Sandy Loam Soil Wetting Patterns of Drip Irrigation: a Comparison of Point and Line Sources

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Abstract

Two drip infiltration conditions were compared (point source and line source) in a sandy loam soil field trial designed to study on dynamic of saturated zone radius, radial and vertical wetted distance. In total, six single-dripper treatments and four multi-dripper treatments which uniformly spaced 28 cm under linear arrangement were conducted. Different application rates were obtained by changing the height differential between the Mariotte tube and the outlet. The width of the surface wetting pattern and vertical wetted depth was measured by tape measure and soil drill, respectively. The results showed that there was positive linear correlation between saturated zone radius and application rate. The relationship between both the radial and vertical wetted distance and drip irrigation time can be described by a power function, respectively. The line source infiltration condition was formed after 1 hour irrigation time under multi-dripper irrigation, after that, the vertical wetted depth was significantly greater than point source (single-dripper).

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Keywords: radial wetted distance; vertical wetted depth; point source; line source; drip irrigation

1 Introduction

Drip irrigation has gained widespread popularity since Xinjiang Construction Group application in the 1990s in China [1]. At the same time, there are lots of problems faced when using drip irrigation. One of the most challenging issues is how to choose emitter flow rate, dripper’s space corresponding to water requirement of crop. To solve above problems, it is necessary to study the wetted pattern of drip irrigation, especially in line source infiltration.

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Mathematical models [2-4], laboratory experiments [5-7] to describe water transport in soil have been available for a long time. Although they are easy to implement, they deal mainly with design considerations of the point source. In fact, infiltration pattern are line source in filed drip irrigating application, and there are a lot of difference between laboratory soil and field soil. So it is very important to research and analysis the characteristics of soil water moving along the vertical and lateral direction under multi-dripper irrigation in field. Therefore, the present field experiments were designed to study the soil water movement from point source and line source. The objectives of this study were to measure differences in the extent of wetting patterns between point source and line source.

2 Materials and methods

Field experiments were conducted at Zhangye Irrigation Experiment Station (ZIES), Zhangye Water Conservancy Bureau in August 2010. ZIES is located in Zhangye City, Gansu Province (Latitude: 38°56′N; Longitude: 100°26′E; 1482.7m above sea level). Average annual precipitation is about 125mm.

The uniform soil profiles field was choused to study the dynamic of radial and vertical wetted distance under single-dripper and multi-dripper irrigation. The field capacity and saturated soil water content for the soil were 0.23 g/g and 0.33 cm³/cm³, respectively. Particle size analysis yielded an average value of 44% sand, 36% silt, and 20% clay, which belonged to sandy loam soil. Its average density was 1.45 g/cm³, and organic matter content in the tillage layer was about 1-1.2%. Soil water retention curves were summarized in Fig. 1. Prior to installation of the drip equipment, the field was deep-cultivated (0.3 m) in two directions. Following installation, a further passes were performed with a vertically tined rotary cultivator to break up some of the larger clods.

Two variables affecting soil water movement, including application rate, and volume applied were considered. In total, six single-dripper treatments were conducted with apparent application rates of 0.5, 1.2, 1.5, 1.7, 1.9, 3.9 L/h. Four additional treatments were included. These were multi-dripper treatments which uniformly spaced 28 cm under linear arrangement with a flow rate of 0.8, 1.1, 1.5, 1.7 L/h. Different application rates were obtained by changing the height differential between the Mariotte tube and the outlet. The width of the surface wetting pattern was measured by tape measure. At the same time, vertical wetted depth was determined by soil drill.

3 Results and analysis

3.1 The dynamic of saturated zone on the soil surface

![Fig.1 Soil water retention curves for 0 – 80 cm depth](#)

\[ y = 758.89e^{-27.133x} \]

\[ R^2 = 0.85 \]
The saturated zone on the soil surface expands rapidly in early drop time (within 1 hour). As time goes on, expanding speed gradually slows down, and saturated radius approaches a constant value after about 3 hour (Fig. 2). The emitter flow rate plays important role in radius of the saturated zone on the soil surface. The saturated zone radius with the dripper flow rate of 3.9L/h is the largest, and the greater the application rate, the faster the constant surface-saturated wetted radius is reached, namely there is positive linear correlation between both.

The ultimate radius of the saturated zone on the surface can be defined Rs, so the radius of the saturated zone on the surface (Rs, cm) as a function of application rate (q, L/h) is described in Fig. 3, and be described as: \( R_s = 4.21q + 8.35 \) (n=8, \( R^2 = 0.83 \)).

![Fig.2 The relationship between saturated wetted radius on the surface and time for different apparent application rates](image)

![Fig.3 The relationship between (Rs) and (q)](image)

### 3.2 The dynamic of wetted distance from point source

#### 3.2.1 The dynamic of surface wetted radius

The surface wetted radius as a function of time for selected application rates is described as Fig.4. Results shows that the higher application rate produces larger the surface wetted radius when the drip irrigation times are same. Surface wetted radius rapidly increases in 0~1 hour, after that increases slowly. The relationship between wetted radius and drip irrigation time can be described by a power function: \( R_h = a t^m \) (“a” is coefficient, “m” is index). The parameters for radial front measurements are summarized in Tables 1.

![Fig.4 Radial wetted distance as a function of time for different apparent application rates](image)

<table>
<thead>
<tr>
<th>q(L/h)</th>
<th>a</th>
<th>m</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>12.90</td>
<td>0.41</td>
<td>0.93</td>
</tr>
<tr>
<td>1.20</td>
<td>14.79</td>
<td>0.39</td>
<td>0.96</td>
</tr>
<tr>
<td>1.50</td>
<td>16.33</td>
<td>0.37</td>
<td>0.84</td>
</tr>
<tr>
<td>1.70</td>
<td>15.80</td>
<td>0.33</td>
<td>0.84</td>
</tr>
<tr>
<td>1.90</td>
<td>17.27</td>
<td>0.38</td>
<td>0.94</td>
</tr>
<tr>
<td>3.90</td>
<td>27.11</td>
<td>0.29</td>
<td>0.82</td>
</tr>
</tbody>
</table>

The index “b” of varying application rates approximates a same value, while coefficient “a” increase along with the emitter flow rate increase except for the emitter of q=1.70L/h (Table 1). This suggests that
the surface wetted radius is controlled by application rate and time. Thus, a correlative analysis is applied to surface wetted radius \( R_h, \text{cm} \) and application rate as well as applied time \( t, \text{h} \). The water volume applied \( L \) is the product of flow \( L/\text{h} \) and time \( h \). The relationship between radial distance \( R_h, \text{cm} \) and water volume applied \( qt, \text{L} \) can be described as Fig. 5 shows, yielding: \( R_h=14.69(qt)^{0.35} \) \( (n=60, R^2=0.87) \).

3.2.2 The dynamic of vertical depth

Fig. 6 illustrates vertical wetted depth as a function of time for selected application rates under point source infiltration. There is no difference of the vertical wetted depth from beginning to 0.1 hour. After that, the vertical wetted depth begins to appear difference, and high emitter flow corresponds to large vertical wetted depth. The vertical wetted depth appears a growing tendency along with the increase of irrigation time. Similarly, the relationship between vertical wetted depth and drip irrigation time can be described by a power function: \( R_v=bt^m \). Parameters for estimation of wetted distance in vertical direction are summarized in Table 2.

The change of index “m” along with the dripper flow rate \( q \) are not obviously, while the coefficient “b” shows a growing tendency totally with dripper flow rate increasing (Table 2). This shows that vertical wetted depth relates to the time and application rate. The relationship between vertical wetted depth \( R_v, \text{cm} \) and water volume applied \( qt, \text{L} \) can be described as Fig. 7 shows, resulting in: \( R_v=7.9(qt)^{0.56} \) \( (n=56, R^2=0.85) \).

3.3 The dynamic of wetted distance under conditions of multi-dripper irrigation
3.3.1 The dynamic of surface wetted radius

The dynamic of surface wetted radius under multi-dripper (evenly space) can be described as Fig.8 shows. All treatment’s radial distances increase rapidly from beginning to 1 hour, after that the radial distance increase slowly.

3.3.2 The dynamic of vertical depth

The dynamic of vertical wetted depth under multi-dripper can be described as Fig.9 shows. The vertical wetted depth are approximately 15~17 cm for 0.8, 1.1, 1.5, and 1.7 L/h rates at the beginning of irrigation to 1 hour. After that, the differences of all treatment’s vertical depth gradually widen, and an increasing application rate results in an increase in the wetted depth (Fig.9). Evidence to support this is: the sum of the radial distance of adjacent drippers is gradually equal to or greater than the dripper’s lateral spacing of 28cm at the time of 1 hour after irrigation beginning (Fig.8). The point source infiltration pattern transforms into line source infiltration at this moment, it makes the amount of infiltrating water in vertical direction increase rapidly to offset the tendency of infiltrating water in radial direction decrease as infiltration diameter lengthening.

3.4 The comparison of wetted distance between single-dripper and multi-dripper condition

3.4.1 The comparison of radial wetted distance

The difference of radial wetted distance between single-emitter and multi-emitter is small when the flow rate is 1.7L/h in 0~4 hours (Fig.10). After that, the radial wetted distance in multi-dripper condition begins to be gradually greater than the single-emitter’s.
3.4.2 The comparison of vertical wetted depth

There is no obvious difference of the vertical wetted depth between multi-dripper irrigation treatment and the single-dripper treatment when irrigation time less than 1 hour (Fig. 11). After that, the vertical wetted depth in multi-dripper condition is gradually greater than the single-dripper’s. Because multi-dripper treatment which evenly spaced 28cm under linear arrangement already belongs to line source infiltration condition, the amount of infiltrating water in vertical direction is obviously greater than the point source’s.

4. Conclusion

The effects of application rate and applied volume on the shape of the wetted soil zone are observed. Observations of water movements in point source reveals that the surface saturated water radius increases with the application rate. For sandy loam soil, the increase in the surface saturated radius with the application rate can be represented by a linear function. Both the surface wetted radius and the vertical wetted depth increased with time and application rate. Results shows that the surface wetted radius and the vertical wetted depth are proportional to the water volume applied, and the relationship can be described a power function.

The results demonstrates that there is little difference of horizontal wetted distance between single-dripper and multi-dripper from the beginning of irrigation to 4 hour, but the difference is obviously in the wetted depth after 1 hour. This may be due to the point source infiltration pattern transforms into line source infiltration at that moment, and it makes the amount of infiltrating water in vertical direction increase rapidly to offset the tendency of infiltrating water in radial direction decrease as infiltration diameter lengthening. The results obtained from this study will be useful for the design, operation, and management of drip irrigation system.

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References