Effect of subsurface drip irrigation manners and percentages of moisture depletion on some hydraulic parameters and potato yield

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Abstract A field experiment was conducted in Silty Loam soil during the fall season 2020 in one of the fields of College of Agriculture (Jazeerat Al-Ramadi - Al Hamidiyah, Research Center) north of Ramadi city, latitude 33° 27” 10.8” N, and longitude 43° 23”. 2.4” E. The soil was morphologically described and classified as (Torrifluvent) according to the American classification system (USDA, 2010). Three methods of subsurface drip irrigation were chosen Partial Drying of the Root zone PRD, Sub-surface Border irrigation SBI and conventional sub-surface irrigation SDI, with two moisture depletion of available water rates (25% and 50%). The results of the study showed that the PRD irrigation method had the highest mean of the total yield when depleting 25% of the prepared water which was 28.628 Meg h⁻¹ and the lowest average was 27.088 Meg ha⁻¹ when depleting 50%. Whereas, the PRD treatment gave the highest yield value of 29.75 Meg h⁻¹ when depleting 25% of the available water, Also the PRD method gave the highest average values of 29,217 kg ha⁻¹ compared to 26,142 kg ha⁻¹ for SDI method. This was reflected in the total infiltration, saturated hydraulic conductivity and addition efficiency, the total infiltration using PRD irrigation method recorded the highest average values of 31.2 cm compared to 24.7 and 22.5 cm for SBI and SDI drip irrigation treatments respectively. The 25% depletion treatment was significantly superior to the 50% depletion treatment, which gave an average of 28.1 cm and 24.1 cm respectively. As for the saturated hydraulic conductivity, the mean values of the saturated hydraulic conductivity increased significantly in the PRD irrigation method for the depth 0-15 m, reaching the highest average values of 2.92 cm h⁻¹ compared to 2.32 and 1.97 cm h⁻¹ for SBI and SDI irrigation methods respectively. The depletion rate of 25% gave the highest rate of conductivity of 2.63 cm per hour⁻¹, while the depletion rate of 50% gave the lowest rate of water conductivity of 2.17 cm h⁻¹. The PRD treatment gave the highest mean values of water conductivity at 3.38 cm h⁻¹ compared to 2.17 and 2.49 cm h⁻¹ for SBI and SDI irrigation methods at 15-30 cm depth respectively. Irrigation with partial drying of the root zone PRD gave the highest efficiency rate, adding depth 15-30 cm, which was 97.07%, compared to 96.52 and 95.35% for SBI and SDI irrigation methods respectively.

1. Introduction

The scarcity of water in arid and semi-arid areas makes the amount of water added at the appropriate time necessary to maintain a good yield of the crop and to increase the efficiency of water use, irrigation methods with high efficiency in water use were applied, including the method of subsurface drip irrigation, and the efficiency of irrigation was high compared to the methods of tourist irrigation
Continuous spraying and surface drip [1], [2] pointed to the need to manage water in an economical, sustainable and environmentally friendly manner, and indicated that the use of nanotechnology in irrigation is more efficient and efficacy over the years, and they emphasized that this technology takes into account every drop of water when measuring crop yield and is not negatively affected by climatic and environmental conditions, due to high temperatures and lack of water resources, indicating that the economic feasibility of this technique is high for most agricultural products.

The potato crop (Solanum tuberosum L.) is one of the important vegetable crops in the Arab world and many countries of the world. The potato is cultivated on a large scale all over the world, as it is a good food source rich in energy compared to other starchy crops of global importance such as wheat, corn and rice. Potato is one of the crops sensitive to high and low moisture stresses, compared to other types of crops, and the effect of water stress is more effective in the last stages of crop growth [3]. [4] found a decrease in the values of saturated hydraulic conductivity when irrigating an interval of 5 days and adding 50% of the amount of water evaporated from the evaporation basin as irrigation water. Its value was 1.74 cm compared to 2.22 cm when irrigating every 3 days and adding 100% of the water evaporated from the evaporation basin as irrigation water, and this is attributed to the study factors represented by the irrigation duration, the level of the irrigation water quantity and the drip drain. [5] found a significant decrease in the values of the total infiltration by increasing the water stress ratios, as the highest values of the total infiltration reached 34.90, 38.70, 42.40 cm at the 40% depletion rate of the ready water, while its values were 30.80, 33.80, 38.50 cm at the 50 depletion rate, % of the ready water, while the lowest values were 26.70, 30.70, 33.20 cm at the depletion rate of 60% of the ready water for the full, half and triple addition treatments by splitting the net irrigation depth sequentially, and the reason for this was attributed to the sudden changes that occur in the soil moisture content, which led to the occurrence of air eruptions, and then the deposition of fine soil particles in the soil substratum. [6] indicated the effect of soil moisture depletion and drip irrigation method on application efficiency, as the data showed a significant effect of partial drying of the soil surface on application efficiency, which amounted to 91.49% compared to 89.42% or traditional surface drip irrigation, and the reason may be the division of irrigation water into two parts, the first part is added in one side of the plants and the other part is added on the other side in the middle of the time for one irrigation, and this technique may reduce deep seepage as well as evaporation losses, and the results showed an increase in the efficiency of addition in soil moisture depletion coefficients by 25%, which amounted to 91.12% compared with 89.78% for the depletion rates of 50%, as the use of short irrigation periods reduced irrigation water losses, which was reflected in the improvement of application efficiency. [7] indicated that the yield of the potato crop under the PRD method was 100% at 202 gm plant⁻¹ and the productivity was at 50% for DI120 gm plant⁻¹. The yield of potato tubers decreased by about 40% when 50% depletion was adopted, and the statistical analysis showed statistically significant differences in the crop tubers for each plant for irrigation treatments between 50 and 70%.

In the current study, we will present the result of a comparison between three different subsurface drip irrigation strategies PRD, SBI and SDI at 25% and 50% moisture depletion of the prepared water and study their effect on some water parameters such as total infiltration, saturated hydraulic conductivity, addition efficiency and potato yield.

2. Materials and Methods

A field experiment was conducted in Silty Loam soil during the fall season 2020 at the site belong to the College of Agriculture (Jazeerat Al-Ramadi - Al Hamidiyah, Research Center) north of the city of Ramadi, about 108 km west of the capital, Baghdad, at latitude 33° 27' 10.8" N and 43° 23' .24" E longitude. Soil morphology was described and classified into (Torrifluvent) according to the American
classification system [8]. Representative samples of field soil were taken from different regions, randomly, with a depth of 0-0.30 m, and some physical and chemical analyzes were conducted on them in Table (1) according to the standard methods mentioned in [9].

### Table (1) Physical and Chemical properties of soil before planting

| No. | Adjective      | quantity | Units  | No. | Adjective      | quantity | Units  |
|-----|----------------|----------|--------|-----|----------------|----------|--------|
| 1   | Sand           | 227      | g kg⁻¹ | 12  | (pH)           | 7.5      | dsm⁻¹  |
| 2   | Silt           | 661      |        | 13  | (EC)           | 1.67     |        |
| 3   | Clay           | 112      |        |     | Ca²⁺          | 5.23     |        |
| 4   | Texture        |          |        |     | Mg²⁺          | 3.92     |        |
| 5   | bulk density   | 1.26     | Mg m⁻³ |    | Na⁺           | 5.77     |        |
| 6   | hydraulic conductivity | 5.3 | Cm h⁻¹ | 14 | Cations |          |        |
| 7   | Volumetric     | 33       |        |     | K⁺            | 0.54 mmol L⁻¹ |        |
| 8   | moisture of the soil (kpa) | 1500 | 9.1 | % | Anions | SO₄²⁻ | 7.63 |
| 9   | Infiltration Basic Rate | 7.2 | Cm h⁻¹ | | | HCO₃⁻ | 1.53 |
| 10  | Mean Weight Diameter | 0.41 | Mm | 15 | | CO₂⁻ | NIL |
| 11  | (CaSO₄)       | 213.3    | g kg⁻¹ | | | Cl⁻ | 6.65 |

The characteristics of irrigation water were estimated according to the methods proposed by the American Salinity Laboratory. Euphrates water was used to irrigate the potato crop, and its chemical properties are shown in Table (2).

### Table (2) Chemical properties of irrigation water

| EC | pH  | Dissolved Ions meq L⁻¹ | NO₃⁻ | SAR | Class |
|----|-----|------------------------|------|-----|-------|
| dsm⁻¹ |     | Ca²⁺ | Mg²⁺ | Na⁺ | K⁺ | Cl⁻ | SO₄²⁻ | HCO₃⁻ | CO₂⁻ |
| 0.9 | 7.6 | 3.48 | 3.55 | 2.71 | 0.15 | 7.08 | 1.8 | 0.91 | NIL |

The experiment was conducted on an area with dimensions of 39 x 12 m (468 m²). The area was prepared by performing leveling operations, then was plowed perpendicularly using a moldboard plow, and then the soil was smoothed. The area was divided into 18 treatments, the dimensions of each of which are 0.8 x 10 m distributed over three sectors each of them contains 6 treatments, and the distance between planting lines is 1.5 m and between each sector and another 2.5 m. The treatments were randomly distributed to each sector, as two branch pipes were extended to each level of 0.20 m for partial root zone drying (PRD) and subsurface boarder drip irrigation (SBI) in a zigzag fashion to approximate the distance between the dots except for the coefficients conventional SDI Subsurface drip irrigation single line.

The side pipes were connected to the main line by triple hydrants, while the secondary (sub) pipes were connected to the side pipes. Each line had an opening and closing ending with a plug, as well as the branch pipes for the purpose of cleaning the system after each irrigation and then digging a trench 0.2 m wide and 0.15 m deep to lay the secondary lines (carrying the dripper) and then put it down in soil.

Potato tubers (*Solanum tuberosum* L.), Rivera cultivar, were planted on September 16, 2020 at a depth of 0.08-0.10 m, with an average of 30 tubers per experimental unit. 540 tubers, equivalent to 20,200 hectares of plants, (this number was based on the area of the experiment).

Irrigation scheduling started from the beginning of the pre-germination phase 16/9/2020 for all transactions and according to the growth stages of the crop, knowing that the first irrigation was carried...
out by delivering soil moisture to the limits of the field capacity and for all experiment transactions, and the Euphrates River was adopted as a source of irrigation water. Depending on the soil moisture description curve, the volumetric moisture was determined at the limits of the field capacity and the permanent wilting point, while the equation of [10] was adopted to calculate the depth of the added water and my agency:

\[ d = \frac{\theta_{fc} - \theta_{pwp}}{100} \times D \]  

(1)

Since:
d: depth of water added (cm). \( \theta_{fc} \): volumetric moisture at field capacity (%).
\( \theta_{pwp} \): volumetric moisture at permanent wilting point (%). D: depth of the root zone to be irrigated (cm).

As for calculating the depth of water added to one irrigation when 25% is depleting, it was from the following equation:

\[ d = (0.25 \Theta \times D) \]  

(2)

And calculating the depth of water added to one irrigation when depleting 50% was from the following equation:

\[ d = (0.50 \Theta \times D) \]  

(3)

Since:
d: the depth of water to be added to the stage (cm).
0.25\( \Theta \): volumetric moisture when 25% of the prepared water has been exhausted.
0.50\( \Theta \): volumetric moisture when 50% of the prepared water has been exhausted.

The depth of the root zone was estimated on the basis of observations specific to each treatment according to the stages of plant growth.

According to the volume of water to be added from the following equation:

\[ Q \times t = A \times d \]  

(4)

Since:
d: water depth (m). A: irrigated area m\(^2\). Q: discharge (liter-hour\(^{-1}\)). \( \times t \): time (hours).

Since the depth of water added represents the actual water consumption, then:

\[ ET_a = d \]  

(5)

The reference evapotranspiration was calculated by substituting equation (5) into equation (6) according to the following equation [11].

\[ ET_c = \frac{ET_a}{Kc} \]  

(6)
Since:

ETa: evapotranspiration (mm day\(^{-1}\)).

ETo: evaporation - reference transpiration (mm day\(^{-1}\)).

Kc: yield coefficient.

The irrigation date was determined by finding the amount of water evaporated from the American evaporation basin, class A, according to the following equation [11].

\[
E_{\text{pan}} = \frac{E_{\text{T}_0}}{K_p} \quad \quad (7)
\]

Since:

ETo = evaporation - reference transpiration (mm day\(^{-1}\)). Kp = evaporation basin coefficient.

Epan = evaporation from the basin (mm day\(^{-1}\)).

Kp 0.75 was adopted according to [12] and it varies according to the type of basin, the vegetation cover surrounding the basin, and the nature of the soil surface.

The amount of irrigation water that must be added to the soil as requirements for salt washing, which is 6.05%, was calculated according to the equation mentioned by [13] of modern irrigation systems, including drip irrigation and the following:

\[
LR = \frac{E_{\text{C}_{\text{w}}}}{2(\text{MAX}_{\text{EC}_{\text{e}}})} \times 100 \quad \quad (8)
\]

Since:

LR : Amount of leaching requirement, (%). EC\(_{\text{w}}\) : The electrical conductivity of the irrigation water, ds m\(^{-1}\).

MAX\(_{\text{EC}_{\text{e}}}\) : the highest electrical conductivity, ds m\(^{-1}\) for the soil of the cultivated crop at which the yield is zero, a value that varies according to the crop and is equal to 10 for potato yield [14].

The height of the plants was measured at the end of the growing season, as it was measured from the point of contact of the vegetative group with the root system to the end of the growing top for an average of five plants taken randomly for each treatment using the measuring tape.

The total yield was calculated by extracting plants after 101 days of planting, and the average yield was calculated for five plants randomly taken from the experimental unit and then transferred on the basis of hectares, as the number of plants per hectare was 20200 plants, which was calculated on the basis of the number of plants in the cultivated area, and the yield was calculated According to the following equation:

\[
\text{Total yield (meg g ha}\ ^{-1}\text{)} = \frac{\text{Average of yield 5 plant per unit (Kg)} \times 20200 \text{ plant. h}^{-1}}{1000}\quad \quad (9)
\]

The saturated hydraulic conductivity was estimated by the Constant Head Method mentioned in [15], on the excitable soil model, as it was hydrated by capillary property for 24 hours, then a fixed column of water was applied to it, and the amount of drained water was then measured from the Soil to calculate the saturated hydraulic conductivity from Darcy's law and according to the following mathematical formula:
\[
K = \frac{V}{A t} \left( \frac{L}{\Delta h} \right) \quad \quad \quad \quad \quad (10)
\]

Since:
- K: saturated aqueous conductivity (cm h\(^{-1}\)).
- A: The cross-sectional area of the soil column (cm\(^2\)).
- V: volume of drained water (cm\(^3\)).
- t: time of collection of drained water (hours).
- L: length of the soil column (cm).
- \(\Delta h\): The change in water potential between the point of entry and exit of the water (cm).

The irrigation efficiency was calculated from dividing the amount of water stored in the root zone by the amount of water added to the field, as the moisture was measured immediately before irrigation and after 48 hours of it as a percentage \% according to what was indicated by [17] as in the following equation:

\[
E_a = \frac{W_s}{W_f}\quad \quad \quad \quad \quad (12)
\]

Ea=Irrigation Efficiency\%  
Ws=amount of water stored (cm\(^3\)).  
Wf = the amount of water added (cm\(^3\)).

The results were statistically analyzed using the GenStat program, according to the method of analysis of variance based on the significant differences between the treatments at a significant level of 0.05 for the least significant difference (L.S.D)) to compare between the study parameters, [18].

3. Results and discussion

3.1. Total yield (Meg ha\(^{-1}\))

Table 3 shows that the PRD method was significantly superior to the two treatments of subsurface irrigation (SDI) and (SBI), which gave the highest values of irrigation by PRD, which reached an average of 29.217 Meg ha\(^{-1}\), while the SBI and SDI gave a rate of 28.216 and 26.142 Meg ha\(^{-1}\) respectively. The reason for this may be due to the lack of moisture in the soil as a result of the addition of partial drying of the root zone, which is less total with the added water compared to the traditional subsurface and strip
subsurface irrigation, which significantly affected the outcome and this is what [19] found. As for moisture depletion, the 25% depletion treatment was significantly superior to the 50% depletion treatment, and the first gave a rate of 28.628 and 27.088 Meg ha\(^{-1}\) in sequence. Distribute the water and maintain the appropriate moisture and not see the water outside the root zone and reflect on the yield.

As for the interaction between the treatments of irrigation systems and moisture depletion, the highest yield reached 29,753 Meg ha\(^{-1}\) from the interaction equation between alternating subsurface irrigation system and moisture depletion 25%, which is significantly superior to all other interaction treatments, while the lowest yield was 24,610 Meg ha\(^{-1}\) from the treatment of the interaction between subsurface irrigation and moisture depletion 50%. The reason is attributed to the fact that the decrease in the amount of added water led to a decrease in the rate of yield as a result of exposing the potato plant to water stress, which led to a decrease in the indicators of vegetative growth of the plant, as this was reflected on the total yield, perhaps due to the reason This is due to the negative impact of water stress at 50% depletion on biological processes, carbon metabolism, nutrient and carbohydrate transport, enzymatic activity, plant hormones, cell elongation and division, which led to a reduction in the number of tubers, their weight and total yield, in addition to providing water and nutrients in the root system area when the plant needs it. It is due to the regular distribution of water and the maintenance of appropriate moisture as a result of reducing evaporation from the surface of the soil and the leakage of water outside the area drastic and reflected on the outcome.

Table (3) Effect of Treatments on total yield (Meg ha\(^{-1}\))

| Drip irrigation methods | Moisture depletion % 25 | Moisture depletion % 50 | Means of drip irrigation methods |
|-------------------------|--------------------------|--------------------------|----------------------------------|
| SDI                     | 27.674                   | 24.610                   | 26.142                           |
| SBI                     | 28.458                   | 27.974                   | 28.216                           |
| PRD                     | 29.753                   | 28.681                   | 29.217                           |
| Depletion Means         | 28.628                   | 27.088                   |                                  |
| LSD \(_{0.05}\)          |                          |                          | 1.444                            |
| LSD \(_{0.05}\)          |                          |                          | 1.179                            |

3.2. Saturated hydraulic conductivity

3.2.1. Depth 0-15 cm
The results of Table 4 showed a significant difference in the average saturated hydraulic conductivity values for depth 0-15 cm under sub-surface drip irrigation methods, as the partial drying of the root zone PRD gave the highest mean of saturated hydraulic conductivity values of 2.92 cm per hour\(^{-1}\), in While the mean values of saturated hydraulic conductivity were 2.32 and 1.97 cm per hour\(^{-1}\) for SBI and SDI conventional subsurface drip irrigation methods, respectively. The reason for this is due to dividing the depth of the pure irrigation water, which reduces the effect of wetting and drying cycles on the soil structure, including the dispersion of soil particles and the sedimentation process[20].

It was also noticed from the same table and appendix that there was a significant difference in the average of saturated hydraulic conductivity values for the moisture depletion treatment, as the 25% moisture depletion treatment gave the highest average of saturated hydraulic conductivity values, which was 2.63 cm h\(^{-1}\) compared to 2.17 cm h\(^{-1}\). The depletion factor is 50%, and the reason is due to the fact that the level of irrigation water added to the soil affected its construction due to the mechanical effect of the excess water quantities in its levels, which contributed to the deterioration of soil aggregates during the continuation of the irrigation process, and this is consistent with what was reached [21],[22].
3.2.2. Depth of 15-30 cm

The results of Table 5 showed a significant difference in the average values of saturated hydraulic conductivity for a depth of 15-30 cm using some subsurface drip irrigation methods, as the partial drying of the root zone PRD gave the highest average values of saturated hydraulic conductivity of 3.38 cm per hour⁻¹, while the average values of the saturated hydraulic conductivity rate were 2.17 and 2.49 cm.hr⁻¹ for the SBI and SDI conventional subsurface drip irrigation methods, respectively. This may be due to the short period between irrigations and the fragmentation of the net irrigation depth, which reduces the effects of the cycles of wetting and drought on soil structure, including the dispersal of soil particles and the sedimentation process, and this is consistent with [4].

Table 5. The effect of some irrigation methods and moisture depletion on the saturated hydraulic conductivity cm hour⁻¹ for a depth of 15-30 cm

| Drip irrigation methods | Moisture depletion % | Means of drip irrigation methods |
|-------------------------|----------------------|---------------------------------|
|                         | 25%                  | 50%                             |                                |
| SDI                     | 2.21                 | 1.73                            | 1.97                            |
| SBI                     | 2.34                 | 2.29                            | 2.32                            |
| PRD                     | 3.34                 | 2.50                            | 2.92                            |
| LSD 0.05                |                      | N.S                             | 0.484                           |
| Depletion Means         | 2.63                 | 2.17                            |                                 |
| LSD                     |                      | 0.395                           |                                 |

3.3. Cumulative depletion

The results of Table 6 showed a significant difference in the cumulative depletion rate under subsurface drip irrigation methods, as the PRD gave the highest cumulative depletion rate of 31.2 cm, while were 24.7 and 22.5 for SBI and SDI sequentially, and the reason for this may be the effect of the traditional drip and tape irrigation, which increases the bulk density of the soil and reduces the porosity, especially the fine pores, and reduces the cross-sectional area of the flow in the soil body, on the contrary. From that, the partial drying of the root zone contributed to a decrease in the bulk density of the soil and an increase in the porosity and this is consistent with [23].

As for the effect of moisture depletion, it was noticed from the same table that there was a significant difference, as the 25% moisture depletion treatment gave the highest rate of 28.1 cm, compared to 24.1 cm for the 50% moisture depletion treatment, and the reason is the level of irrigation water added to the soil affected its construction due to the mechanical effect of the excessive amounts of water in its levels, which contributed to the deterioration of the soil pools during the continuation of the irrigation process, and this is consistent with the findings of [21] and [22].
While for the interaction between some treatments of irrigation methods and moisture depletion, the highest cumulative depletion value was 35.1 cm when treating irrigation by PRD with 25% moisture depletion, which is significantly superior to all other interaction treatments, while the lowest cumulative depletion value was 20.5 cm For the SDI treatment at 50% moisture depletion, the reason for this is due to the increase in the apparent density and low porosity due to the high moisture content, which led to the washing of salts and the deposition of slurry and lubricants to the bottom, in addition to the lack of aeration (increased moisture content) and low the activity of aerobic microorganisms and the lack of their organic secretions, and this affected the porosity responsible for the movement of water and thus the tip, and this is consistent with what [23] found.

### Table (6). Effect of some irrigation methods and moisture depletion on the cumulative depletion cm

| Drip irrigation methods | Moisture depletion % | means of drip irrigation methods |
|------------------------|----------------------|---------------------------------|
|                        | 25%                  | 50%                            |
| SDI                    | 24.40                | 20.50                          |
| SBI                    | 24.90                | 24.50                          |
| SDI                    | 35.10                | 27.20                          |
| **LSD 0.05**           | **0.39**             | **0.27**                       |
| Depletion Means        | 28.10                | 24.10                          |
| **LSD 0.05**           | **0.22**             |                                |

### 3.4. Efficiency of adding

#### 3.4.1 Depth 0-15 cm

The results of Table 7 showed a significant difference in the rate of application efficiency of depth 0-15 cm under some subsurface drip irrigation methods, as the partial drying of the root zone PRD gave the highest average of application efficiency values of 96.63%, while the average of application efficiency values was 95.9 And 95.1% for the SBI and SDI traditional subsurface drip irrigation methods, respectively. The reason may be dividing the irrigation water into two parts, one part is added to one side of the plants and the other part is added on the other side in the middle of the time for one irrigation, and this technique may reduce deep seepage as well as evaporation losses and this is consistent with [24]. While, the effect of moisture depletion, the same table and appendix indicate an apparent difference in the average values of the addition efficiency, as the moisture depletion treatment gave 25% the highest rate of addition efficiency, which amounted to 96.08% compared to 95.68% for the 50% moisture depletion treatment, and perhaps the reason for this is that the treatment of moisture depletion 25% depletion made the period between irrigation and another short and with less addition quantities, which made the loss of irrigation water less and improved soil moisture in contrast to the treatment of depletion 50%, as for the interaction between the treatments of some irrigation methods and moisture depletion, it is noted from the table and appendix that there is an apparent difference, as The value of the addition efficiency was 96.8% for the partial drying method of the root zone when depleted 25% PRD, while the lowest added efficiency was 94.97% for the traditional subsurface drip irrigation when the moisture was depleted 50% SDI.
Table 7. The effect of some irrigation methods and moisture depletion on the efficiency of adding % of depth 0-15 cm

| Drip irrigation methods | Moisture depletion % | Means of drip irrigation methods |
|------------------------|----------------------|---------------------------------|
|                        | 25%  | 50%  |                                      |
| SDI                    | 95.23 | 94.97 | 95.10                                |
| SBI                    | 96.21 | 95.6  | 95.90                                |
| PRD                    | 96.80 | 96.47 | 96.63                                |
| LSD_0.05               | 0.05 | N.S   | 0.565                                |
| Depletion Means        | 96.08 | 95.68 |                                    |
| LSD                    |      | N.S   |                                    |

3.4.2. Depth 15-30 cm

The results of Table 8 showed a significant difference in the average values of application efficiency of 15-30 cm depth under some subsurface drip irrigation methods, as the partial drying of the root zone PRD gave the highest average of application efficiency values, which amounted to 97.07%, while the average values of PRD were 97.07%. The addition efficiency is 96.52 and 95.35% for the SBI and SDI traditional subsurface drip irrigation methods sequentially, due to dividing the water into two parts. The other is until this percentage is completed, and so on, in addition to the use of nano-dots that are resistant to clogging and distribute water well and homogeneously at the approved depth of 15 cm, and this is consistent with what was reached by [24].

Table 8. The effect of some irrigation methods and moisture depletion on the efficiency of the addition % for depth 15-30 cm

| Drip irrigation methods | Moisture depletion % | Means of drip irrigation methods |
|------------------------|----------------------|---------------------------------|
|                        | 25%  | 50%  |                                      |
| SDI                    | 95.49 | 95.20 | 95.35                                |
| SBI                    | 96.57 | 96.47 | 96.52                                |
| PRD                    | 97.60 | 96.53 | 97.07                                |
| LSD_0.05               | 0.846 | N.S   | 0.846                                |
| Depletion Means        | 96.55 | 96.07 |                                    |
| LSD                    |      | N.S   |                                    |

References

[1] Abdul Razzaq, Muhammad Mubarak Ali, Makiya Kazem Alak, Abdul Razzaq Abdul Latif Al-Zubaidi and Zina Allawi Al-Ruwaishdi. 2016. The Effect of Drip Irrigation and Subsurface Irrigation System on Maize Yield and Its Components. Iraqi Journal of Agricultural Sciences. 47(1): 238-245.
[2] Williams, JF.; SR. Robert. 2007. Managing water for weed control in rice field. Dept of Plant Sciences. University of California Davis.
[3] Shock, C.C. 2004. Efficient Irrigation Scheduling. Malheur Experiment station, Oregon state university, Oregon, USA.
[4] Al-Saadoun, Jamal Nasser Abdel-Rahman. 2006. The effect of some drip irrigation standards on the distribution of water and salts in alluvial clay soil and on the growth and production of okra crop. PhD thesis. college of Agriculture , Baghdad University
[5] Al-Shaabani, Ilhab Muhammad Hussein. 2017. Effect of water stress and fractionation of fixed surface drip irrigation on some physical properties of soil and potato growth and yield. College of Agriculture, University of Anbar.
[6] Aldulaimy, S. E. H., Salman, A. K., Abood, M. A., & Hamdi, G. J. 2019. Influence of moisture depletion and surface drip irrigation style on some soil hydraulic properties and potato crop.
[7] Elhami, S., Haddadi, M., Csákvári, E., Zantar, S., Hamim, A., Villányi, V., Douaik, A., & Bánfalvi, Z. 2019. Effects of partial root-zone drying and deficit irrigation on yield, irrigation water-use efficiency and some potato (Solanum tuberosum L.) quality traits under glasshouse conditions. Agricultural Water Management. 224 (2019): 1-10. https://doi.org/10.1016/j.agwat.2019.105745

[8] USDA. "Keys to Soil Taxonomy" Eleventh Edition. 2010. Natural Resources Conservation Service. (NRCS).

[9] Black, C.A.; D.D. Evans; L.E. Ensminger; J.L. White and F.E. Clark, 1965. Methods of soil analysis, part (1). Agron. No. 9. Am. Soc. Agron, Madison, WI (USA).

[10] Kovda, V.A. 1973. Irrigation Drainage and salinity. FAO/UNESCO. An International Source Book. Hutchinson and Co. Ltd.P.468,478.

[11] FAO, Agricultural Finance Corporation (1998). Evaluation of Drip Irrigation System. Agricultural Finance Corporation Limited, Mumbai.

[12] Al-Hadithi, Issam Khudair, Ahmed Madlool Al-Kubaisi, and Yas Khudair Al-Hadithi. 2010. Modern Irrigation Technologies and Other Water Issues. Ministry of Higher Education and Scientific Research. college of Agriculture. University of Anbar.

[13] Dorota Z. Haman. 2000. Irrigation with high salinity water. Florida Cooperative Extension service, Institute of food an agricultural sciences, University of Florida.

[14] Ayers, R; and D. Westcot. 1976. Water quality for agriculture irrigation and drainage. Paper No. 29. FAO publication, Rome

[15] Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. In Black, C.A. et al., (eds). Method of soil analysis. Agron. Mono. 9 (1): 253-261. Amer. Soc., Agron, Madison, Wisconsin, USA.

[16] Haise, H. R.; W. W. Donnan.; j. T. Phetan.; L. F. Lawhan; and D. G. Shckley. 1956. The use of cylinder infiltration to determine the intake characteristics of irrigation soils. U.S.A. D. pul. Ars 7 - 41, 10 p in Jensen, M. E. 1980. Design and operation of form irrigation systems.

[17] Al-Taif, Nabil Ibrahim and Essam Khudair Al-Hadithi.1988. Irrigation: its basics and applications. Ministry of Higher Education and Scientific Research. University of Baghdad - College of Agriculture.

[18] Al Sahoki, Medhat Majid and Karima Mohamed Waheeb. 1990. Applications in the design and analysis of experiments. Ministry of Higher Education and Scientific Research. University of Mosul-College of Agriculture.

[19] Al-Issawi, Jabbar Shehab Aeada. 2010. Effect of partial drying and incomplete irrigation on drip irrigation efficiency, growth and yield of Potato (Solanum tuberosum L.). Master Thesis. College of Agriculture - University of Anbar.

[20] Ahmad S, Raza MAS, Saleem MF, Zaheer MS, Iqbal R, Haider I, Aslam MU, Ali M, Khan IH. 2020. Significance of partial root zone drying and mulches for water saving and weed suppression in wheat. J.Anim.Plant.Sci. 30(1):154–162.

[21] Al-Shami, Yahya Ajeeb Odhe. 2013. Effect of adding improvers and moisture levels on the physical properties of clay soil and water use efficiency of maize crop Zea mays. L under the drip and irrigation systems. Master's thesis - College of Agriculture - University of Basra.

[22] Al-Daraji, Furqan Khaled Kechiche. 2019. Study of some hydraulic parameters of tape drip irrigation system and the effect of soil conditioners on some soil properties and wheat plant growth (Triticum aestivum L. Master's thesis, College of Agriculture, University of Basra.

[23] Aidan, Hamid Hamdan,. 2019. Comparison of the performance of mobile drip irrigation and subsurface drip irrigation using nanotechnology in (Vicia faba L.) growth and yield of bean. Master Thesis. College of Agriculture, University of Anbar.

[24] Qin, J., Ramirez, D. A., Xie, K., Li, W., Yactayo, W., Jin, L., & Quiroz, R. 2018. Is Partial Root-Zone Drying More Appropriate than Drip Irrigation to Save Water in China? A Preliminary Comparative Analysis for Potato Cultivation. Potato Research. 61(4): 391–406.