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Effect of soil matric potential on tomato yield and water use under drip irrigation condition

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ABSTRACT

Field experiment was carried out to investigate the effect of soil matric potential (SMP) on tomato yield, evapotranspiration (ET), water use efficiency (WUE) and irrigation water use efficiency (IWUE) under drip irrigation condition in North China Plain. The experiment included five treatments, which controlled SMP at 0.2 m depth immediately under drip emitter higher than −10 (S1), −20 (S2), −30 (S3), −40 (S4) and −50 kPa (S5), respectively, after tomato plant establishment. The results showed that different SMP affected irrigation amount and tomato ET. Irrigation amount decreased from 185 mm (S1) to 83.6 mm (S5) in 2004, and from 165 mm (S1) to 109 mm (S5) in 2005, respectively. The ET decreased from 270 mm (S1) to 202 mm (S5) in both years. However, it was found that SMP did not affect the tomato yield significantly, for the range of SMP investigated. Both WUE and IWUE increased as SMP decreased. The maximum WUE (253 and 217 kg/ha mm) and IWUE (620 and 406 kg/ha mm) were for S5 in 2 years, whereas the minimum WUE (178 and 155 kg/ha mm) and IWUE 261 and 259 kg/ha mm) were for S1 in 2004 and 2005. Based on the above results, therefore, it is recommended that if the tomatoes are well irrigated (SMP is higher than −20 kPa) during establishment, controlling SMP higher than −50 kPa at 0.2 m depth immediately under drip emitter can be used as an indicator for drip irrigation scheduling during following period of tomato growth in North China Plain.

1. Introduction

Tomato is one of main vegetables planted in North China Plain. Its dominant irrigation methods are furrow and basin irrigation, which not only causes large percolation losses but also restrains the increase in production due to soil frequent drought at irrigation intervals and poor irrigation management. Efficient use of water is highly critical to sustained agricultural production, when competition for water between agricultural, industrial and urban consumers increases continually in this region.

Drip irrigation can distribute water uniformly, precisely control water amount, increase plant yields, reduce evapotranspiration (ET) and deep percolation, and decrease dangers of soil degradation and salinity (Batchelor et al., 1996; Ayars et al., 1999; Karlberg and Frits, 2004). The trend in recent years has been towards conversion of surface irrigation to drip irrigation to improve plant quality and yield. While, in present, some farmers are not sure when and how much water they should irrigate under drip irrigation condition, and they tend to confirm irrigation timing and amount according to conventional experience, and then, induce new water loss

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under new technology. So, an easy-operation irrigation scheduling method is very stringent for tomato drip irrigation condition.

Some researchers (Jordi et al., 1995; Erika et al., 1999; Bob, 2004) used tension meter as an index of soil water content to schedule irrigation under drip irrigation. Using this method, irrigation is based on measurement of actual soil water condition; rainfall and evaporation need not be measured; minimized drainage losses through the choice of appropriate target potentials; tensiometer measurements are rapid, cheap and easy to make (Hodnett et al., 1990). So, it is very adaptive for farmers to use. Shock et al. (2000) found a soil-matric potential of approximately −20 kPa bar at 0.2 m soil depth might be the most economical level to maintain an onion crop. Kang and Wan (2005) found the highest radish WUE value was achieved with −35 kPa soil water potential at 0.2 m depth; Kang et al. (2004) observed the maximum potato yields and the highest WUE values were achieved with a soil matric potential (SMP) threshold of −25 kPa in North China.

The objectives of this study are: (1) to investigate the effect of different target SMPs on tomato ET, yield, water use efficiency (WUE) and irrigation water use efficiency (IWUE) in North China Plain; (2) to find an appreciate controlling index of SMP for tomato drip irrigation scheduling in North China Plain.

2. Materials and methods

2.1. Experimental sites

The experiment was conducted at Tongzhou Farmland Water Cycle and Modern Water-saving Irrigation Experimental Station, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. The experimental station is located in Yongledian town (latitude: 39°36′ N; longitude: 116°48′ E; 20 m above sea level), Tongzhou District, Beijing. Average annual temperature is about 11.2 °C, and average annual precipitation is about 620 mm, which mainly concentrated from June to September. It is a typical monsoon climatic in this region. The dominant soil is silt loam with an average bulk density of 1.38 g/cm^3. Field soil water capacity is about 33.2%. The soluble mineral content of the area's groundwater is less than 0.9 g/l. The top 0.2 m soil layer is uniform and contained total nitrogen 0.119%, total phosphate 0.175%, alkali-hydrolyzable nitrogen 78.9 ppm, available phosphate 7.05 ppm, available potassium 84.5 ppm and organic matter 1.51%, respectively.

2.2. Experimental design

Five treatments were designed for this study, with SMP adjacent to the tensiometer ceramic cub at 0.2 m immediately under emitter higher than −10 kPa (S1), −20 kPa (S2), −30 kPa (S3), −40 kPa (S4) and −50 kPa (S5), respectively, the corresponding dial reading was −14.5, −24.5, −34.5, −44.5 and −54.5 kPa, after tomato plant establishment. Three replications were set for each treatment. All experimental plots were following a complete randomized design.

Each treatment plot was equipped with an independent gravity type drip irrigation system. The irrigation system consisted of a plastic barrel with 93.7 l used as water source, a ball valve installed under the bottom of the barrel to control irrigation and an outlet 1.2 m above ground surface. Drip tape with 0.2 m dripper spacing, the operating press ranged from 1.7 to 1.2 m and the emitter discharge rate ranged from 1.65 to 1.39 l/h. Dial vacuum tension meter was installed 0.2 m immediately under the drip tape in the middle raised bed of each plot in the second replication. The relationship between soil water content and SMP could be expressed as Eq. (1) based on actual measurement data.

$$\theta = 0.279e^{-0.0125\psi} \quad (1)$$

where θ is soil volumetric water content and ψ is soil matric potential.

When the water potential was below the target SMP, the irrigation was begun.

2.3. Agronomic practices

Size of each experimental plot was measuring 4.4 m × 4.2 m and each plot contained three raised beds. The spacing and length of raised beds were 1.4 and 4.4 m, and the width and height of the raised bed were 0.6 and 0.15 m, respectively. Tomatoes were double-row planted on each bed with row spacing of 0.3 m and interplant spacing of 0.4 m in one row.

Tomato (cv. *Lycopersicon esculentum L-402*) was transplanted into the field on April 12, 2004 and April 19, 2005, respectively. Black waterproof PE film with 1.2 m width and 0.008 mm thickness was laid over the raised bed after transplantation to prevent soil evaporation and soil salt accumulation in the soil surface. When the rainfall was less than 5 mm, it did not affect the soil water content under the film. Irrigation treatments were initiated on May 16 (36 days after transplant, DAT) in 2004 and on May 19 (31 days after transplant) in 2005, respectively. In this experiment region, according to our practical experiences, the water applied by drip irrigation about 5.1 mm can establish a favorable soil moisture condition in the root zone. So the irrigation amount each time was adopted as 5.1 mm and was equivalent for different treatments. Only the first four inflorescences were reserved before top pruning. Other cultivation practices (cut branch stem, pest and disease control) were exactly the same for all treatments. Experiment was completed on July 25, 2004 and July 26, 2005, respectively.

Before the soil was plowed, the fertilizer of ammonium dihydrogen phosphate was applied with application of 600 kg/ha. Urea fertilizer was applied with irrigation when treatment started and the total amount was 270 kg/ha.

2.4. Observation and equipments

2.4.1. SMP

Dial vacuum tension meter data was recorded four times per day: 7:30, 10:30, 15:00 and 18:00 h, respectively. When the data was below the target SMP, the irrigation was begun.

2.4.2. Tomato evapotranspiration and yield

Weighing lysimeter was installed in the center raised bed of each plot in the first replication to measure evapotranspiration. Each lysimeter consisted of an inner tank for crop