Scientia Horticulturae 235 (2018) 181–188

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Tomato yield, quality and water use efficiency under different drip fertigation strategies

Hui Luo[a,b], Fusheng Li[a,b,*]

[a] College of Agriculture, Guangxi University, Nanning 530005, China
[b] Guangxi Academician Work Station of The New Technology of Water-Saving Agriculture in Karst Region, Nanning 530005, China

ARTICLE INFO

Keywords:
Alternate partial root-zone drip irrigation
Comprehensive benefit
Comprehensive quality
Ratio of basal fertilizer to topdressing
Yield

ABSTRACT

The advantage of alternate partial root-zone drip irrigation combined with ratio of basal N fertilizer to topdressing N fertilizer via drip fertigation on tomato yield, quality and water use remains unresolved. This study has investigated the influences of three drip irrigation methods, including conventional drip irrigation (CDI), alternate partial root-zone drip irrigation (ADI), and fixed partial root-zone drip irrigation (FDI), and five N treatments ($N_{0\text{-}100}$: 100% of N fertilizers as topdressing, $N_{10\text{-}90}$: 10% as basal fertilizer and 90% as topdressing, $N_{20\text{-}80}$: 20% as basal fertilizer and 80% as topdressing, $N_{30\text{-}70}$: 30% as basal fertilizer and 70% as topdressing, and $N_{40\text{-}60}$: 40% as basal fertilizer and 60% as topdressing. All treatments received the same N rate) on tomato yield, quality and water use efficiency, and then the comprehensive quality and comprehensive benefits of different treatments were respectively evaluated by principal component analysis and TOPSIS (technique for order preference by similarity to ideal solution) to obtain optimal water and N supply mode. Compared to CDI, ADI decreased tomato yield slightly, but increased water use efficiency (WUE) by 7.8%, while FDI reduced tomato yield and maintained WUE. In comparison of the five N treatments, $N_{30\text{-}70}$ had higher tomato yield and lycopene and vitamin C contents and sugar/acid ratio in fruits, but it had lower organic acid content in fruits. Among all treatments, ADI-$N_{30\text{-}70}$ had the optimal tomato comprehensive quality and comprehensive benefit. Therefore, ADI-$N_{30\text{-}70}$ was the optimal water and nitrogen supply mode for tomato production in this study.

1. Introduction

Alternate partial root-zone irrigation (APRI) or alternate partial root-zone drip irrigation (ADI) is a water-saving technique by supplying alternate wetting and drying of root-zones (Kang et al., 1997; Kang and Zhang, 2004). APRI can achieve the aim of no yield decreasing, irrigation water saving and water use efficiency (WUE) enhancing, and has been used in different crops, such as tomato, maize and cotton. Liang et al. (2013) indicated that APRI declines more water consumption than total dry mass of sticky maize, thus it increases the WUE on the basis of total dry mass. Compared to conventional irrigation, APRI has no obvious effects on tomato yield and enhances the WUE by 56%, and in comparison with deficit irrigation, APRI raises tomato yield and vitamin C (Vc) by 7–10 and 12.6%, respectively, but reduces organic acid by 5.3% (Kirda et al., 2004). ADI enhances grapevine WUE by 26.7–46.4% without the yield reduction, and improves the fruit quality significantly by comparing with conventional drip irrigation (Du et al., 2008), and ADI also has better fruit quality of cucumber along with the increases in WUE without obvious yield decreasing (Zhao et al., 2014).

Nitrogen (N) fertilizer as basal fertilizer or only topdressing at one stage in vegetable production causes uncoordinated N supply, so appropriate nitrogen management is a key measure in improving vegetable yield, quality and nitrogen use efficiency. Fertigation is a precise irrigation and fertilization method. Compared with conventional irrigation and fertilization, drip fertigation raises the tomato yield by 24.8%, and enhances soluble solid, Vc and soluble solid acid ratio by 9.6, 25.2 and 31.2%, respectively (Zang et al., 2015). And in comparison with furrow irrigation and fertilization, drip fertigation increases the tomato yield and fruit Vc by 46.9 and 61.8%, respectively (Xing et al., 2015).

Principal component analysis, as a method to reduce high dimensional data by rejecting unimportant parts, simplifying data structure and replacing most information of original high dimensional data with fewer composite indicators (Li and Chen, 2010), has been applied in evaluating the comprehensive quality (Breksa et al., 2015; Chen et al., 2015; Li et al., 2016; Wang et al., 2017). The comprehensive benefit of tomato is difficult to evaluate by single index and it should be the sum of the interaction of multiple indices, including yield, quality and water

* Corresponding author at: College of Agriculture, Guangxi University, Nanning 530005, China.
E-mail addresses: zhenz@gxu.edu.cn, lpfu6@163.com (F. Li).

https://doi.org/10.1016/j.scienta.2018.02.072
Received 10 January 2018; Received in revised form 20 February 2018; Accepted 26 February 2018
0304-4238/

Table 1
Nitrogen treatments at different growth stages of tomato. $N_{0\text{-}100}$: 100% of N fertilizer as topdressing, $N_{10\text{-}90}$: 10% as basal fertilizer and 90% as topdr Fruit shapeessing, $N_{20\text{-}80}$: 20% as basal fertilizer and 80% as topdressing, $N_{30\text{-}70}$: 30% as basal fertilizer and 70% as topdressing, and $N_{40\text{-}60}$: 40% as basal fertilizer and 60% as topdressing. Basal fertilizer was applied to the soil before the transplanting, topdressing via drip fertigation was done at the seedling, flowering, fruit-enlarging and fruit maturity stages, respectively, the same as below.

N treatment	Basal fertilizer percentage	Topdressing percentage at different growth stages							
		Seedling stage		Flowering stage		Fruit enlarging stage		Fruit maturity stage	
	Mar 24	Apr 4	Apr 6	Apr 28	Apr 30	May 13	May 15	Jun 3	Jun 5
$N_{0\text{-}100}$	0	5	5	15	15	15	15	15	15
$N_{10\text{-}90}$	10	4.5	4.5	13.5	13.5	13.5	13.5	13.5	13.5
$N_{20\text{-}80}$	20	4	4	12	12	12	12	12	12
$N_{30\text{-}70}$	30	3.5	3.5	10.5	10.5	10.5	10.5	10.5	10.5
$N_{40\text{-}60}$	40	3	3	9	9	9	9	9	9

use. Therefore, seeking a comprehensive evaluation method to determine the optimal water and fertilizer supply mode for tomato production is urgent under different fertigation strategies. Technique for order preference by similarity to ideal solution (TOPSIS) is a multi-objective decision-making method. By calculating the relative similarity between different evaluation objects and the positive and negative ideal solutions, the comprehensive benefit is obtained to make a decision for the objects (Bondor and MuresAn, 2012; Chamodrakas et al., 2009). Previous studies have evaluated comprehensive benefit of coffee and greenhouse grown tomato using TOPSIS (Liu et al., 2014, 2016a).

Though previous studies showed that ADI or optimal ratio of basal N fertilizer to topdressing N fertilizer has benefit effect on tomato yield, quality and WUE (Wang et al., 2014), the advantage of ADI combined with ratio of basal N fertilizer to topdressing N fertilizer via drip fertigation on tomato yield, quality and water use remains unclear. And how to coordinate yield, quality and water use of tomato under different drip fertigation strategies is worth further investigation. So the hypothesis of this study was that ADI integrated with appropriate ratio of basal N fertilizer to topdressing N fertilizer via drip fertigation can coordinate tomato yield, quality and water use. Therefore, tomato yield, quality and water use were investigated under three irrigation drip methods and five N treatments, and then the comprehensive quality and comprehensive benefits of different treatments were respectively evaluated by principal component analysis and TOPSIS, so as to acquire optimal water and N supply mode for tomato production.

2. Materials and methods

2.1. Experimental site and materials

Pot experiment was conducted during March to July in 2015 in a greenhouse at Guangxi University, south China. The greenhouse was in subtropical monsoon climate zone, with mean daily temperature of 21.5–26.5 °C and relative humidity of 45–55% during the experimental period. The experimental soil is latosolic red soil (Orthic Acrisol, FAO-UNESCO system). The soil texture is clay soil, with organic matter of 26.2 g kg^{-1}, available N of 45.9 mg kg^{-1}, available P of 53.2 mg kg^{-1}, available K of 177.5 mg kg^{-1}, and water content at field capacity (θ_f, mass basis) of 28.6%. Tomato (*Solanum lycopersicum* L., xidayinghong-1) was used for this experiment.

2.2. Experimental method

The experiment had three drip irrigation methods and five N treatments. The experimental plan yielded 15 treatments (i.e. 3 × 5) and each treatment was replicated four times, totally 60 pots. The 12 pots in a row were randomly arranged in the east-west direction and shifted the position of the pots every week.

Three drip irrigation methods included conventional drip irrigation (CDI, each half of the pot was simultaneously irrigated and (or) fertilized by one dripper), alternate partial root-zone drip irrigation (ADI, both halves of the pot was alternately irrigated and (or) fertilized by one dripper) and fixed partial root-zone drip irrigation (FDI, only half of the pot was fixedly irrigated and (or) fertilized by one dripper). Irrigation amount in CDI was applied according to physiological characteristics and water requirement at different growth stages of tomato (45%–55% of field capacity (θ_f) at the seedling stage, 55–75%θ_f at the flowering-fruit setting stage, and 65–85%θ_f at the fruit setting stage 65–85%θ_f) proposed by Wang et al. (2005). Irrigation amount in ADI and FDI was 80% of each watering in CDI during the growth stages of tomato.

Five N treatments included $N_{0\text{-}100}$: 100% of N fertilizers as topdressing, $N_{10\text{-}90}$: 10% as basal fertilizer and 90% as topdressing, $N_{20\text{-}80}$: 20% as basal fertilizer and 80% as topdressing, $N_{30\text{-}70}$: 30% as basal fertilizer and 70% as topdressing, and $N_{40\text{-}60}$: 40% as basal fertilizer and 60% as topdressing. All treatments were applied with N, P_2O_5, K_2O and Ca of 0.2, 0.1, 0.3 and 0.1 g per kg soil. N fertilizer was supplied with urea (N 46%), P fertilizer with KH_2PO_4 (P_2O_5 52%), K fertilizer with KH_2PO_4 (K_2O 34%) and K_2SO_4 (K_2O 54%), and Ca fertilizer with $CaCO_3$ (Ca 40%), and all fertilizers were analytical reagents. All P, K and Ca fertilizers and part of N fertilizers were mixed with the soils before the transplanting, and the rest of N fertilizers as topdressing via drip fertigation were performed at the seedling, flowering, fruit-enlarging and fruit maturity stages, respectively. Nitrogen treatments at different growth stages of tomato were shown in Table 1.

The experiment was carried out in plastic bucket (23.5 cm in depth and 30 cm in diameter). The inside of the pots was evenly separated into two containers with plastic sheets sealed in the middle to prevent water exchange. V-shaped notches were made in the center of plastic sheets for the transplanting of tomato seedling. Each pot was filled with 18 kg and each part contained 9 kg soil.

Soil water contents for all treatments were maintained at 80%θ_f before the transplanting. One uniformity tomato seedling for pots was transplanted on March 24, 2015, and controlled water during April 10 to June 27. All CDI treatments were weighed in the afternoon every day or two days according to the climate condition and plant growth status. Tomato water consumption (*ET*) was calculated using water balance method, and irrigation amount was recorded.

$$ET = I - \Delta S \quad (1)$$

where *I* is the total amount of irrigation water during the growth stage, and ΔS is the difference between the amount of soil water storage at the harvesting and the beginning. Moreover, there were no leakage and runoff in this experiment.

When nitrogen fertilizer was not applied, the needed amount of irrigation water was done via drip irrigation imitation system hanged at the height of 1.8 m above the soil surface (Fig. 1), with flow rate of 0.6 L h^{-1} for each dripper. When nitrogen fertilizer was applied, urea was firstly dissolved in irrigation water and then fertilized via drip irrigation system, as indicated above. The experiment ended on July 15.