THE EFFECT OF DRIPPER DISCHARGE ON THE WATER AND SALT MOVEMENT IN WETTED SOLUM UNDER INDIRECT SUBSURFACE DRIP IRRIGATION

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滴头流量对间接地下滴灌下湿润体内土壤水盐运移的影响

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ABSTRACT

Jujube fruit, also called Chinese jujube (Zizyphus jujuba Mill.), is the main economic crop in Southern XinJiang province of China. However, due to the lack of suitable jujube irrigation technology, it not only wastes water resources, but also increases soil salinization. Indirect subsurface drip irrigation is a kind of high efficient water-saving irrigation technology, suitable for fruit tree irrigation. Dripper discharge is an important parameter in irrigation design. In this paper, an indoor experiment was adopted, and the effect of different dripper discharges on the distribution rules of water and salt were analysed in wetted body under indirect subsurface drip irrigation, and appropriate dripper discharges was selected to adjust the growth environment of crop root system. This study aims to provide theoretical guidance on using the indirect subsurface drip irrigation technology for jujubes in arid area.

摘要

特色林果—红枣是中国新疆南疆的主要经济作物，但由于缺乏适宜红枣的灌溉技术，不合理的灌溉技术不仅浪费水资源，而且加剧了土壤次生盐渍化。间接地下滴灌是一种高效节水的灌溉技术，适宜于果树灌溉。其滴头流量是灌溉设计中的重要参数，为研究滴头流量对间接地下滴灌下土壤水盐运移的规律，本文通过室内试验研究，分析不同滴头流量对湿润体特征及湿润体内水盐分布变化的影响规律，选择适宜的灌溉流量，以调节作物根系的生长环境。以期为间接地下滴灌技术在干旱区枣树中应用提供理论指导。

INTRODUCTION

Drought and soil salinization are the main factors that hinder the agricultural development of arid areas in southern XinJiang province of China *(Yang Yu et al. 2016; Xiaodong Li et al., 2016; Xiaoming Li et al., 2011)*. In recent years, jujube fruit called Chinese jujube (*Zizyphus jujuba Mill*.) with a high economic value has been grown in large areas, enabled rapid development and promoted the local economy and ecological environment *(Xiaoou Li et al., 2014; Ming Hong , et al., 2014)*. However, local irrigation technology not only wastes water resources but also causes serious soil salinization because of the lack of a suitable fruit irrigation technology. A suitable water-saving and salt-inhibiting irrigation technology for jujubes in arid areas should be identified.

Indirect subsurface drip irrigation is an efficient water-saving irrigation technology. This technology mainly consists of a surface drip irrigation system and a water-conducting device and it is characterized by the effect of using a surface-dripping method to achieve subsurface drip irrigation. In the process of irrigating fruit trees, a water-conducting device can be used to supply water to the root zone of fruit trees and to reduce surface evaporation and interception. This device is suitable for irrigating fruit trees. Experimental results show that compared to surface drip irrigation, indirect subsurface drip irrigation can better reduce evaporation among trees and improve water utilization efficiency *(Meshkat et al., 1998)*.

Similar to surface drip irrigation, indirect subsurface drip irrigation is a type of partial root-zone irrigation that has a limited soil-wetting area. The size and distribution of the soil-wetting area can affect crop yield.

Dripper discharge is one of the most important elements in local irrigation design *(Mingsi Li et al., 2006)*, with its size affecting not only the shape and moisture distribution of wetted body but also the salt leaching and salt distribution in wetted body *(Shu Wang et al., 2005; Chunqin Liu et al., 2007).* Accordingly, laboratory tests were adopted and the effect of different dripper discharges on the water and salt distribution were evaluated in wetted body under the condition of using indirect subsurface drip irrigation in this study.

This study aimed to provide theoretical guidance on using the indirect subsurface drip irrigation technology for jujubes in arid area.

MATERIAL AND METHODS

Water-conducting device components

The test system was composed of three parts *(Sanmin Sun, et al., 2015)*: a soil-box, a water supply device, and a water-conducting device. The soil-box was a 500 mm (L) × 500 mm (W) × 500 mm (H) cube made of 8 mm-thick plexiglass. The water supply device was composed of a water bottle and guide pipe with flow control valve. The water-conducting device was composed of water permeable boundary and impermeable boundary, impermeable boundary for PVC tube. In order to observe the water level in the PVC tube, the PVC tube was symmetrically divided along the tube diameter, placed into half of the inside wall of the soil box at a depth of 20 cm, and the testing soil was put into the box. Gravels screened in 2–5 mm were filled into the bottom of the PVC tube, which formed permeable boundary 5 cm high.

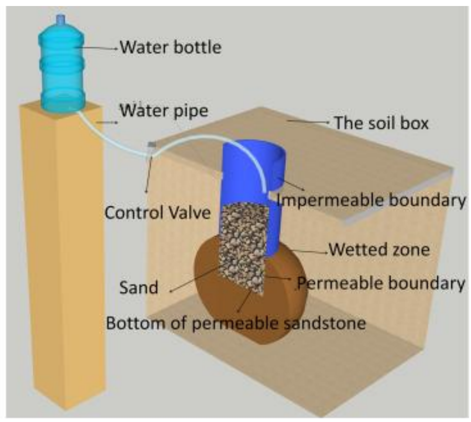


Fig. 1- Diagram of the components of indirect subsurface drip irrigation

Method and materials

The sample soils were selected from 0-50cm sandy loam soil of Tarim Irrigation Area in the southern Xinjiang province of China. The soil samples were air-dried and layered in the soil-box according to the predetermined soil bulk density of 1.40g/cm^3, after the screening of the sieve with the pore size of 1 mm.

After 24 hours of irrigation, soil samples were collected from different profiles at 10, 20, and 30 cm (Profiles A, B, and C, respectively) away from the water-conducting device horizontally. The sampling depth of each profile was 40 cm, and every 5 cm depth was determined as one soil layer. Each treatment has 24 soil samples, and a total of 72 soil samples were collected. Soil moisture content was measured by the oven-drying method. After mixing 5 and 25 g of dried soil and water, respectively, and filtering the solution with filter paper, the electrical conductivity of the leach solution was measured with the DDSJ-308A electrical conductivity meter (INESA).

Testing program: The test-designed diameter for the water-conducting device and the height for the permeable stratum were fixed at 90 mm and 50 mm, respectively. Water flow was fixed at 1.5, 2, and 4 L/h, respectively. The irrigation amount was fixed at 4 L.

The purpose of the experiment was to study the distribution of water and salt under different water flow rates and the relationship between the distribution of water and salt in the wet body.

Data processing

The conversion between soil salinity content and soil conductivity was calculated according to the references *(Yu Zhang et al., 2011; Qiaoxia An et al., 2016)*.

RESULTS

Effect of dripper discharge on soil moisture distribution

Under the subsurface drip irrigation condition, the capillary force of soil is the main force that affects water movement in soil. The force is equal in all directions. When the soil is dry, capillary force is greater than gravity. Thus, water flows evenly in all directions, including the upward direction. When the soil becomes moist, soil pore reaches saturation, capillary force becomes weak, gravity exceeds capillary force and water flow downward *(Zhenghua Wang et al., 2006)*. Along with the increasing irrigation time, a saturated area will be formed around the dripper. The saturated area has high water matric potential and gravitational potential. However, the soil outside the saturated area has low matric potential. Thus, water spreads in all directions from the dripper. When the distance between soil and dripper increases, soil water content decreases. Therefore, the area close to dripper has the highest water content in wetted solum. However, the water content decreases gradually in all directions. In this experiment, the water-conducting device was buried 20 cm deep into the ground. After irrigation, the soil layer at a depth of 20–30 cm had the highest water content. When the distance between soil and water outlet increased, the water content of each vertical soil layer gradually decreased in the upward and downward directions. In the horizontal direction, soil water content gradually decreased when the distance between soil and water outlet increased (Figure 2).

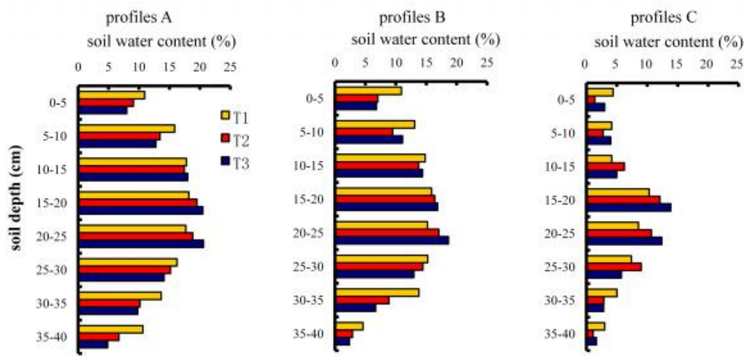


Fig. 2- Effect of dripper discharge on soil water distribution

Figure 2 shows that the dripper discharge had a significant effect on the distribution of water content in wetted solum. When the other conditions were the same, the soil water content of three soil profiles at a depth of 15–30 cm near the water outlet gradually increased with dripper discharge increase. By contrast, the soil water content of soil layers at depths of 0–15 cm and 30–40 cm gradually decreased. Accordingly, a large dripper discharge could facilitate water movement in the horizontal direction, whereas a small dripper discharge could facilitate water movement in the vertical direction.

Effect of dripper discharge on the soil salt distribution in the vertical profile

Under the indirect subsurface drip irrigation, water moves upward and downward in the vertical direction, and the water content of soil near the water outlet is large. Therefore, the water potential gradient of soil is large. Water moves rapidly, so that the soil salinity is effectively diminished. When the distance between soil and water outlet increases, soil water content decreases, soil matric potential decreases, soil suction capacity increases, salt content gradually decreases with water movement and salt content in soil accumulates at the upper and lower edges. In this experiment, a water-conducting device was buried 20 cm deep into the soil, so that the salt content of soil layer at 15–30 cm deep near the water outlet reached its minimum (Fig. 3).

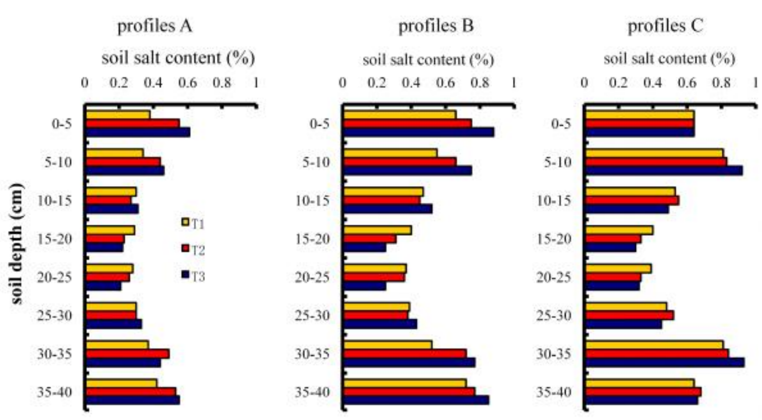


Fig. 3 - Effect of dripper discharge on the soil salt distribution in the vertical profiles

The salt contents of other soil layers in profiles A and B basically increased when the distance between soil layer and water outlet increased. The salt content of other soil layers in profiles C initially increased and then decreased when the distance between soil layer and water outlet increased. The salt content of soil layer at 5–10 cm and 30–35 cm was the highest, which might be caused by the decreased vertical wetting distance of profiles C. The 5–10 cm and 30–35 cm soil layers were at the edge of the wetting front. Salt accumulated in these soil layers, resulting in the highest salt content.

Effect of dripper discharge on the soil salt distribution in the horizontal section

The variation characteristics of salt content in each horizontal soil layer are shown in Figure 4. In the 5–35 cm soil layer, the salt content of all soil layers in profile A was the lowest. When the horizontal distance between soil layer and water outlet increased, salt spreads rapidly with water and gradually accumulated at each soil layer. Consequently, the salt content of each soil layer basically showed an increasing trend from profile A to profile B to profile C. By contrast, the 0–5 cm and 35–40 cm soil layers in profile B had the highest salt content. The soil salt content of each section initially increased and then decreased. This trend might be related to the relative position of different sections and wetting front edges. Profile B was only at the edge of the wetting front, where salt accumulated. Profile C was outside the wetting front and its salt content was substantially consistent with the base salt content of soil.

Dripper discharge had different salt-leaching effects on different sections. Figure 4 shows that, at the 10–30 cm soil layer, a large dripper discharge leads to a low soil salt content. The salt content of the 0–10 cm and 30–40 cm soil layers decreased when dripper discharge increased. This result indicated that a large dripper discharge could promote water and salt leaching, whereas a small dripper discharge could promote salt leaching in the vertical direction *(Tao Li et al., 2010)*.

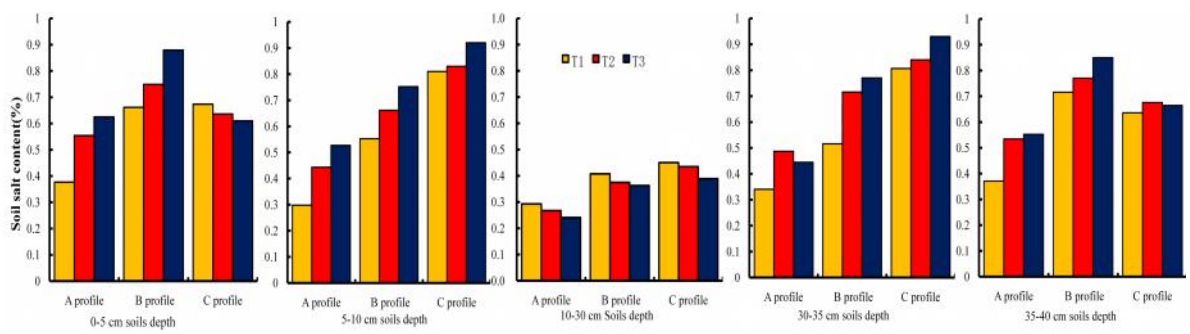
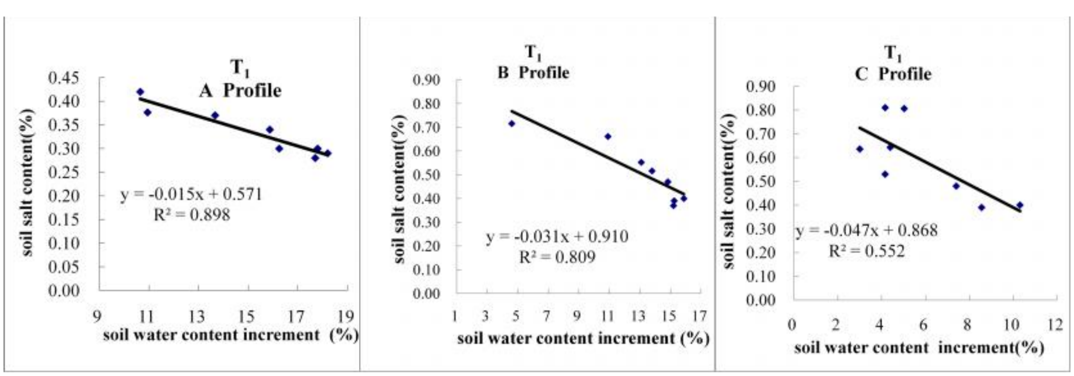


Fig. 4 - Effect of dripper discharge on the soil salt distribution in the horizontal section

Relationship between salt distribution and water content increment in wetted solum

The sampled soil was homogeneous air-dried loam soil and had a consistent salt content. Soil water content increases after irrigation, the soil water content increment is equal to the difference of the soil water content between after irrigation and before irrigation, the soil salt content at a certain area could represent the effect of water content on soil salt leaching, i.e., a low soil salt content could indicate a good desalination effect. In the experiment, the soil water content increment and the soil salt content of each section were fitted (Fig. 5).



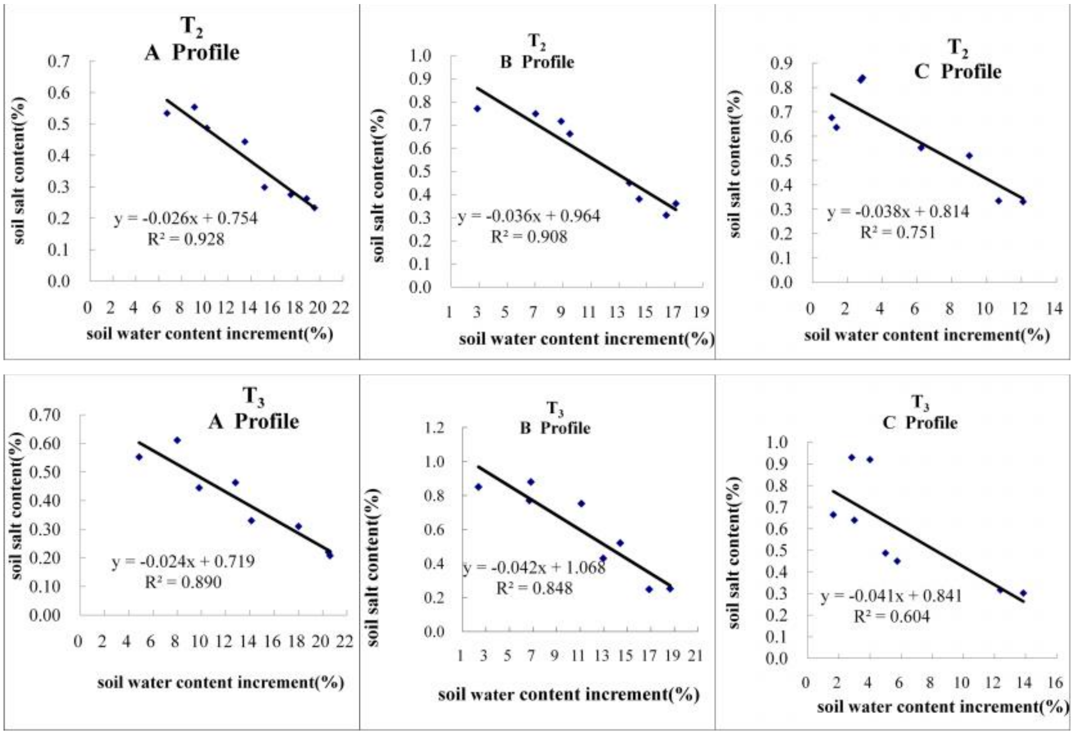


Fig. 5 - Relationship between salt distribution and water content increment in wetted solum

Figure 5 shows that, after three treatments, the soil moisture increment and the soil salt content in profile A and B had a good correlation. A high soil moisture increment had a good soil salt-leaching effect and could decrease soil salt content. The soil moisture increment and the soil salt content in profile C had a poor correlation. This result might be due to the fact that profile C was near the edge of wetted solum. Different sampling points and wetting fronts also had different relative positions (several points were not in the wetting front, several points were on the wetting front, and several points were in the wetting front). The fitting result indicated that, in wetted solum, a high soil moisture increment could have an evident salt-leaching effect.

CONCLUSIONS

(1) Under the experimental conditions, the 20–30 cm soil layer had the highest soil water content. As the distance between soil layer and water outlet increased, the soil water content of vertical soil layers gradually decreased in the upward and downward directions. In the horizontal direction, the soil water content gradually decreased when the distance between soil layer and water outlet increased. In wetted solum, the soil that was near the water outlet had a low soil salt content. When the distance between soil layer and water outlet increased, soil salt content increased.

(2) Dripper discharge had a significant effect on the distribution of water and salt movement in wetted solum. A large dripper discharge could promote water movement in the horizontal direction, whereas a small dripper discharge could facilitate water movement in the vertical direction. The corresponding large dripper discharge could promote salt leaching in the horizontal direction, whereas small dripper discharge could promote salt leaching in the vertical direction.

(3) In wetted solum, when the soil moisture increment in the same profile was high, then salt leaching would become evident.

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