THE EFFECT OF SUBSURFACE DRIP IRRIGATION SYSTEM ON VARIATION OF SOIL MOISTURE

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ABSTRACT

In Turkey, is limited water resources, Surface irrigation methods are used in about 85% of the irrigated area. In the irrigation operation, the rotation method is applied widely and therefore the irrigation interval cannot be reduced to 7 days. For this reason, too much irrigation water is applied in soil by the irrigation system. In order to reduce the water losses from irrigation systems, applications of subsurface drip irrigation are being investigated in different plants and different region in the country. In those researches, the moisture variation of the soil profile is measured every 10 cm by means of drill drop moisture sensors and monitored on an hourly basis. In this study, the situation before irrigation, during irrigation and after irrigation will evaluate the variation of soil moisture in the plant root region. By means of this assessment, how to approach the subsurface drip irrigation method will be determined for different amounts of irrigation water and terms of irrigation time planning.

Key Word: Subsurface drip irrigation, Irrigation depth, Deficit irrigation, Soil moisture monitoring.

Introduction

Increasing the water supply in Turkey is a big problem. Policy to achieve water security and food security is to increase the water use efficiency and water productivity producing more with less water in all water sectorial uses particularly the agriculture sector receiving nearly 74% of the available water resources. Major efforts are directed toward agriculture through increasing crop water productivity, reducing water losses and raising the water use efficiency. Technically, several approaches are now implemented for better water saving in the irrigated agriculture among them the introduction of the new irrigation techniques such as surface and subsurface drip irrigation, sprinkler (classical, pivot and linear systems, etc.) irrigation.

Subsurface drip irrigation (SDI) is the most advanced method of irrigation, which enables the application of the small amounts of water to the soil through the drippers placed below the soil surface with discharge rates generally in the same range as surface drip irrigation. SDI offers many advantages over the surface drip irrigation such as reduction in evaporation and deep percolation losses and elimination of surface runoff (Camp 1998). Water infiltration in the SDI takes place in the region directly around the dripper, which is small compared with the total soil volume of an irrigated field. A subsurface dripper usually forms a small cavity around it into which water can freely flow (Shani and Or 1995). Uptake of water by plant roots causes soil drying and subsequently increased soil water tension.
Selected drippers discharge should not exceed the root uptake rate (Clothier and Green 1994, 1997; Lazarovitch 2001; Badr and Abuarab, 2013).

Micro-irrigation offers opportunities to reduce deep percolation losses to a minimum. Phene et al. (1993) identified subsurface drip irrigation as the best management practice for controlling drainage outflow and reducing groundwater contamination. Subsurface drip irrigation (SDI) systems are very popular as a result of the development of plastic micro-irrigation technology in the last century. Nowadays, SDI is used to a great extent to irrigate field crops, vegetables and fruit (Camp, 1998). In general, the advantages of SDI systems are improved efficiency of nutrient uptake, less water loss from the soil surface due to surface evaporation, less weed germination and growth. Moreover, SDI systems can implement the application of fertilizers in the solution. Usually, SDI water use savings range from 0 to 50% when compared with traditional irrigation systems (Camp, 1998; Diamantopoulos and Elmaloglou, 2012).

Design and management of SDI systems require an understanding of the wetted zone pattern around the buried emitter. The soil moisture movement pattern under the drippers plays a large role in deciding the depth of lateral placement. The wetting pattern can be obtained either by field experiments or by simulation. Soil wetting patterns under subsurface irrigation have been simulated by Cote et al. (2003), Skaggs et al. (2004), Gardenas et al. (2005) and Patel and Rajput (2008) using the Hydrus 2D model (Šimůnek et al., 1999). In addition, since the evaporation through the soil will be eliminated or reduced by the subsurface drip irrigation, water will be saved as the whole water will be used for the plant need. As the irrigation water is applied directly to the root system of the plant with the underwater drip irrigation system, deep percolation will not be allowed. In addition, continuous cohesion in the soil will be ensured through pores as the water will tend to climb upwards with continuous cohesion in the soil. Thus, the most suitable moist and airy root zone will be provided for plant development (Ayars et al., 1999).

Especially in today's most important part of the water resources used in agricultural production, in order to open up larger areas for irrigation, irrigation in agricultural production needs to be done correctly and economically. Especially in the underwater drip irrigation systems, water saving is very important in this respect. One of the most important issues in sub-surface drip irrigation is the change in the root area of the plant. This study was carried out to determine these changes. In this study, pre-irrigation, irrigation order and moisture change in the soil after irrigation were investigated by using sub-surface drip irrigation system.

Materials and methods

The study was carried out in two different locations, which were in the Haymana Researchand Application Farm of Ankara University, and Researchand Application Farm of Ankara Sugar Institute. The soil properties of the test sites are given in Tables 1 and 2. In this study, Pioneer 31Y43 silage corn variety was cultivated in Haymana Research Application Farm as plant material. Baloo variety of sugar beet was cultivated in the Sugar Institute. In the sub-surface drip irrigation system used in the research, laterals with a dripper flow rate of 2.1 l/h were placed at 70 cm intervals and at depth of 40 cm. Different irrigation water levels have been applied in order to see the effect of plant yield and yield components in limited water conditions. The water applications were calculated according to the estimated ETc values and calculated according to the application level by taking into account the depth of 60 cm. Different rates of ETc in sugar beet were used as irrigation water level (S1= 100% ETc, S2= 80% ETc, S3= 60%ETc and S4=40% ETc). Similarly, in silage corn were chosen as irrigation water levels (S1= 125% ETc, S2= 100% ETc, S3= 75%ETc and S4=50% ETc).
During the production season, the soil moisture was monitored by soil moisture sensors before, after and during irrigation processes. The data on soil moisture is calculated hourly for each sensor in a specially crafted portal. In this way, a moisture change is observed in which all layers in the soil. Moisture probes were placed in 10 cm interval and measured at depth of 1 m. The probes were placed 10 cm away from the laterals between the two drippers, between the two laterals (Figure 1). In this way, the volumetric soil water content was measured continuously in all applications with moisture sensors and in all applications until the soil moisture was changed in every layer of soil.

**Table 1.** Physical properties of Haymana research station’s soil

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Sand (%)</th>
<th>Clay (%)</th>
<th>Loam (%)</th>
<th>Texture</th>
<th>Volume Weight (gr cm$^3$)</th>
<th>Field Capacity (%)</th>
<th>Wilting Point (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>24.3</td>
<td>58.9</td>
<td>16.8</td>
<td>C</td>
<td>1.14</td>
<td>41.48</td>
<td>23.30</td>
</tr>
<tr>
<td>30-60</td>
<td>25.9</td>
<td>57.8</td>
<td>16.3</td>
<td>C</td>
<td>1.16</td>
<td>42.3</td>
<td>23.70</td>
</tr>
<tr>
<td>60-90</td>
<td>25.1</td>
<td>56.4</td>
<td>18.5</td>
<td>C</td>
<td>1.16</td>
<td>41.19</td>
<td>23.50</td>
</tr>
</tbody>
</table>

**Table 2.** Physical properties of Sugar Institute Research’s soil

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Sand (%)</th>
<th>Clay (%)</th>
<th>Loam (%)</th>
<th>Texture</th>
<th>Volume Weight (gr cm$^3$)</th>
<th>Field Capacity (%)</th>
<th>Wilting Point (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>42.9</td>
<td>44.2</td>
<td>12.9</td>
<td>C</td>
<td>1.18</td>
<td>39.4</td>
<td>21.4</td>
</tr>
<tr>
<td>30-60</td>
<td>43.9</td>
<td>41.6</td>
<td>14.5</td>
<td>C</td>
<td>1.19</td>
<td>39.2</td>
<td>21.3</td>
</tr>
<tr>
<td>60-90</td>
<td>41.8</td>
<td>43.4</td>
<td>14.8</td>
<td>C</td>
<td>1.18</td>
<td>38.5</td>
<td>21.1</td>
</tr>
</tbody>
</table>

**Figure 1.** Insertion of moisture probes

**Results and Discussion**

In the area where corn production is performed, significant differences in soil moisture distribution of applied irrigation water levels (Figures 3 and 4). Especially in the field where 25% more applied to ETc (Figure 2), it is seen that the soil moisture goes at 0-30, 30-60, 60-90 and 90-120 cm depths close to each other. It has been determined that the irrigation water level has the moisture around every four layers of field capacity. When the values are analysis carefully, it is seen that at the irrigation water level at the level of 90-120 cm deep percolation into the soil layer. The soil depth at which the soil moisture changes most is 0-30 cm soil.
depth. In this layer, there is both evaporation and water intake with the roots of the plants in response to the upward movement of soil moisture with capillarity. However, despite the approximately 5-day irrigation interval, no signs of stress have been identified in that layer. A similar situation is seen in S2 application (Figure 2). The difference of S2 from S1 is the change in the 0-30 cm soil layer. When the soil moisture in the same layer was compared to tow application, the change of S2 application was higher than S1. In S2 application, soil moisture at 30-60, 60-90 and 90-120 cm depths occurred around the field capacity and at the same time deep percolation was determined.

Figure 2. Changing of soil moisture on S1 and S2 application

Figure 3. Changing of soil moisture on S3 and S4 application
Figure 4. Changing of soil moisture on Sugar beet plant

A similar situation in S1 and S2 applications was also observed in S3 application (Figure 3). In particular, change of soil moisture on the S3 application were similar other applications in 0-30, 30-60, 60-90 and 90-120 cm depth of soil. The difference of S3 from S2 is 0-30 cm in the soil layer. Soil moisture didn't change in the period until the first irrigation time in the first layer. However, the soil moisture sensor was found to be faulty in that period. In the first irrigation time, the moisture sensor was repaired. In the S3 application, soil moisture at the depths of 30-60, 60-90 and 90-120 cm was realized around the field capacity and at the same time, deep percolation was determined. The change in soil moisture of S4 application is similar to that of S3 (Figure 3). Particularly, S4 and S3 are similar in terms of soil moisture in 0-30, 30-60, 60-90 and 90-120 cm depths. The difference of S3 from S4 is 0-30 cm soil layer. The change in soil moisture in the time to the first irrigation is similar to that of S2. The change in a soil depth of 30-60 cm was more pronounced than the other three applications. In the application of S4, soil moisture in the depths of 60-90 and 90-120 cm was realized around the field capacity and at the same time, deep percolation was determined.

In sugar beet plant, the situation is similar to silage corn. When the applicable of irrigation water levels was analyzed, it was determined that almost all irrigation water levels changed in 0-30 cm soil depth. In all irrigation water levels, especially in the irrigation water season, soil moisture was almost around the field capacity at the depths of 60 and 90 cm. A significant portion of the irrigation water applied during the irrigation season, especially S1, S2 and S3 applications, was determined the deep percolation. Changing of soil moisture have been carried out in classical drip irrigation (Tas and Kirnak, 2011) and subsurface drip irrigation (Cote et al. 2003; Skaggs et al. 2004; Gardenas et al. 2005; Patel and Rajput 2008; Elmaloglou, 2012). Automation of SDI systems based on soil moisture sensors may further improve water use efficiency. Shae et al. (1999) described an SDI system coupled with tensiometers and pressure transducers that initiated irrigation of potato when soil tension exceeded 30 kPa. This approach resulted in significantly less irrigation water applied (129 mm) compared to a surface drip irrigation treatment that was scheduled based on a soil moisture balance (220 mm). Similar yields were reported for both treatments.

Conclusion

Subsurface drip irrigation (SDI) is being adopted in areas to conserve water while maintaining economical production of crops. The presented data indicated that there was a gradual decrease in soil moisture content with the increment in soil depth. Subsurface drip
irrigation systems may increase water use efficiency due to reduced soil and plant surface evaporation and because only the root zone or the partial root zone is irrigated as opposed to sprinkler irrigation where the entire field area is wetted. According to the results of the study, it is necessary to reduce/correct the $ET_c$ value while determining the amount of irrigation water to be applied in the subsurfacedrip irrigation. Considering the regional conditions, the $ET_c$ value calculated in corn and sugar beet production should be reduced by almost 50% rate. In this way, both the loss of percolation losses and the reduction of the irrigation water is achieved, and the production inputs (energy, fertilizer, medicine etc.) are significantly more profitable.

References


