Influence of Drip Irrigation by Automation Controller System on Soil Moisture Distribution, Water Amount, Faba Bean Yield, and Water use Efficiency

Abdullah S. Aljughaiman
Department of Environmental and Natural Resources
College of Agriculture & Food Science
King Faisal University, Saudi Arabia
E-mail: aaljughaiman@kfu.edu.sa

Abstract
The aim of the current study is to investigate the effect of drip irrigation through using an automation controller system, different soil surface slope conditions and different field capacities on soil moisture distribution patterns, water amounts and Faba bean yield. Field experiments were carried out in a sandy loam soil with Faba bean (Vicia Faba-variety G461) at Al Hassa Oasis, Kingdom of Saudi Arabia. Faba bean seeds were planted on late October where the growth period extended for 150 days. Under automation controller drip irrigation system, three irrigation rates of the following field capacities: 60, 80, and 100 and two land slopes: non slope 0% and sloped down by 5%. Soil distribution patterns were affected significantly by the different field capacities. The highest values were under 100% FC, then 80% FC, followed by 60% FC. Whereas the effect of sloped down by 5% was observed to be more than under non slope 0% but not significant. The interactions among field capacities and slopes were found to be significant. Finally, it can be concluded with the recommendation of using the third field capacity of 60% FC because the treatment of the two slopes 0 and 5% water amount has been saved and produced faba bean yield not significantly different compared to other treatments of field capacities. Moisture distribution with sloped down by 5% has been improved under field capacity treatments of FC 60 and FC 80 % because water hold capacities were increased by 1.2 and 0.8 (v/v %), respectively. Faba bean yield values of FC (60, 80, and 100) % were (1.77, 1.65; 1.57) and (1.86, 1.72; 1.63) under non-sloped 0% and sloped down by 5%, respectively. Water use efficiency (WUE) values of FC (60, 80, and 100) % were (0.042, 0.033; 0.028) and (0.043, 0.034; 0.030) under non-sloped 0% and sloped down by 5%, respectively.

Keywords: Automation controller, drip irrigation, slopes, field capacity, soil moisture distribution, water, Faba bean yield

1. Introduction
Drip irrigation has advantages over conventional systems of irrigation as an efficient mean of applying water; especially where water amounts is limited. The trickle system used to uniformly distribute water in agricultural fields. If water can be applied efficiently in an irrigation field, water could be saved and both crop quantity and quality could be increased. Several issues have emerged concerning the adaptation of the drip technology (Camp, 2000; Mansour et al. 2015).
Maximizing uniformity in the application of water is one of the ways to saving the irrigation water. Should be evaluating the uniformity emission of the drip irrigation system in the field. Earl and Jury (1977) Stated that the moisture profile of the frequently irrigation treatments under the cropped conditions show that downward water movement is restricted to depth of 0.6 m in which lateral movement occurs no further than 0.6 m from the emitter and commented that water movement is observed to almost 1.0 m from the emitter, while downward movement is restricted to about 0.75 m. Soil moisture distribution when the irrigation water was applied form a water source, but with different rates of the drippers discharge. The continuous drip irrigation treatments showed a water loss, by the deep percolation of 26 percent of the total water amount of irrigation water below 0.6 m depth after 720 min. The lateral liens of water distribution, in the same treatments, showed that 80 percent of the water in the wetted volume was distributed up to 0.45 and 0.43 m horizontally from the point source after 720 and 1440 min, respectively. Only 12 percent of water loss under the depth of 0.6 m was found with pulsed irrigation group and 0.29 and 0.4 m lateral distribution after 720 and 1440 min, respectively (Levin et al. 1979).

Many researches (Bacon and Davy 1982; Eissa et al. 2014) stated that drip irrigation system resulted in outward movement of water from the application point to the wetted profile. The size and duration of wetted profile depended on the irrigation period, irrigation intervals and the length of the season time for drip irrigation while the deployment depth was caused by the lowest hydraulic conductivity of the irrigated soil. The lateral movement of drip irrigation was enhanced as the soil was stratified, initial soil moisture was low, and the rate of application was low as well. At the high moisture tension (low moisture content), the lateral movement of drip irrigation system was low in coarser layers and pronounce in the fine soil layers (Norris and Tennessee 1985).

The moisture content of the top soil (0-0.2 m) was higher in the drip system than those of surface, and sprinkler irrigation systems. In contrast, the low moisture content in the same layers was in the surface irrigated field (El-Gindy, 1988). Under drip-irrigation system, the distribution of soil water is completed through a soil surface wetted zone that is small relative to the total soil surface zone. In point source dripper, the soil water distribution into the soil wetted zone follows three-dimensions towards the intake, different from the one-dimension (vertical) intake type of conventional irrigation systems, where the surface wetted area (through which water intakes into the soil) is the whole soil surface area. The high frequency of irrigation, typical of drip systems, reveals that the intake process prevails, relative to other systems of irrigation, over the soil water extraction phase of the irrigation cycle, (Bressler, 1977; Sevostianova and Leinauer, 2014).

Assouline, (2002) found that under drip irrigation system, the size of the wetted zone around the dripper is strongly related to both the water application amount, discharge rate and the soil properties. Accordingly, the water discharge rate of dripper is one key factor determining the soil moisture content in the wetted zone. However, increasing the water amount application has a significant effect on either drip irrigation system efficiency or the final grain yield. For example, very high applied rates of water can eliminate water stress of some crops, but it will also give low drip irrigation system efficiency because the amount of applied water will increasing and it will lead to nutrients leaching with deep percolation away from root zone (Morton et al., 1988; Maharjan et al., 2014).

Researches by (Tayel et. al., 2007; El-Metwally and El-Saidy, 2016) studied the effect of different water amounts of drip irrigation expressed as a percent of reference evapotranspiration, crop evapotranspiration, on soil water holding capacity and (irrigation requirement / cumulative basin evaporation) ratio, it was obviously found that yield (quantity and quality), growth characteristics and water use efficiency increased with the increase of irrigation water applied up to specific amounts depending on crop species, climate, irrigation method and soil.
2. Material and Methods

This study was conducted at Al Hassa City, Kingdom of Saudi Arabia. The city located at longitude of 49° 36' E, latitude of 25° 24' N and elevation of 147 m, wherein the soil is classified as sandy loam. The aim was to study the effect of automation controller of drip irrigation system, different slopes conditions, and different field capacities on soil moisture distribution patterns, water amounts and Faba bean yield.

2.1 The Experiments

Field experiments were carried out under drip irrigation by automation controller system, three treatments of field capacity were used, which were 100%, 80% and 60%, where the 100 % FC was used as a control. Faba bean (Vica Faba) variety (G-461). Faba bean seeds were planted on the 2nd week of October and growing season lasted 150 days. Soil physical properties were determined after Gee and Bauder (1986) as shown in Table (1). Soil bulk density (B.D.) was measured according to Black and Hartage (1986). Soil moisture content at field capacity (F.C) and permanent wilting point (P.W.P) were measured after Walter and Gardener (1986) as shown in Table (1). The available water (AW) was calculated from the following equation:

\[ AW = \text{F.C} - \text{P.W.P} \]  
(1)

Where, AW: available water (\(\Theta_w\) %), F.C: field capacity (\(\Theta_w\) %) and P.W.P: permanent wilting point (\(\Theta_w\) %). Soil hydraulic conductivity (HC) was determined under a constant head technique Klute and Dirksen, (1986).

Soil chemical characteristics were determined according to Jackson (1967) and (Soil Survey Staff, 1993) as shown in Table (2). Ground water is the source of irrigation water. Irrigation water analysis is given in Table (3).

Table 1: Soil physical properties of the experimental site

<table>
<thead>
<tr>
<th>Soil sample Depth (cm)</th>
<th>Particle size distribution (%)</th>
<th>Texture class</th>
<th>*FC (V/V %)</th>
<th>*WP (V/V %)</th>
<th>*AW (V/V %)</th>
<th>BD (g/cm(^3))</th>
<th>HC (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>3.7 coarse sand 54.5 fine sand 25.2 silt 16.6 clay</td>
<td>SL</td>
<td>0.22</td>
<td>0.11</td>
<td>0.11</td>
<td>1.45</td>
<td>1.11</td>
</tr>
<tr>
<td>15-30</td>
<td>3.8 coarse sand 55.8 fine sand 24.6 silt 15.8 clay</td>
<td>SL</td>
<td>0.22</td>
<td>0.11</td>
<td>0.11</td>
<td>1.43</td>
<td>1.28</td>
</tr>
<tr>
<td>30-45</td>
<td>4.6 coarse sand 53.7 fine sand 26.0 silt 15.7 clay</td>
<td>SL</td>
<td>0.22</td>
<td>0.11</td>
<td>0.11</td>
<td>1.43</td>
<td>1.28</td>
</tr>
<tr>
<td>45-60</td>
<td>4.6 coarse sand 55.9 fine sand 25.5 silt 14.0 clay</td>
<td>SL</td>
<td>0.21</td>
<td>0.10</td>
<td>0.11</td>
<td>1.42</td>
<td>1.53</td>
</tr>
</tbody>
</table>

(*) Determined as percentage in (V/V %) cm\(^3\) Water/ cm\(^3\) Soil, (SL): Sandy loam, Soil; HC: Hydraulic conductivity; and BD: Bulk density.

Table 2: Chemical analysis of the soil

<table>
<thead>
<tr>
<th>Soil sample depths (cm)</th>
<th>Cations (Meq/l)</th>
<th>Anions(Meq/l)</th>
<th>pH</th>
<th>E.C (dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca(^{++})</td>
<td>Mg(^{++})</td>
<td>Na(^+)</td>
<td>K(^+)</td>
</tr>
<tr>
<td>0-15</td>
<td>6.43</td>
<td>4.89</td>
<td>185.0</td>
<td>18.84</td>
</tr>
<tr>
<td>15-30</td>
<td>11.53</td>
<td>6.49</td>
<td>237.1</td>
<td>25.01</td>
</tr>
<tr>
<td>30-45</td>
<td>12.15</td>
<td>7.97</td>
<td>279.1</td>
<td>26.63</td>
</tr>
<tr>
<td>45-60</td>
<td>12.56</td>
<td>4.17</td>
<td>307.1</td>
<td>32.28</td>
</tr>
</tbody>
</table>

Table 3: Chemical analysis of irrigation water

<table>
<thead>
<tr>
<th>Cations(Meq/l)</th>
<th>Anions(Meq/l)</th>
<th>pH</th>
<th>E.C (dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca(^{++})</td>
<td>Mg(^{++})</td>
<td>Na(^+)</td>
<td>K(^+)</td>
</tr>
<tr>
<td>0.7</td>
<td>1.72</td>
<td>128</td>
<td>13</td>
</tr>
</tbody>
</table>

A Time Domain Reflectometer (TDR) device was used for the measurement of different soil types. The TDR working based on the direct measurements of the dielectric constant of soil and its conversion to water volume content. As shown in (Fig. 1). In order to achieve this and
to ensure greater accuracy, soil moisture probes with five sensors each were used and permanently installed in the 12 experimental plots, where they were in continuous contact with the soil. Each probe had sensors which measured the soil moisture content at five different depths: 0–0.1, 0.1–0.2, 0.2–0.3, and 0.3–0.4 m. The average values were calculated from the five depth reads taken.

Figure 1: TDR device and probe with five sensors

2.2 Statistical Analysis

COSTAT program was used to carry out the statistical analysis. The treatment means were compared using the analysis of variance technique (ANOVA) and the least significant difference between systems at 1 % (Steel and Torrie 1980).

3. Results and Discussion
3.1 Effect of Different Slopes Conditions and Different Field Capacities Treatments under Drip Irrigation by Automation Controller Systems on Moisture Distribution Pattern

Data of Table (4) and Figs. (2 and 3) show the effect of different slope conditions and different FC treatments on moisture distribution patterns given in volumetric percentage basis (v/v %). It is important to mention that, at non sloped 0% level, the mean soil moisture contents v/v % were 12.03, 12.21 and 10.63 % under 100% FC, 80% FC, and 60% FC before irrigation, respectively. Whereas, they were 30.31, 27.89 and 27.54 % after irrigation in the same sequence.

On the other hand, under sloped down by 5 % condition, the means of moisture (v/v %) were 12.54, 11.97 and 10.40 % before irrigation, respectively. while they were 30.41, 27.72 and 27.52 % after irrigation under 100% FC, 80% FC, and 60% FC, respectively. There was a slight increase in (v/v %) with depth, whether soil moisture was measured before or after irrigation. This may be attributed to the decrease of clay percent with depth.
According to the mean soil moisture content (v/v %), field capacity treatments used could be arranged in the following ascending orders: 60% FC<100% FC<80% FC before irrigation, and 60% FC<80% FC<100% FC after irrigation when non-sloped 0 % conditions. Differences in (v/v %) between any two field capacity treatments were significant at the 1 % level.

Concerning (v/v %), the field capacity treatments, it could be put in the following ascending orders 60% FC<80% FC<100% FC before and after irrigation both at the stage when sloped down by 5% conditions. Difference in (v/v %) between any two field capacity treatments were significant at the 1 % level, this may be due to decrease in salt accumulation under 100% FC before irrigation in comparison with 80% FC and 60% FC.
Figure 2: Contour maps for soil moisture distribution patterns by using automation control drip irrigation system before and after irrigation when slope 0 % conditions under different FC.

![Contour maps for soil moisture distribution patterns before and after irrigation when slope 0 % conditions under different FC.](image)

Figure 3: Contour maps for soil moisture distribution patterns by using automation control drip irrigation system before and after irrigation when slope 5 % conditions under different FC.

![Contour maps for soil moisture distribution patterns before and after irrigation when slope 5 % conditions under different FC.](image)

Maximum and minimum values of moisture content (v/v %) were observed to be 12.56 % (30 cm) and 10.48 % (0 cm) under 80% FC and 60% FC, respectively before irrigation and 31.75 % (30 cm) and 27.27 % (40 cm) under 100% FC and 80% FC, respectively after irrigation when slope 0 % condition. But when sloped down by 5 % conditions, the values of (v/v %) were 13.76 (30 cm) and 10.32 % (0 cm) for 100% FC and 60% FC before irrigation and 31.54% (0 cm) and 27.08 % (40 cm) under 100% FC and 80% FC, respectively after irrigation. The obtained contour maps for soil moisture distribution are shown in Figs. (2 and 3). These have been observed when lateral length was 40 m under different drip irrigation connection methods after and before irrigation when slopes (0 % and 5 %) conditions, respectively. These data agreed with both Filintas et al. (2007), Dioudis et al. (2008), Dioudis et al. (2003a) and Dioudis et al. (2003b).
Effect of Different Slopes and Different Field Capacities under Drip Irrigation by Automation Controller System, on Faba Bean Yield and WUE

As shown in Table (5) and Fig. (4), when non-sloped 0% under drip irrigation by automation controller system used, Faba bean yield produced the highest value (1.77 ton/fed) by using (FC 100%), followed by (FC 80%) value producing (1.65 ton/fed). The lowest value (1.57 ton/fed) was achieved under (FC 60%). There was significant difference at the 1% level in faba bean yield among the three treatments. When sloped down by 5% as show in Table (5) and Fig. (4), (FC 100%) treatment of faba bean yield was at the highest value (1.86 ton/fed), followed by under (FC 80%) value (1.72 ton/fed). While the lowest value (1.63 ton/fed) was obtained under (FC 60%).

Table 5: Effect of drip irrigation by automation controller system, different slopes and different field capacities, on Faba bean yield, irrigation water used, and WUE

<table>
<thead>
<tr>
<th>Slope (I)</th>
<th>Treatments (FC %) (II)</th>
<th>Yield (Ton/fed)</th>
<th>Irrigation water used (m³/fed)</th>
<th>Water use efficiency WUE (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>100</td>
<td>1.77a</td>
<td>62.85</td>
<td>0.028a</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>1.65b</td>
<td>50.28</td>
<td>0.033b</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1.57c</td>
<td>37.71</td>
<td>0.042c</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.67</td>
<td>50.28</td>
<td>0.034</td>
</tr>
<tr>
<td>5%</td>
<td>100</td>
<td>1.86d</td>
<td>62.85</td>
<td>0.030d</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>1.72e</td>
<td>50.28</td>
<td>0.034eb</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1.63f</td>
<td>37.71</td>
<td>0.043fc</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.74</td>
<td>50.28</td>
<td>0.036</td>
</tr>
<tr>
<td>LSD 1%</td>
<td></td>
<td>0.05</td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>Interaction (I) X (II)</td>
<td></td>
<td>0.07</td>
<td></td>
<td>0.001</td>
</tr>
</tbody>
</table>

There were significant differences at the 1% level in faba bean yield between any two field capacity treatments. The increase in Faba bean yield under sloped down by 2% were 4.8, 4.1 and 3.7 % in comparison with non sloped 0% under FC (60, 80, and 100) %, respectively.

Figure 4: Effect of drip irrigation by automation controller system, different slopes and different field capacities, on faba bean yield

According to water use efficiency WUE (ton yield/m³ water) as show in Table (5) and Fig. (5), field capacity treatments used could be arranged in the following ascending orders: 60% FC > 80% FC > 100% FC under non-sloped down 0 % and sloped by 5%. WUE values of FC (60, 80, and 100) % were (0.04, 0.033; 0.028) and (0.043, 0.034; 0.030) under non-sloped 0% and sloped by 5%, respectively.
Figure 5: Effect of drip irrigation by automation controller system, different slopes and different field capacities, on WUE

Differences in (v/v %) between any two field capacity treatments and interactions were significant at the 1 % level. The increase in WUE under sloped down by 5% were 6.6, 2.9 and 2.3 % in comparison with non-sloped 0% under FC (60, 80, and 100) %, respectively.

4. Conclusion
Under drip irrigation by automation controller system, it could be concluded that:

- Field capacity treatments used could be arranged in order: 60% FC<100% FC<80% FC before and after irrigation when non-sloped 0% and sloped down by 5%.
- Difference in (v/v %) between any two field capacity treatments were significant at the 1 % level, this may be due the decrease of salt accumulation under 100% FC before irrigation in comparison with 80% FC and 60% FC.
- Moisture distribution with sloped down by 5% had been improved under field capacity treatments FC 60 and FC 80 % because water holding capacities were increased by 1.2 and 0.8 (v/v %), respectively.
- Faba bean yield values of FC (60, 80, and 100) % were (1.77, 1.65; 1.57) and (1.86, 1.72; 1.63) under non-sloped 0% and sloped down by 5%, respectively.
- The increase in faba bean yield under sloped down by 2% were 4.8, 4.1 and 3.7 % relative to sloped by 0% under FC (60, 80, and 100) %, respectively. This increase was due to the improvement in the moisture distribution under 5% sloped more than 0% sloped.
- WUE values of FC (60, 80, and 100) % were (0.042, 0.033; 0.028) and (0.043, 0.034; 0.030) under non-sloped 0% and sloped down by 5%, respectively.
- The increase in WUE under sloped down by 5% were 6.6, 2.9 and 2.3 % in comparison with sloped 0% under FC (60, 80, and 100) %, respectively. This increase was due to the improvement in the moisture distribution, increase in the yield, using little water amount comparing with 0% sloped down.

Acknowledgement
The author thanks the Deanship of Scientific Research at King Faisal University for the financial support of this project.
References


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