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# Effect of different irrigation systems on root growth of maize and cowpea plants in sandy soil

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## Abstract

A field experiment was conducted at the Experimental Farm, Faculty of Agriculture, Suez Canal University to study the influence of different irrigation systems on root length density and specific root length of maize and cowpea plants cultivated in sandy soil. Three irrigation systems (Surface, drip and sprinkler irrigation) were used in this study. The NPK fertilizers were applied as recommended doses for maize and cowpea. Root samples were collected from the soil profile below one plant (maize and cowpea) which was irrigated by the three irrigation systems by using an iron box (30 cm × 20 cm) which is divided into 24 small boxes each box is (5 × 5 × 5 cm). At surface irrigation, root length density of cowpea reached to soil depth 30-40cm with lateral distances 5-10 cm and 15-20 cm. Vertical distribution of root length density of maize was increased with soil depth till 20-25 cm, and then it decreased till soil depth 35-40cm. Under drip irrigation, root length density of cowpea increased horizontally from 0-5cm to 10-15cm then it decreased till soil depth 25-30 cm and below this depth root length density disappeared. For the root length density and specific root length of maize under drip irrigation, the data showed that root length density and specific root length decreased with increasing in soil depth. The root length density of cowpea under sprinkler irrigation at 0-5cm disappeared from horizontal distance at 25-30 cm. The data showed that root length density of maize under sprinkler irrigation was higher at the soil top layers 0-5 cm and 5-10 cm than other layers from 10-40 cm.

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## Introduction

Plant root systems are responsible for plant growth, absorption of water, and nutrients uptake (Lynch, 1995). The root system must adapt to nutrient availability, lack and excess of moisture, and wind shear on the shoot, along with other abiotic factors such as soil compaction and texture. The impact of biotic factors on root systems includes insect pests, diseases, nematodes, weeds, and competition due to high planting densities. Deep rooting is particularly beneficial for allowing water uptake from great soil depths during the drought times (Gaiser et al., 2012). The crop response to water system strategies was different (Lu et al., 2001), and the effect of irrigation on the plant root systems is also different from one irrigation system to another because of differences in soil water regimes. It has been proven that for crop growth, the earlier the irrigation water was applied, the better the root system grew (Carefoot and Major, 1994). Machado et al., (2003) reported that the distribution of water within the soil profile as a result of the level of irrigation affects the development of horizontal and vertical root growth as well as transportation and uptake of nutrients by plant roots in the soil. Similar finding was reported by (Sperry et al., 2002; Song and Li, 2006; Hu et al., 2009).

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Lü et al. (2015) studied the effect of different irrigation methods on root distribution in winter wheat fields. They found that more fine roots were produced in the border irrigation treatment when soil water content was low and topsoil bulk density was high. Root growth restrained in the deep layers in the surface drip irrigation treatment, followed by sprinkler irrigation and border irrigation, which was due to the different water application frequencies. The aim of this research is to study the root length density and specific root length of two crops under different irrigation methods in sandy soil.

## Material and Methods

This study was conducted in the experimental site of Agricultural College of Suez Canal University during the summer season in 2015. The soil of the experimental site was sandy in texture, very low in organic matter (0.3%) with pH (7.2) and EC (2.4 dSm$^{-1}$) as showen at Table 1. The available N, P and K were 35, 7, 70 mg/kg, respectively before the initiation of the experiment according to Page et al. (1982). At summer season, the maize *(Zea mays)* and cowpea *(Vigna unguiculata)* seeds were sowed at the field on 21 May 2015, with the spacing of 30 cm between the rows and 30 cm between plants in a row and irrigated by surface, drip and sprinkler irrigation systems. The level of fertilizers adopted in the study were 47.6 kg N ha$^{-1}$, 47.6 kg $P_2O_5$ ha$^{-1}$ and 71.4 kg $K_2O$ ha$^{-1}$ for cowpea plants and 333 kgN ha$^{-1}$, 71.4 kg $P_2O_5$ ha$^{-1}$ and 71.4 kg $K_2O$ ha$^{-1}$ for maize plants. The recommended fertilizers which were used in the experiment with the two plants were ammonium nitrate, potassium sulphate and diammonium phosphate. All fertilizers were incorporated into the soil at a depth of 10 cm.

Table 1. Properties of the soil of the experimental site

| | | | | | |
|---|---|---|---|---|---|
| Texture | Clay, % | 2.00 | | | |
| | Silt, % | 3.50 | | | |
| | Sand, % | 94.50 | | | |
| Chemical property | pH, 1:2.5, w/v | 7.20 | Soil nutrients, mg kg$^{-1}$ | Available N | 35.00 |
| | EC, dSm$^{-1}$ | 2.40 | | Available P | 7.00 |
| | Organic matter, % | 0.30 | | Available K | 70.00 |
| Soluble cations, mmol$_c$L$^{-1}$ | $Ca^{2+}$ | 5.25 | Soluble anions, mmol$_c$L$^{-1}$ | $CO_3^{2-}$ | <0.01 |
| | $Mg^{2+}$ | 4.00 | | $HCO_3^-$ | 5.00 |
| | $Na^+$ | 4.00 | | $Cl^-$ | 10.50 |
| | $K^+$ | 2.00 | | $SO_4^{2-}$ | 4.50 |

Root samples were collected from the soil profile below one plant (maize and cowpea) which was irrigated by the three irrigation systems by using an iron box (30 cm × 20 cm) which is divided into 24 small boxes each box is (5 × 5 × 5 cm) as shown at Figure 1. This iron box which has a sharp edge is pressed horizontally in soil profile to depth of 40cm as shown at Figure 2. To separate roots from soil of each small box, the samples were poured through a sieve 0.2mm. Similar method was carried out (Gao et al., 2010)

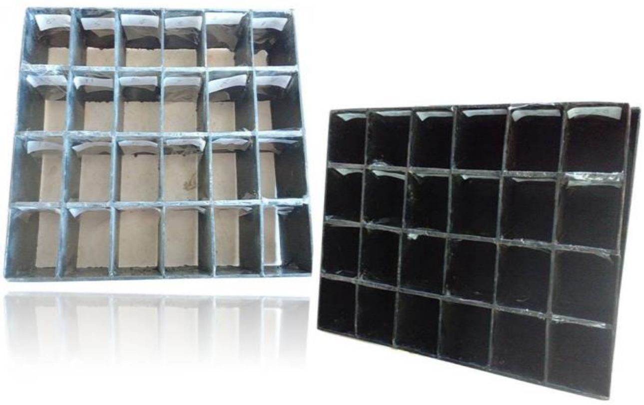

Figure 1. Iron box divided into 24 small boxes; each of them is (5× 5× 5 cm)


Figure 2. The iron box which has a sharp edge is pressed horizontally in the soil profile

Some parameters of root distribution were calculated such as root length was measured by the formula that was simplified and adjusted by Tennant (1976) as following:

$$\text{Root length (R)} = \frac{11}{14} \text{ x Number of intersections (N) x Grid unit.}$$

Root length density (RLD) was calculated with the equation of Fageria et al. (2006)

$$\text{Root Length density (cm cm}^{-3}\text{)} = \frac{\text{Root length in cm}}{\text{Soil volume where roots have been collected cm}^3}$$

Specific root length (SRL) has been widely used as an indicator for the root morphology indicator. It could be calculated with the equation of Zobel (2005)

$$\text{Specific Root Length (cm g}^{-1}\text{ root dry weight)} = \frac{\text{Root Length (cm)}}{\text{Root dry weight (g)}}$$

## Results and Discussion

At surface irrigation, water moves with soil gravity so that roots penetrated soil profile to deep depths to uptake available soil water. With respect to this concept, root length density of cowpea reached to soil 30-40 cm with lateral distances 5-10 cm and 15-20 cm as illustrated at Table 2. Root length density decreased with increasing in soil depth. At 10-15 cm, the root length density was 1.51 cm.cm$^{-3}$at 0-5 cm and decreased to 0.5 cm.cm$^{-3}$at soil depth 35-40 cm. The lowest root length density was 40 cm.cm$^{-3}$ at soil depth 35-40 cm with lateral distance 5-10 cm. At horizontal distance 25-30 cm, root length density is disappeared.

Table 2. Distribution of root length density (RLD) and specific root length (SRL) of cowpea along soil profile under surface irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ |
| 0-5 | 9.81 | 0.63 | 21.59 | 1.38 | 23.50 | 1.51 | 19.63 | 1.26 | 15.70 | 1.00 | - | - |
| 5-10 | 9.36 | 0.60 | 13.74 | 0.88 | 15.00 | 0.96 | 12.76 | 0.82 | 14.72 | 0.94 | - | - |
| 10-15 | 8.75 | 0.56 | 11.88 | 0.76 | 14.72 | 0.94 | 12.50 | 0.80 | 13.74 | 0.88 | - | - |
| 15-20 | 15.70 | 1.00 | 13.74 | 0.88 | 14.00 | 0.90 | 11.88 | 0.76 | 13.74 | 0.88 | - | - |
| 20-25 | 8.13 | 0.52 | 11.25 | 0.72 | 12.50 | 0.80 | 11.50 | 0.74 | 12.76 | 0.82 | - | - |
| 25-30 | 7.50 | 0.48 | 10.88 | 0.70 | 11.36 | 0.74 | 11.00 | 0.70 | 11.87 | 0.75 | - | - |
| 30-35 | 6.25 | 0.40 | 9.50 | 0.61 | 10.00 | 0.64 | 8.30 | 0.54 | 11.25 | 0.72 | - | - |
| 35-40 | - | - | 7.50 | 0.48 | 8.00 | 0.50 | 6.25 | 0.40 | - | - | - | - |

With regard to root distribution of maize, the data at Table 3 showed that root length density and specific root length was higher at soil depth 20-25 cm at all horizontal distances. Vertical distribution of root length density of maize was increased with soil depth till 20-25 cm, and then it decreased till soil depth 35-40 cm. At horizontal distance 10-15 cm and 15-20 cm, the root length density recorded the highest values among the other distance where the maize plant was located at these distances then root length density decreased with the increase in horizontal distance. At horizontal distance 10-15 cm, the root length density of maize increased up to soil depth 30-35 cm. In general, root length density of maize and cowpea decreased with increased with soil depth. Similar findings were obtained by Raj et al. (2013) reported that under surface irrigation, maize roots increased with soil depth to uptake more water, this is because of the depletion of moisture below the root zone and the plants had to extract water from deeper layers.

Table 3. Distribution of root length density (RLD) and specific root length (SRL) of maize along soil profile under surface irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ |
| 0-5 | 1.51 | 8.02 | 0.75 | 4.01 | 1.07 | 5.68 | 2.51 | 13.36 | 1.16 | 6.15 | 1.26 | 6.68 |
| 5-10 | 1.00 | 5.34 | 0.69 | 3.67 | 0.88 | 4.68 | 2.64 | 14.03 | 0.73 | 3.87 | 0.75 | 4.01 |
| 10-15 | 0.98 | 5.21 | 0.94 | 5.01 | 1.63 | 8.69 | 1.70 | 9.02 | 0.85 | 4.54 | 1.63 | 8.69 |
| 15-20 | 0.94 | 5.01 | 1.63 | 8.69 | 1.88 | 10.02 | 1.83 | 9.75 | 1.80 | 9.55 | 0.63 | 3.34 |
| 20-25 | 2.01 | 10.69 | 2.26 | 12.03 | 2.51 | 13.36 | 2.14 | 11.36 | 2.51 | 13.36 | 2.01 | 10.69 |
| 25-30 | 1.00 | 5.34 | 1.88 | 10.02 | 1.68 | 8.95 | 1.26 | 6.68 | 1.26 | 6.68 | 0.94 | 5.01 |
| 30-35 | 0.63 | 3.34 | 1.51 | 8.02 | 2.51 | 13.36 | 0.75 | 4.01 | 0.63 | 3.34 | 0.63 | 3.34 |
| 35-40 | 1.07 | 5.68 | 1.19 | 6.35 | 1.00 | 5.34 | 0.75 | 4.01 | 0.72 | 3.81 | 0.63 | 3.34 |

Under drip irrigation, root length density of cowpea is higher at the soil surface from 0 to 20 cm as presented at Table 4. The highest value of root length was 2.51 cm.cm$^{-3}$at 10-15 cm with soil depth 0-5 cm. The lowest root length density was 0.40 cm.cm$^{-3}$ recorded at 15-20 cm with soil depth 25-30 cm. At lateral distance 25-

30 cm, root length density and specific root length disappeared along soil profile. In general, root length density increased horizontally from 0-5cm to 10-15cm then it decreased till soil depth 25-30 cm and below this depth root length density disappeared. Similar findings were observed by Moroke et al. (2005) who found that root growth in the soil profile for cowpea, sunflower and grain sorghum were characterized by the highest root length density found in the upper 0.5 m of the soil profile and decreasing with depth.

Table 4. Distribution of root length density (RLD) and specific root length (SRL) of cowpea along soil profile under drip irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ |
| 0-5 | 0.88 | 14.09 | 1.26 | 20.13 | 2.51 | 40.26 | 2.26 | 36.23 | 1.26 | 19.63 | - | - |
| 5-10 | 0.82 | 13.08 | 1.0 | 16.10 | 1.26 | 20.13 | 1.51 | 23.55 | 0.88 | 13.78 | - | - |
| 10-15 | 0.72 | 11.25 | 0.82 | 12.76 | 0.88 | 13.74 | 1.38 | 21.59 | 0.75 | 11.78 | - | - |
| 15-20 | 0.63 | 10.06 | 0.75 | 12.08 | 0.82 | 12.76 | 0.94 | 14.78 | 0.69 | 10.79 | - | - |
| 20-25 | 0.44 | 7.05 | 0.61 | 9.74 | 0.63 | 10.06 | 0.75 | 11.78 | 0.63 | 10.06 | - | - |
| 25-30 | - | - | - | - | 0.56 | 8.97 | 0.40 | 6.41 | - | - | - | - |
| 30-35 | - | - | - | - | - | - | - | - | - | - | - | - |
| 35-40 | - | - | - | - | - | - | - | - | - | - | - | - |

For root distribution of maize, Table 5 presented the root length density and specific root length of maize under drip irrigation. The data showed that root length density and specific root length decreased with increasing in soil depth. The highest values of root length density and specific root length were 5.02 $cm.cm^{-3}$ and 25.12 $cm.g^{-1}$root at horizontal distance 15-20 cm with soil depth 0-5 cm. Root length density increased with the increase in horizontal distance from 0-5 cm till 10-15cm 15-20 cm then it decreased from 5.02 $cm.cm^{-3}$ to 2.14 $cm.cm^{-3}$ with increasing in horizontal distance. The lowest root length density was 0.63 $cm.cm^{-3}$ observed at the horizontal distance 0-5 cm with the soil depth 35-40cm. These results are compatible with Gao et al. (2010) who found that the peak horizontal spread of maize roots occurred in the 16-22 cm layer of the soil and root depth increased with the increase in soil depth.

Table 5. Distribution of root length density (RLD) and specific root length (SRL) of maize along soil profile under drip irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ | SRL, $cm.g^{-1}$ root | RLD, $cm.cm^{-3}$ |
| 0-5 | 2.51 | 12.56 | 4.14 | 20.27 | 4.65 | 23.24 | 5.02 | 25.12 | 2.89 | 14.44 | 2.14 | 10.68 |
| 5-10 | 1.88 | 9.42 | 1.63 | 8.16 | 2.32 | 11.62 | 2.80 | 14..0 | 1.07 | 5.34 | 1.19 | 5.97 |
| 10-15 | 1.51 | 7.54 | 2.01 | 10.05 | 2.14 | 10.68 | 2.26 | 11.30 | 1.26 | 6.28 | 2.14 | 10.68 |
| 15-20 | 1.38 | 6.91 | 1.26 | 6.28 | 1.51 | 7.54 | 4.02 | 20.10 | 2.26 | 11.30 | 2.64 | 13.19 |
| 20-25 | 1.26 | 6.28 | 2.51 | 12.56 | 1.00 | 5.02 | 3.77 | 18.84 | 2.07 | 10.36 | 2.01 | 10.05 |
| 25-30 | 1.88 | 9.42 | 1.26 | 6.28 | 1.88 | 9.42 | 2.14 | 10.68 | 0.50 | 2.51 | 2.26 | 11.30 |
| 30-35 | 1.38 | 6.91 | 0.63 | 3.14 | 0.94 | 4.71 | 1.44 | 7.22 | 0.88 | 4.40 | 0.75 | 3.77 |
| 35-40 | 0.63 | 3.14 | 0.50 | 2.51 | 0.63 | 3.14 | 0.82 | 4.08 | 0.75 | 3.77 | 0.69 | 3.45 |

The data at Table 6 showed that the root length density and specific root length of cowpea cultivated under sprinkler irrigation. The root length density at 0-5 cm was 0.75 $cm.cm^{-3}$ and increased to 1.26 $cm.cm^{-3}$ at 10-15 cm then it decreased to 20-25 cm and disappeared from horizontal distance at 25-30 cm. The lowest root length density was 0.50 $cm.cm^{-3}$ recorded at horizontal distance 0-5 cm with soil depth 20-25 cm. The root length density is founded at horizontal distance 10-15 cm from soil depth 0-5 cm to soil depth 30-35 cm. This is may be due to the shortage of water through soil profile because of the movements of irrigation water by gravity. At horizontal distance 15-20 cm, the root length density at the soil surface was 1.07 $cm.cm^{-3}$ then it decreased to 0.63 $cm.cm^{-3}$at soil depth 25-30 cm. The data showed that root length density disappeared from soil profile 25-30 cm. The same results were obtained by Steel and Summerfield (1985) who found that cowpea had a rapid root growth to gain available soil water in arid and semiarid regions.

With regard to root length density and specific root length of maize under sprinkler irrigation. The data at Table 7 showed that root length density was higher at the soil top layers 0-5 cm and 5-10 cm than other layers from 10-40 cm. The highest root length was 2.22 $cm.cm^{-3}$ recorded at horizontal distance 10-15 cm at the top layer from 0-5cm. The lowest value was 0.63 $cm.cm^{-3}$ at horizontal distance 25-30 cm with soil depth 35-40cm. The data showed that root length density increased horizontally from 1.63 $cm.cm^{-3}$ at 0-5 cm then it began to decrease to 0.79 cm.cm$^{-3}$at 25-30 cm. This result was observed at all depths with horizontal distances. Talking of vertical distribution of roots, root length density decreased with the increase in soil depth. This is because of sprinkler irrigation is attributed to be higher frequency. Correspondingly, Lv et al. (2010) found that the maize root length density is high at the top layer of soil.

Table 6. Distribution of root length density (RLD) and specific root length (SRL) of cowpea along soil profile under sprinkler irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ |
| 0-5 | 0.75 | 10.47 | 0.88 | 12.21 | 1.26 | 17.44 | 1.07 | 14.83 | 0.82 | 11.34 | - | - |
| 5-10 | 0.69 | 9.59 | 0.82 | 11.34 | 1.13 | 15.70 | 0.88 | 12.21 | 0.75 | 10.47 | - | - |
| 10-15 | 0.63 | 8.72 | 0.79 | 11.0 | 1.07 | 14.83 | 0.82 | 11.34 | 0.69 | 9.59 | - | - |
| 15-20 | 0.75 | 7.85 | 0.75 | 10.47 | 0.94 | 13.08 | 0.79 | 11.0 | 0.65 | 9.09 | - | - |
| 20-25 | 0.50 | 6.88 | 0.69 | 9.59 | 0.85 | 11.86 | 0.69 | 9.59 | 0.63 | 8.72 | - | - |
| 25-30 | - | - | 0.63 | 8.72 | 0.78 | 10.82 | 0.63 | 8.72 | - | - | - | - |
| 30-35 | - | - | - | - | 0.65 | 9.07 | - | - | - | - | - | - |
| 35-40 | - | - | - | - | - | - | - | - | - | - | - | - |

Table 7. Distribution of root length density (RLD) and specific root length (SRL) of maize along soil profile under sprinkler irrigation

| Soil depth, cm | Horizontal Distance (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-5 | | 5-10 | | 10-15 | | 15-20 | | 20-25 | | 25-30 | |
| | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ | SRL, cm.g$^{-1}$ root | RLD, cm.cm$^{-3}$ |
| 0-5 | 1.63 | 5.67 | 1.00 | 3.49 | 2.22 | 7.72 | 1.88 | 6.54 | 0.82 | 2.83 | 0.79 | 2.75 |
| 5-10 | 1.19 | 4.14 | 0.88 | 3.05 | 1.0 | 3.49 | 0.98 | 3.40 | 0.85 | 2.97 | 0.75 | 2.62 |
| 10-15 | 0.95 | 3.34 | 0.75 | 2.62 | 1.07 | 3.71 | 0.88 | 3.05 | 0.79 | 2.75 | 0.69 | 2.40 |
| 15-20 | 0.94 | 3.27 | 0.63 | 2.18 | 0.82 | 2.83 | 0.78 | 2.70 | 0.70 | 2.44 | 0.67 | 2.31 |
| 20-25 | 0.94 | 3.27 | 0.88 | 3.05 | 1.00 | 3.49 | 1.13 | 3.93 | 1.07 | 3.71 | 0.69 | 2.40 |
| 25-30 | 0.85 | 2.97 | 0.80 | 2.79 | 0.88 | 3.05 | 1.26 | 4.36 | 0.69 | 2.40 | 0.67 | 2.31 |
| 30-35 | 0.78 | 2.70 | 1.26 | 4.36 | 1.88 | 6.54 | 0.75 | 2.62 | 0.67 | 2.31 | 0.64 | 2.19 |
| 35-40 | 0.65 | 2.20 | 0.68 | 2.35 | 0.70 | 2.42 | 1.00 | 3.49 | 0.75 | 2.62 | 0.63 | 2.18 |

## Conclusion

Understanding the plant root length density and specific root length are an important consideration when using different irrigation methods. This study was conducted at the experimental site of Agricultural College of Suez Canal University during the summer season using two crops maize and cowpea growing under three irrigation systems. The data showed that the root length density and specific root length of cowpea under surface irrigation decreased vertically with soil depth and it disappeared horizontally at 25-30 cm. At all soil depths and distances, the root length density was found. At drip irrigation, root length density of cowpea is higher at the soil surface from 0 to 20 cm. For maize crop, the data showed that root length density and specific root length decreased with increasing soil depth. At sprinkler irrigation, the root length density at 0-5 cm was 0.75 cm.cm$^{-3}$ and increased to 1.26 cm.cm$^{-3}$ at 10-15 cm then it decreased to 20-25 cm and disappeared from horizontal distance at 25-30 cm. For maize crop under sprinkler irrigation, the lowest value was 0.63 cm.cm$^{-3}$ at the horizontal distance 25-30 cm with soil depth 35-40 cm.

## References

Carefoot, J.M., Major, D.J., 1994. Effect of irrigation application depth on cereal production in the semi-arid climate of southern Alberta. *Irrigation Science* 15(1): 9-16..

Fageria, N.K., Baligar, V.C., Clark, R.B., 2006. Physiology of crop production. Haworth Press Inc. New York, USA. 335p.

Gaiser, T., Perkons, U., Küpper, P.M., Puschmann, D.U., Peth, S., Kautz, T., Pfeifer, J., Horn, R., Köpke, U. 2012. Evidence of improved water uptake from subsoil by spring wheat following lucerne in a temperate humid climate. *Field Crops Research* 126: 56-62.

Gao, Y., Duan, A., Qiu, X., Liu, Z., Sun, J., Zhang, J., Wang, H., 2010. Distribution of roots and root length density in a maize/soybean strip intercropping system. *Agricultural Water Management* 98(1): 199-212.

Hu, T., Kang, S., Li, F., Zhang, J., 2009. Effects of partial root-zone irrigation on the nitrogen absorption and utilization of maize. *Agricultural Water Management* 96(2): 208-214.

Lu, J., Liu, Y.L., Hirasawa, T., 2001. Study on intermittent irrigation for paddy rice: II Crop responses. *Pedosphere*11(3): 224-234.

Lü, G.H., Song, J.Q., Bai, W.B., Wu, Y.F., Liu, Y., Kang, Y.H., 2015. Effects of different irrigation methods on micro-environments and root distribution in winter wheat fields. *Journal of Integrative Agriculture* 14(8): 1658-1672.

Lv, G., Kang, Y., Li, L., Wan, S., 2010. Effect of irrigation methods on root development and profile soil water uptake in winter wheat. *Irrigation Science* 28(5): 387-398.

Lynch, J., 1995. Root architecture and plant productivity. *Plant Physiology* 109(1): 7-13.

Machado, R.M.A., do Rosário, M., Oliveira, G., Portas, C.A.M., 2003. Tomato root distribution, yield and fruit quality under subsurface drip irrigation. *Plant and Soil* 255(1): 333-341.

Moroke, T.S., Schwartz, R.C., Brown, K.W., Juo, A.S.R., 2005. Soil water depletion and root distribution of three dryland crops. *Soil Science Society of America Journal* 69(1): 197-205.

Page, A.L., Miller, R.H., Keeney, D.R., 1982 Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy (ASA) - Soil Science Society of America (SSSA), Number 9, Maqdison, WI, USA.

Raj, A.F.S., Muthukrishnan, P., Ayyadurai, P., 2013. Root characters of maize as ınfluenced by drip fertigation levels. *American Journal of Plant Sciences* 4: 340-348.

Song, H.X., Li, S.X., 2006. Root function in nutrient uptake and soil water effect on $NO_3^-$-N and $NH_4^+$-N migration. *Agricultural Sciences in China* 5(5): 377-383.

Sperry, J.S., Stiller, V., Hacke, U.G., 2002. Soil water uptake and water transport through root systems. In: Plant Roots: The Hidden Half. Waisel, Y., Eshel, A., Kafkafi, U. (Eds.). 3rd Edition, Marcel Dekker Inc. New York, USA. pp. 1008-1040.

Steel, W.M., Summerfield, D.J., 1985. Cowpea [*Vigna unguiculata* (L.) Walp]. In: Grain legume crops. Summer, D.J., Roberts, E.H. (Ed.). William Collins Sons and Co. Ltd. London, UK. pp 520–583.

Zobel, R.W., 2005. Tertiary root systems. In: Roots and soil management: Interactions between roots and the soil. Zobel, R.W., Wright, S.F., (Ed.). Agronomy Monograph No. 48, American Society of Agronomy, Madison, WI, USA. pp.35-56.