Bangladesh J. Bot. **44**(5): 699-708, 2015 (December), Supplementary

EFFECT OF RECLAIMED MUNICIPAL WASTEWATER IRRIGATION AND NITROGEN FERTILIZATION ON YIELD OF TOMATO AND NITROGEN ECONOMY

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Key words: Greenhouse tomato, Rhizosphere, Partial factor productivity, Apparent N loss

Abstract

To examine the effects of nitrogen and reclaimed municipal wastewater irrigation on yield of greenhouse tomato and nitrogen economy, field experiments were carried out. Root-layer mineral nitrogen, total nitrogen, abundance of soil microorganisms, tomato yield, nitrogen in fruit, partial factor productivity from applied N, apparent N loss and nitrogen supplying capacity were analyzed. The results indicated that RMW irrigation leaded to an average of 1.72 - 40.39% increase in mineral nitrogen and total nitrogen of rhizosphere soil in 1st, 2nd and 4th cluster fruit expanding stage. RMW irrigation significantly increased the microbial population of rhizosphere soil in the crop growth stage, yield of tomato, nitrogen in fruit, partial factor productivity from applied N and nitrogen supplying capacity. RMW irrigation reduced the amount of topdressed nitrogen and promoted rhizosphere nitrogen supplying capacity and this prevent disposal of RMW to the river and minimize groundwater exploitation.

Introduction

Starting in the 1980s, China began to reclaim municipal wastewater (RMW) irrigation in order to address the differences between water supply and demand for water and to improve agriculture water management through research technology. In recent years, the testing and application of RMW irrigation have been implemented in Beijing, Tianjin, Dalian and other places (Shi *et al*. 2008). With rapid increases in the practice of irrigating with RMW, many environmental problems have occurred. Surface soil accumulation of microorganisms, salts, organic contaminants, and heavy metals have resulted in human health risks, soil degradation, declines in production capacity, etc. (Fatta-Kassinos *et al*. 2010, Pereria *et al*. 2011, Michael *et al*. 2012). Excessive soil nitrification from wastewater irrigation has resulted in a marked increase in soil acidity since the 1980s (Guo *et al*. 2010). RMW derived from urban sewage has higher concentrations of N, P, K, Ca, Mg (Fonseca *et al*. 2007, Sophocleous *et al*. 2009), which could accumulate in surface soils. Cropland soil production capacity therefore, becoming worse with RMW irrigation under a conventional fertilization regime.

The rhizosphere is the micro-zone surrounding the root system, it ranges from less than 1 to a few mm thickness and provides the portal for water and mineral nutrients to enter the root system. Chemical and physical soil properties, microorganism community structure, soil nutrient status, and root secretions all influence the biological cycle and greatly influence plant growth, nutrient use

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efficiency, and the yield of biochemical processes (Hinsinger *et al*. 2009, Fan *et al*. 2012, Dinesh *et al*. 2012). Mineral nitrogen in rhizosphere soil was found to be significantly lower than in surrounding soil owing to increased microbial immobilization and root uptake (Zhao *et al*. 2010), the abundance of rhizosphere microbial was significantly higher than that of the surrounding soil. Enzymatic activity associated with soil microorganisms further changed the availability of soil nutrients (Rouphael *et al*. 2005, Guan *et al*. 2011, Kołodziej *et al*. 2012). Plant growth-promoting rhizobacteria are free-living bacteria which actively colonize plant roots, exerting beneficial effects on plant development (Pérez-Montano *et al*. 2014). However, sound understanding of the mechanisms of rhizosphere soil nitrogen supplying capacity is important in order to decide how amount of nitrogen to be topdressed for maximizing yield of greenhouse tomato irrigated with RMW.

In this work, attempt was made to ascertain the nitrogen supplying capacity of the tomato rhizosphere and the relationship between yield determining factors irrigated with RMW. Finally, targets were considered for reducing the amount of fertilizer in relation to nitrogen utilization and RMW irrigation.

Materials and Methods

Field experiments were carried out on 2013 in a greenhouse at the Agriculture Water and Soil Environmental Field Science Research Station, Chinese Academy of Agricultural Science, Xinxiang city, Henan province, China (latitude 35°15′09″N, longitude 113°55′05″E, and altitude 73.2m). Xinxiang city has a temperate climate with an annual average rainfall of about 588.8 mm.

The RMW for irrigation was taken from the Luotuo Wan water source plant in Xinxiang city Henan province. From Luotuo Wan water source plant, under treatment process of anaerobic-anoxic-oxic denitrification biofilter and ozone oxidation. Municipal sewage was the main source of wastewater for the plant, basic properties of RMW and tap water used were listed in the Table 1. The field trial was a fully randomized design with three replicates of five treatments (ReN1, ReN2, ReN3, ReN4 and CK) using RMW and tap water irrigation with subsurface drip irrigation systems. The ReN1, ReN2, ReN3, ReN4 and CK treatments consisted of nitrogen topdressing as 90, 72, 63, 45 and 90 kg/hm^2, respectively. Base fertilizers included dried chicken manure, nitrogen, phosphorus, potassium fertilizers, rated at 8 000, 180, 180 and 180 kg/hm^2, respectively. Irrigation scheduling was based on soil water content, as measured by a Time Domain Reflectometer (TDR). Plots of RMW treatments were irrigated two times with tap water during seedling stage, and with RMW after the blooming and fruit setting period. Furthermore, plots of CK treatment were irrigated with tap water during the growth span of tomato. The total irrigation amounted was 3736 m^3/hm^2. The traditional strip planting regime for tomatoes was used, which had a border width × interval of 1.0 × 0.5 m, a row spacing of 0.3 m, a line spacing of 0.75 m and a planting density of 45 000 plants per hectare. Tomato plants were transplanted on March 23, 2013 and tomatoes were harvested on July 27, 2013. Tomato plants were evaluated at the developmental stages consisting of 5 clusters and topdressing with nitrogen was performed at the 1st, 2nd and 4th cluster fruit expanding stage. Other management practices during the whole growth season were completely standard.

Soil strongly adhering to the roots was considered to belong to the rhizosphere (Chen *et al*. 2006) and was collected for analysis. Bulk soils were sampled from a location approximately 15 cm from the root at the 1st, 2nd and 4th cluster fruit expanding stage and late growth stage (Garcia *et al*. 2005). Soil samples were collected at depth of 0 - 10 cm, 10 - 20 cm, 20 - 30 cm, 30 - 40 cm and 40 - 60 cm with a standard 3.5 cm Ø soil auger at tomato transplanting and harvest stages, 5 samples were collected per plot and stored at room temperature before analyzing for NO_3-N, NH_4-N, total N, Total P, K, pH and total counting of bacteria. Three plant samples per plot were taken post-harvest, stored at room temperature, samples were analyzed for NO_3-N, NH_4-N, total N, available P and K in root, stem, leaf and fresh fruit.

Table 1. Properties of reclaimed municipal wastewater and tap water used.

Date of	NO_3^--N	NH_4^+-N	Total N	Total P	Cu	Total Cd	Cr^{6+}	COD_{Mn}	pH	TDS
sampling	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(μg/l)	(μg/l)	(g/l)		(g/l)
2013-3-25	1.70	0.86	3.90	2.88	0.005	0.68	6.38	7.86	7.52	1.63
2013-4-10	1.59	0.64	2.09	2.62	0.008	0.87	7.08	7.56	7.48	1.70
2013-04-29	15.63	10.16	48.75	2.31	0.020	2.74	17.78	10.80	7.42	1.30
2013-05-10	17.80	11.39	57.20	3.50	0.022	3.03	21.94	12.67	7.57	1.47
2013-05-31	29.34	14.79	53.82	2.80	0.019	3.32	18.86	18.91	7.38	1.78
2013-06-10	25.00	12.71	32.84	3.60	0.025	3.69	19.64	13.17	7.24	1.91
2013-06-21	10.96	7.43	34.86	2.60	0.027	3.74	21.22	11.70	7.38	1.81
2013-07-20	25.00	10.15	43.35	2.80	0.024	3.46	21.03	12.95	7.38	1.95

COD = Chemical oxygen demand, TDS = Total dissolved salt.

Analysis of variance (ANOVA) was performed with one-way ANOVA using DPS14.50 software. Treatments were compared for significant differences ($p < 0.05$ level) using DMRT.

Results and Discussion

The rhizosphere soil mineral nitrogen content of ReN1, ReN2, ReN3, ReN4 and CK was lower than that of bulk soil by 27.59, 10.47, 10.89, 0.96 and 19.26% in the 1st cluster fruit expanding stage, and by 15.82, 12.63, 11.66, 1.33 and 12.69% in the 2nd cluster fruit expanding stage, and by 10.04, 10.92, 10.75, 1.91 and 31.98% in the 4th cluster fruit expanding stage, and by 18.27, 10.29, 10.90, 8.90 and 25.99%, respectively in the late growth stage. In comparison with CK, ReN2 leaded to an average of 40.39, 5.42 and 10.63%, respectively, increase in mineral nitrogen of rhizosphere soil in 1st, 2nd and 4th cluster fruit expanding stage (Table1). Except for late growth stage, the content of mineral nitrogen of rhizosphere soil decreased by 5.53%. The mineral nitrogen (N min) decrements in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN1 were 178.56, 52.32, 17.58, –10.03, –15.64 kg/hm^2, respectively (Fig.1). The Nmin decrements in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN2 were 174.10, 44.71, 7.91, –14.45, –24.73 kg/hm^2, respectively. The Nmin decrements in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN3 were 167.64, 28.56, 3.00, –23.77, –28.25 kg/hm^2, respectively. The Nmin decrements in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN4 were 175.00, 35.08, –7.06, –22.19, –28.14 kg/hm^2, respectively. The Nmin decrements in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of CK were 155.20, 26.39, 7.33, –18.04, –37.48 kg/hm^2, respectively. After post-harvest, residual mineral nitrogen in the 0 - 10, 10 - 20 and 40 - 60 cm soil layer of ReN2 was significantly lower than that of CK, differing by 18.90, 22.90 and 10.11%, respectively ($p < 0.001$, Fig. 1). Except for 20 - 30 cm and 30 - 40 cm soil layer, the Nmin residual showed no significant difference. Mineral nitrogen consumption in the 0 - 30 cm root soil layer could be therefore used to evaluate soil nitrogen for biological effectiveness and root layer nitrogen as supplying capacity (Palese *et al.*

2009, Chen *et al*. 2012). Mineral nitrogen content of ReN2 and ReN3 in the 0 - 30 cm root soil layer was maintained above 40 mg/kg, which was key evidence because nitrogen supplying capacity under RMW irrigation and suitable topdressing (Zhao *et al*. 2010). Post-harvest mineral nitrogen residual in the 10 - 20 and 20 - 30 cm layers of ReN2 and ReN3 was significantly higher than that of ReN1 and CK, however, total nitrogen residual in the 30 - 40 cm and 40 - 60 cm layers of ReN1 was significantly higher than that of ReN2 and ReN3, which indicated that nitrogen accumulation in the lower soil was coincident with the excessive application of topdressing with RMW irrigation. The growth of tomato acquired plenty of mineral nutrients that came mainly from the rhizosphere soil (Pereira *et al*. 2011, Fonseca *et al*. 2005), however, the differences in mineral content between the rhizosphere and bulk soil suggested that the mineral nutrients of bulk soil migrated into the rhizosphere. Thus, the mineral nitrogen content between rhizosphere and bulk soil were not significantly different during the tomato post-harvest.

Table 2. Changes of soil mineral nitrogen content of different growth stage under different topdressing amount of N with RMW and tap water irrigation in the rhizosphere and bulk soil.

Soil division	Treatments	The content of mineral nitrogen (mg/kg)			
		The 1st cluster expanding stage	The 2nd cluster expanding stage	The 4th cluster expanding stage	Late growth stage
Rhizosphere soil	ReN1	73.10 ± 6.27 ab	93.02 ± 12.68 cd	52.49 ± 2.22 b	51.42 ± 4.16 b
	ReN2	77.41 ± 4.28 a	104.26 ± 7.06 bc	51.62 ± 5.11 b	41.32 ± 4.64 c
	ReN3	55.90 ± 6.68 c	101.50 ± 5.50 bc	56.63 ± 1.98 b	42.84 ± 1.64 c
	ReN4	49.32 ± 3.08 c	86.92 ± 4.46 d	54.06 ± 3.26 b	50.52 ± 3.13 b
	CK	55.14 ± 2.42 c	98.90 ± 6.85 c	46.66 ± 2.48 c	43.74 ± 1.36 c
Bulk soil	ReN1	83.27 ± 14.17 a	107.74 ± 3.27 ab	57.77 ± 5.76 ab	60.81 ± 3.03 a
	ReN2	85.51 ± 9.29 a	117.42 ± 8.83 a	57.26 ± 2.83 ab	45.57 ± 6.06 bc
	ReN3	61.99 ± 5.90 bc	113.34 ± 12.86 ab	62.72 ± 4.63 a	47.51 ± 2.42 bc
	ReN4	49.79 ± 10.93 c	88.09 ± 2.90 cd	55.41 ± 1.56 b	51.69 ± 1.70 b
	CK	65.76 ± 3.16 bc	111.45 ± 7.64 ab	61.58 ± 3.58 a	55.11 ± 2.12 a

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments within a soil division (Data processing system 7.05 DMRT.

The rhizosphere total N content of ReN1, ReN2, ReN3, ReN4 and CK was higher than that of bulk soil by 7.76 - 14.93% in the 1st cluster fruit expanding stage, and by 6.34 - 12.78% in the 2nd cluster, and by 0.22 - 7.12% in the 4th cluster, and by 3.05 - 8.97% in the late growth stage. In comparison to CK, ReN2 leaded to an average of 7.27, 1.71 and 2.83%, respectively increase in total N in the 1st, 2nd and 4th cluster fruit expanding stage in the rhizosphere soil layer. Except for late growth stage, the content of total N of rhizosphere soil decreased by 3.85%. The total N decrement in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN1 was 119.65, –95.09, –67.17, –61.81, –151.71 kg/hm^2, respectively. The total N decrement in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN2 was 191.98, –70.09, –41.77, –81.42 and –5.71 kg/hm^2, respectively. The total N decrement in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN3 was 162.85, –106.71, –81.81, – 126.08 and –7.71 kg/hm^2, respectively. The total N decrement in

0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of ReN4 was 131.32, –36.96, –126.35, –149.37 and –29.71 kg/hm^2, respectively. The total N decrement in 0 - 10, 10 - 20, 20 - 30, 30 - 40, 40 - 60 cm soil layer of CK was 84.80, –61.91, –179.19, –165.86, –113.71 kg/hm^2, respectively (Fig. 2). In comparison to CK, residual TN in the 0 - 10, 10 - 20, 20 - 30, 30 - 40 and 40 - 60 cm soil layer of ReN2 showed no significant difference after post-harvest. The total N content of the rhizosphere in all treatments was higher than that of the bulk soil, which might be mainly due to significantly higher quantity of microorganisms in rhizosphere and root exudates (Hinsinger *et al.* 2009, Inselsbacher *et al.* 2010), furthermore, the total N content of the rhizosphere and bulk soil of ReN2 was lower than that of CK, which might be mainly due to significantly higher nitrogen utilization and nitrogen priming effect by RMW irrigation (Zhu *et al.* 2014, Chen *et al.* 2015).

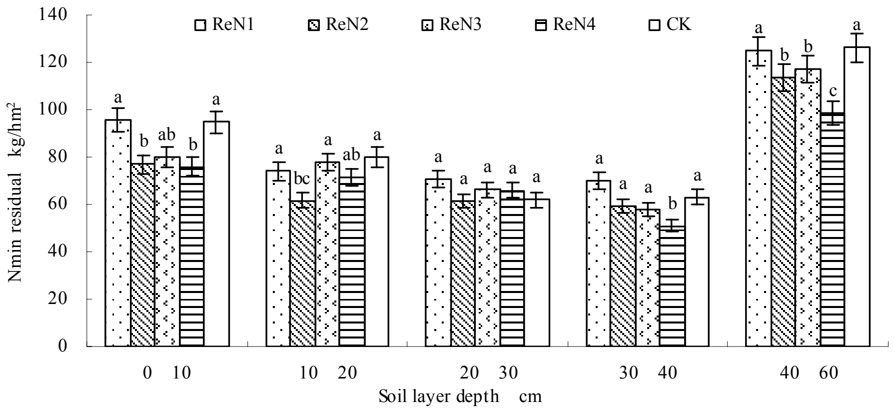

Fig. 1. Residual Nmin of soil layers under topdressing with RMW irrigation after post-harvest. Different letters above the bars indicate significant differences ($p < 0.05\%$) at the same soil layer depth among different treatments (Data processing system 7.05 DMRT.

The number of rhizosphere microbial of ReN1, ReN2, ReN3, ReN4 and CK was significantly higher than those of bulk soil in the 1st cluster, differing by 0.79, 0.40, 0.42, 0.53 and 0.63-fold, 6.03, 7.80, 6.18, 4.65 and 5.79-fold and 0.85, 0.70, 0.24, 0.33 and 0.25-fold in the 4th cluster, and 6.46, 4.64, 3.82, 4.94 and 3.17-fold, respectively in the late growth stage (Table 4). Microbial immobilization and mineralization that occurred at the same time were important parts of soil nitrogen cycle, rhizosphere mineral nitrogen was consumed by microbial and plant roots, which further promoted the migration from bulk soil to the rhizosphere, thus, a sufficient rhizosphere nutrient supply further boosted microbial growth and increased the amount of organic nitrogen (Inselsbacher *et al.* 2010). Nitrogen was an important elemental constituent of all organisms, and soil nitrogen content influenced the microbial community composition. Nitrogen mineralization and immobilization was closely related to the abundance of microorganisms (Rosa *et al.* 2007), the extent of rhizosphere microbial growth influenced the biological cycle, the area of root activities on soil nutrients, and the microbial community composition (Fan *et al.* 2012). Root exudates into the rhizosphere provided an abundance of nutrients needed by microorganisms (Lee *et al.* 2006, Hinsinger *et al.* 2009), thus, the quantity of rhizosphere microbial was significantly higher than that of bulk soil. Compared to ReN2, ReN3 and ReN4, the quantity of rhizosphere microbial in ReN1 was significantly higher than that of ReN2, ReN3 and ReN4. Furthermore, rhizosphere microbial activity promoted the process of mineral nitrogen immobilization (Chen *et al.* 2007), with decreased in rhizosphere mineral nitrogen, the migration of mineral nitrogen from bulk soil to the rhizosphere was further stimulated (Lioussanne *et al.* 2010). The mineral nitrogen of ReN1 during the tomato growth stage was lower than that of ReN2, which further confirmed the dynamic change of mineral nitrogen in the rhizosphere.

Table 3. Changes of soil total nitrogen content of different growth stages under different topdressing amount of N with RMW and tap water irrigation in the rhizosphere and bulk soil.

Soil division	Treatments	The content of total nitrogen (g/kg)			
		The 1st cluster expanding stage	The 2nd cluster expanding stage	The 4th cluster expanding stage	Late growth stage
Rhizosphere soil	ReN1	1.24 ± 0.12 a	1.23 ± 0.14 a	1.15 ± 0.06 a	1.18 ± 0.02 a
	ReN2	1.18 ± 0.02 ab	1.19 ± 0.02 a	1.09 ± 0.03 ab	1.00 ± 0.08 bc
	ReN3	1.11 ± 0.06 abc	1.17 ± 0.11 a	1.05 ± 0.10 ab	1.02 ± 0.14 bc
	ReN4	1.05 ± 0.05 bc	1.17 ± 0.09 a	1.09 ± 0.04 ab	1.02 ± 0.06 bc
	CK	1.10 ± 0.03 abc	1.17 ± 0.11 a	1.06 ± 0.05 ab	1.04 ± 0.04 bc
Bulk soil	ReN1	1.08 ± 0.05 abc	1.16 ± 0.21 a	1.08 ± 0.03 ab	1.12 ± 0.05 ab
	ReN2	1.05 ± 0.15 bc	1.07 ± 0.13 a	1.04 ± 0.04 b	0.97 ± 0.04 c
	ReN3	1.00 ± 0.10 c	1.04 ± 0.08 a	1.05 ± 0.10 b	0.98 ± 0.10 c
	ReN4	0.98 ± 0.11 c	1.04 ± 0.06 a	1.05 ± 0.02 b	0.99 ± 0.02 c
	CK	0.96 ± 0.06 c	1.07 ± 0.08 a	1.05 ± 0.06 b	1.00 ± 0.07 c

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments within a soil division (Data processing system 7.05 DMRT.

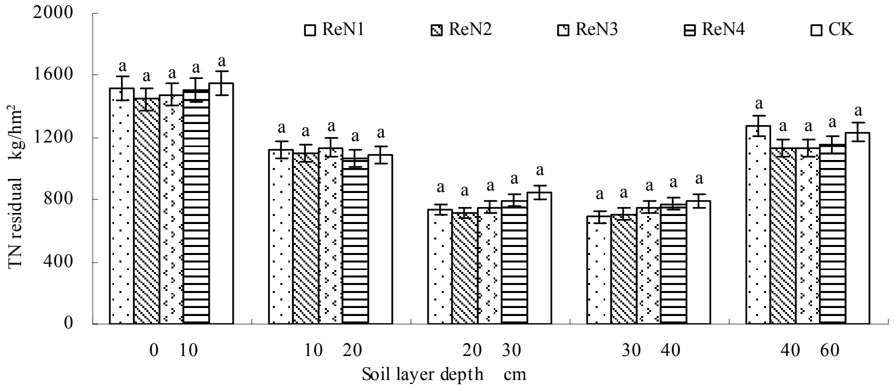

Fig. 2. Residual total N of soil layers under topdressing with RMW irrigation after tomato harvest. Different letters above the bars indicate significant differences ($p < 0.05\%$) at the same soil layer depth among different treatments (Data processing system 7.05 DMRT).

Table 4. Changes of soil microbial population at different growth stages of tomato in the rhizosphere and bulk soils.

Soil division	Treatments	Microbial population 10^4 CFU/g)			
		The 1st cluster expanding stage	The 2nd cluster expanding stage	The 4th cluster expanding stage	Late growth stage
Rhizosphere soil	ReN1	88.33 ± 5.03 a	202.67 ± 10.41 a	77.00 ± 1.00 b	189.00 ± 9.17 a
	ReN2	83.00 ± 6.25 ab	167.17 ± 8.81 b	89.33 ± 2.52 a	152.33 ± 6.81 b
	ReN3	77.67 ± 4.93 b	91.00 ± 1.00 c	75.17 ± 5.35 b	72.33 ± 4.16 c
	ReN4	70.33 ± 3.06 c	72.50 ± 0.50 d	69.33 ± 1.53 c	65.33 ± 4.73 c
	CK	68.00 ± 1.73 c	97.33 ± 4.35 c	67.83 ± 0.73 c	66.67 ± 1.52 c
Bulk soil	ReN1	49.33 ± 2.52 ef	28.83 ± 1.76 e	41.67 ± 2.08 f	25.33 ± 3.51 d
	ReN2	59.33 ± 3.06 d	19.00 ± 2.65 f	52.50 ± 1.50 e	27.00 ± 1.00 d
	ReN3	54.67 ± 3.06 de	12.67 ± 1.53 f	60.67 ± 3.06 d	15.00 ± 2.00 e
	ReN4	46.00 ± 2.00 fg	12.83 ± 1.44 f	52.00 ± 2.00 e	11.00 ± 1.00 e
	CK	41.67 ± 3.84 g	14.33 ± 1.04 f	54.17 ± 1.35 e	16.00 ± 1.00 e

Different letters in the same row indicate significant differences ($p < 0.05\%$) among different treatments within a soil division (Data processing system 7.05 DMRT.

The tomato yields of ReN1, ReN2, ReN3, ReN4 and CK were 139.80, 153.65, 146.70, 140.70 and 140.48 t/hm^2, respectively (Table 5). The biomass of ReN2 was significantly higher than that of CK differing by 8.66%, but significantly lower than that of ReN1 differing by 11.08%. The tomato yield of ReN2 was significantly higher than that of ReN1, ReN3, ReN4 and CK differing by 9.91, 4.74, 9.20 and 9.38%, respectively. The nitrogen in plant and fruit of ReN2 was significantly higher than that of ReN3, ReN4 and CK differing by 46.62, 83.14 and 62.51%, respectively. Partial factor productivity from applied N of ReN2 was significantly higher than that of ReN1 and CK differing by 21.18 and 20.59%, respectively. Apparent nitrogen loss of ReN2 was significantly less than that of ReN1 and CK differing by 14.27 and 6.34%, respectively. Nitrogen supplying capacity of ReN1, ReN2 and ReN3 were not significantly different but nitrogen supplying capacity of ReN1, ReN2 and ReN3 were significantly higher than that of ReN4 and CK differing from 6.82 to 11.68%. Comparing to CK, biomass, yield and nitrogen in fruit of RMW irrigation with suitable topdressing N treatment were significantly improved, resulting in higher partial factor productivity from applied N and nitrogen supplying capacity. The tomato plant biomass of ReN1 was significantly higher than that of ReN2 and ReN3, however, the ReN1 treatment resulted an increased growth of the tomato plants at the expense of tomato yield (Zhu *et al.* 2004). Thus, the yield of ReN2 and ReN3 was significantly higher than that of ReN1. Furthermore, partial factor productivity from applied N for ReN2 and ReN3 was improved when compared with ReN1, and nitrogen apparent loss for ReN2 and ReN3 was decreased (Elia *et al.* 2012). Obviously, the increase in tomato yield and improvement in the nitrogen supplying capacity of root layer could be achieved by reducing the topdressing applied N along with RMW irrigation. The salinity of RMW could influence the soil capacity for sustainable production after long-term irrigation (Xu *et al.* 2010, Palacios-Díaz *et al.* 2009), further research was needed to establish this effect on the root layer nitrogen supply capacity.

Table 5. Tomato biomass, yield and soil nitrogen supplying capacity under different topdressing with RMW irrigation.

Treat-ments	Nitrogen rate/(kg/hm^2)		Nitrogen in irrigation water (kg/hm^2)	Biomass (t/hm^2)	Yield (t/hm^2)	Nitrogen in plant and fruit (kg/hm^2)	Nitrogen in fruit (kg/hm^2)	PFP (kg/kg)	NAL (kg/hm^2)	NSC (kg/hm^2)
	Base fertilizer	Topdressing								
ReN1	310.4	270	87.34	7.76a	146.76a	139.80c	41.88a	240.87c	642.19a	225.13a
ReN2	310.4	216	87.34	6.90bc	146.79a	153.65a	43.16a	291.88b	550.57c	226.73a
ReN3	310.4	189	87.34	7.00b	122.64b	146.70b	29.43b	293.75b	543.01c	222.27a
ReN4	310.4	135	87.34	6.74c	112.58bc	140.70c	23.56d	315.89a	508.33d	203.02b
CK	310.4	270	10.83	6.35d	109.10c	140.48c	26.56c	242.05c	587.86b	209.20b

Values followed by different letters of the same column show significant differences ($p < 0.05$) among treatments, PFP from applied N PFP = Tomato yield/nitrogen rate (kg/kg), NAL = N min residual of 0 to 30 cm root layer before the tomato transplant + base fertilizer + topdressing + nitrogen in irrigation water-nitrogen in plant and fruit - Nmin residual of 0 to 30 cm root layer after the tomato post-harvest. Nitrogen supplying capacity (NSC) = Nmin variation of 0 to 30 cm soil depth.

A field experiment was conducted in Xinxiang city, Henan province, China to evaluate the effects of reclaimed water irrigation with topdressing N on soil nitrogen supplying capacity of greenhouse soils. Our main findings are: (1) Reclaimed water irrigation led to an average of 5.42 - 40.39%, increase in mineral nitrogen of rhizosphere soil in 1st, 2nd and 4th cluster fruit expanding stage, and then an average of 1.72 - 7.27% , increase in total N of rhizosphere soil in 1st, 2nd and 4th cluster fruit expanding stage. (2) RMW irrigation could significantly increase the microbial population of rhizosphere soil in the tomato growth stage. The average rhizosphere microbial population was significantly increased by about 1.64-fold in the key growth stage. (3) RMW irrigation could significantly improve the biomass and yield of tomato, and then the nitrogen in fruit, partial factor productivity from applied N and nitrogen supplying capacity. The biomass and yield were significantly increased by 8.66 and 9.38%, respectively. Furthermore, the nitrogen in fruit and partial factor productivity from applied N were significantly improved by 62.50 and 6.34%, respectively. (4) RMW irrigation could significantly improve nitrogen supplying capacity and reduce the amount of topdressing N. The nitrogen supplying capacity was significantly improved by 8.38%. The amount of topdressing N decreased by 20 - 30% under RMW irrigation.

Acknowledgements

The authors are grateful for financial support from the National Natural Science Foundation of China (51009141, 51209209, 51209208), the National 863 Plans Project of China (863 Program, 2012 AA101404), and the Special Fund for Agro-scientific Research in the Public Interest (2012 03077) for this study.

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(Manuscript received on 17 July, 2015; revised on 13 October, 2015)