of crops so as to ensure that the crop is high in quality and yield and reduce nonpoint source pollution at the same time. The drip irrigation technique has been adopted to reclaim domestic sewage in rural areas to enhance the utilization efficiency of nutritive substances such as nitrogen and phosphorus in reclaimed water, saved fertilizer and water, increase yield and reduce surplus pollutants introduced into the environment and ecological system, which is of great significance for China as it needs to alleviate its water resource crisis, prevent nonpoint source pollution and promote the development of a cyclic economy (ShibaoLu et al., 2015b; Del Campo and Perez, 2014; Lu et al., 2016a). This paper performs a study of and compares the dynamic change pattern of nitrogen elements in soil in every crop growth period after drip irrigation by reclaimed water and groundwater by conducting an experiment on the premise that the other conditions are identical.

Reclaimed water utilization is one of key measures to substantially alleviate the shortage of agricultural water taken both here and aboard, being the development trend for environmental protection by waste water reclamation to mitigate secondary pollution

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by the reduction of waste water discharge which has been widely adopted in many developed countries (Lu and Liang, 2016a, 2016b; Venkata Mohan et al., 2008). Irrigation by reclaimed water is used as a means to reduce nonpoint source pollution due to irrigation by waste water and offer important nutrients necessary for plant growth as well as promote plant growth and development and improve yield. However, the excessive nutrients, poisonous chemical substances and pathogens in reclaimed water flow into ecological systems in the environment and result in environmental pollution to a certain extent of which may jeopardize the environment and human health. As an important component of life, the nitrogen element is the main factor that generates water body pollution and eutrophication (Daniel David et al., 2009; Zoltan Boboescu and Daniel Gherman, 2014; Karra et al., 2013). In addition, human activities, such as the application of agricultural nitrogen fertilizer in quantities and the willful discharge of daily waste water create a large quantity of nitrogen elements in the form of NO_3^-N and NH_4^+-N unabsorbed by the crop in soil flow in the process of volatilization and leaching and run-off, have brought actual and potential pollution into the environment. Therefore, in theory, it is valuable and instructive in operation to conduct a study on the nitrogen element present in soil, especially the dynamic change of NO_3^-N and NH_4^+-N in terms of prediction and control of nonpoint source pollution in agriculture.

In addition, drip irrigation is able to adjust soil moisture and nutrients based on the characteristics of irrigation time, irrigation quantity, soil infiltration range and height control point as well as physical properties, root system distribution and water consumption of the crop so as to ensure that the crop is high in quality and yield and to ensure the reduction of nonpoint source pollution simultaneously (Feng et al., 2015; Lu et al., 2013, 2016b). The drip irrigation technique is adopted to reclaim domestic sewage in rural areas to enhance the utilization efficiency of nutritive substances such as nitrogen and phosphorus in reclaimed water, save fertilizer and water, increase yield and reduce surplus pollutants introduced into the environment and ecology systems, of which is of great significance for China as it needs to alleviate its water resource crisis, prevent nonpoint source pollution and promote the development of a cyclic economy.

Research on yield and quality of vegetables subjected to irrigation by reclaimed water both here and abroad are inadequate. Vegetable moisture, content, crude protein, amino acid content, total soluble sugar, vitamin C, crude ash, nitrate nitrogen and nitrite nitrogen are important nutritive indexes or quality indexes, and there are few research reports on the influence of irrigation and fertilization on yield and quality of greenhouse crops (Wu and Zhang, 2015; Yang et al., 2015a; Lam et al., 2015). This paper conducted a study of and compared the dynamic change patterns of the nitrogen element in every crop growth period after drip irrigation by reclaimed water and groundwater as well as the influence of irrigation by reclaimed water on yield and quality of vegetables to offer a technical basis for the selection of crops suitable for irrigation by reclaimed water.

2. Experiment material and method

2.1. Brief introduction to the experiment, irrigation and fertilization

The experiment field is located in the comprehensive demonstration zone of nonpoint source pollution control in water source area for the middle route of the South to North Water Diversion Project jointly built by the Institute of Geographical Sciences and Natural Resources Research, CAS and the Northern Water Diversion Office under State Council, and is in the mountainous area of the southern part of Maojian District, Shiyan City, Hubei Province in a northern subtropical monsoon climate region, in which annual solar radiation is 106.6 kcal/cm^2, physiological radiation is 50.4 kcal/cm^2, annual average sunshine duration is 1925.8 h, perennial mean temperature is 15.3 °C, extreme minimum temperature is −14.9 °C and the extreme maximum temperature is 41 °C. The accumulated temperature of the days whose temperature ≥10 °C in the year is 4936.5 °C, the frost-free period in the year is 246 days, the multi-year mean precipitation is 855 mm with a significant inter-annual variation in the amount of precipitation and the amount of precipitation in the flood period (May 1 − Oct. 20) accounting for 58%–62% of the annual amount of precipitation. The soil in the study area is yellow-brown soil with a unit weight varying from 1.56 to 1.71 g/cm^3. The water for irrigation has been subjected to testing for 15 quality indicators, the statistical results of which are shown in Table 1.

All operations are subject to the same irrigation and fertilization system (Shao et al., 2013; Cui and Ouyang, 2015), irrigation quantity shall be determined according to the evaporation capacity of an evaporation dish with a diameter of 20 cm placed in a position as high as a tomato with irrigation carried out 11 times in a growth period with the irrigation quantity up to 272 mm in which fertilization and irrigation have been performed 4 times with the same amount of fertilizer applied every time and carbamide selected as the fertilizer. The amount of fertilizer applied in every operation is 180 kgN/hm^2.

2.2. Experiment layout

The operation was carried out from Sept. 20 to Dec. 10 in the growth period for tomatoes in 2014. Tomato growth is based on ridge culture with the ridge shoulder being 60 cm in width, center-to-center spacing between ridges being 140 cm, and the ridge being 15 cm in height with two rows planted on the ridge and plant spacing being 40 cm. Prior to tomato growing, 20 kg of diammonium phosphate compound fertilizer was applied to every mu of field. There are three types of water for irrigation, namely T1 (irrigation by reclaimed water), T2 (irrigation by reclaimed water and groundwater, in which reclaimed water accounts for 50% of total irrigation quantity) and C (irrigation by groundwater), as shown in Table 2. Every operation was repeated for 3 plots; every plot contains 3 ridges with a length of 4 m, and every plot is 4 m × 4 m in area. Irrigation is carried out in the form of gravity drip irrigation with a drip irrigation tape laid in the center of every ridge; dripper spacing is 20 cm, being identical with plant spacing, dripper flow rate is 2.7 L/h, and every tomato plant root has a

Table 1
Testing result of reclaimed water and groundwater quality indicators.

Test item	Reclaimed water		Groundwater
	Average value	Standard deviation	
Calcium ion	59.12	31.01	24.30
Magnesium ion	29.65	12.27	21.90
Sodium ion	138.50	16.19	75.00
Chlorine ion	181.32	86.58	26.70
Bicarbonate ion	381.89	310.53	240.00
Carbonate ion	42.12	24.04	36.70
Sulfate ion	94.87	12.82	50.00
Ion	0.16	0.08	0.13
Manganese	0.04	0.02	Not detected
BOD	40.32	8.79	11.60
COD	79.63	26.87	15.10
Total salt	720.20	136.48	334.00
Total nitrogen	28.10	19.85	1.36
Total phosphorus	1.04	0.87	0.04
TSS	70.75	24.77	Not detected