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REVIEW ARTICLE

EFFECT OF SUBSURFACE DRIP IRRIGATION METHODS ON SOME PHYSICAL PROPERTIES OF SOIL, GROWTH AND YIELD OF POTATOES

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Abstract: A field experiment has been conducted in Silty Loam soil during agricultural season 2020 in Al-Hamdiya Research Center, north of Ramadi city, located at latitude 33° 27' 10.8" N, longitude 43° 23' 2.4" E. Three methods of subsurface drip irrigation were used, they are partial root-zone drying PRD, subsurface border irrigation SBI and conventional subsurface drip irrigation SDI, and moisture depletion rates are 25% and 50%. The results of the study showed that the PRD irrigation method had a significant effect on the bulk density values both of depths 0-15 and 15-30 cm, as it was 1.28 and 1.32 Mg m^{-3} respectively, and it had a significant effect on the values of the MWD at a rate of 0.39 and 0. 29 mm, respectively. The moisture depletion was 25% for a depth of 15-30 cm, with the highest MWD of 0.22 mm. The PRD method achieved the highest average values for plant height and leaf area of 45.5 cm and 39.5 dm^2 compared to 44.3 cm and 33.9 dm^2 when treating the SDI, while it was 45.10, 44.4 cm and 38.33, 33.83 dm^2 for the moisture depletion treatments 25 and 50%, respectively. The PRD method achieved the highest average of the total yield when depleting 25% of field capacity with a value of 28.60 Mg ha^{-1} and the lowest average of 27.08 Mg ha^{-1} when depleting 50%, while the PRD treatment gave the highest value of total yield amounting to 29.75 Mg ha^{-1} when depleting 25% of field capacity.

***Key words*:** Mean weight diameter, Bulk density, Least significant difference, PRD treatment.

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1. Introduction

The lands located within the dry and semi-arid areas are suffering from a lack of rain and precipitation, so the solutions towards irrigated agriculture in order to secure water resources for the purpose of producing a sustainable crop and increasing the area of agricultural land and then increasing the production. Moreover, global population are increasing dramatically in the in last few decades, which in turn requires increasing the quantities of irrigation water [AL-Taey *et al*. (2017), Ali *et al*. (2021)]. Therefore, it is necessary for water users to develop methods for irrigation water and securing it for those areas that are planned to be cultivated in a scientific manner. Accordingly, all required scientific methods must be used to reduce water waste and losses such as deep seepage and runoff. Many researchers went with reducing water evaporation as much as possible, which lead to achieving the highest efficiency of water use in order to get the highest possible production per quantity unit of water [Shabib (2010), Shekinah *et al.* (2012), Hamza and AL-Taey (2020)]. The limited availability of fresh water encouraged researchers to work on developing methods and practices in the field of irrigation. Perhaps one of the most important studies was exposing the plant to water stress during its growth stages, which does not necessarily cause a significant decrease in yield if the soil and plant conditions were considered a scientific and studied way. Thus, a quantity of water can be saved and used for agricultural expansion [Al-Najm (2013),

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Kudari *et al*. (2016)]. Therefore, optimizing and increasing the efficiency of water use is necessary for a country such as Iraq, by scheduling irrigation to determine the appropriate irrigation timing and adding the quantities of water needed by the plant, which leads to saving large quantities of water and increasing the irrigated area. This makes irrigation inappropriateness time is essential to maintain the productivity of the crop [AL-Taey and Burhan (2021)].

The potato crop (*Solanum tuberosum* L.) is one of the important vegetable crops in the Arab world and many countries around 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 important starchy crops such as wheat, corn and rice [Al-Shareefi *et al*. (2020)]. Potato is one of the sensitive crops 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 [Shock (2004), AL-Taey *et al*. (2019)].

Al-Khatib and Hussein (2017) found a decrease in the total yield with increasing water stress rates. The highest values for the characteristic were 20.27, 21.69, and 26.23 tons ha^{-1} when 40% of the provided water was depleted, while the yield reached 19.09, 21.34, and 23.77 tons ha^{-1} at the depletion of 50%, while it reached 18.92, 20.40 and 21.72 tons of ha^{-1} at the depletion of 60% at the processes of full, half and triple addition sequentially. Reducing the efficiency of photosynthesis, and in addition to the fact that the plant is sensitive to moisture stress, will negatively affect productivity. The DI and PRD irrigation strategies that used to provide irrigation water were able to save about 20-30% of the water used in plants by the full irrigation method, the PRD irrigation method significantly increase the productivity of the marketable potato crop by 15%, due to the improving of Potato tuber size distribution. In addition, the PRD method significantly increased the antioxidant content by about 10%, under high temperatures [Jensen *et al*. (2010)]. Al-Janabi (2012) indicated that increasing the levels of deficient drip irrigation achieved the highest increase in the total yield of potato tubers hitting 39.8 tons ha^{-1} in the full irrigation treatment (adding the full depth of irrigation), which was significantly superior compared to the levels 75% and 50% of the calculated irrigation depth, with the values of 34.7 and 29.5 tons ha^{-1}, with an increasing ratio of 14.7% and 34.6%, respectively.

In the current study, we are going to present a comparison result between three different subsurface drip irrigation strategies PRD, SBI and SDI with two moisture depletion 25% and 50% from the available water and study their effect on some physical properties of soil such as bulk density and Mean Weight Diameter MWD, growth and yield of potatoes.

2. Materials and Methods

A field experiment was conducted in Al-Hamdiya Research Center northern of Ramadi city, about 108 km west of the capital Baghdad, at latitude 33° 27' 10.8" N and 43° 23' 2.4" E longitude. Soil morphology was described and classified into (Torrifluvent) according to the American classification system [USDA (2010)]. Representative samples of field soil were taken from different regions, randomly, with a depth of 0-0.30 m. Many physical and chemical analyzes were conducted on these samples according to the standard methods mentioned in Black *et al*. (1965) and the data are shown in Table 1.

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

2.1 Mean weight diameter (MWD)

The mean weight diameter for depths between 0-15 and 15-30 cm was estimated according to the wet sieving method as stated in Youder (1936), and the average weighted diameter (MWD) was calculated from the following equation:

$$MWD = \sum_{i=1}^{n} X_i W_i \qquad (1)$$

where,

MWD = Mean Weight Diameter (mm).

W_i = mass of aggregates relative to the total weight of the sample.

X_i = Average diameter of the aggregates (mm).

2.2 Soil bulk density

The bulk density has been estimated of the soil before planting according to the method mentioned by Black *et al*. (1965) using the Core method and it was calculated from the following equation:

$$\rho_b = \frac{m}{V} \qquad (2)$$

where,

ρ_b: bulk density (Mg m^{-3}).

m: soil mass (Mg).

V: the volume of the soil (m^3).

The experiment was conducted on a land with dimensions of 39 × 12 m, an area of 468 m^2. The land was prepared by performing leveling operations, then plowed perpendicularly using a moldboard plow. After that the soil was smoothed, then divided into 18 treatments, the dimensions of each were 0.8 × 10 m distributed over three sectors. Each one contains 6 treatments. The distance between planting lines was 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 zig-zag fashion to approximate the distance between the drippers except for the treatments SDI Subsurface drip irrigation Single line. The side pipes were connected to the main line by means of triple hydrants, while the secondary (sub) pipes were connected to the side pipes. Each line had an opening and closing, and each sideline ended 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 drippers) and then bury it.

Potato tubers (*Solanum tuberosum* L.), Rivera cultivar were planted on 16/09/2020 at a depth of 0.08-0.10 m and 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).

The irrigation scheduling started from the beginning of the pre-germination phase on 16/9/2020 for all treatments according to the growth stages of the crop. The first irrigation was carried out by making soil moisture for all experiment treatments reaching the field capacity limit. The Euphrates River was considered as a source of irrigation water during the study period. The volumetric moisture was determined depending on the soil moisture description curve, at the limits of the field capacity and the permanent wilting point, while the equation of Kovda (1973) was used to calculate the depth of the added water as follows:

$$d = \frac{\theta_{fc} - \theta_{pwp}}{100} \times 100 \quad (3)$$

where,

d: depth of added water (cm).

θ_{fc}: volumetric moisture at field capacity (%).

θ_{pwp}: volumetric moisture at permanent wilting point (%).

D: depth of the root zone to be irrigated (cm).

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

$$d = (\Theta 0.25 \times D) \quad (4)$$

And calculating the depth of added water to one irrigation system at 50% was exhausted, it was from the following equation:

$$d = (\Theta 0.50 \times D) \quad (5)$$

where,

d: the depth of water to be added to the stage (cm).

Θ0.25: volumetric moisture when 25% of the prepared water has been exhausted.

Θ0.50: volumetric moisture when 50% of the prepared water has been exhausted.

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

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

$$Q \times t = A \times d \quad (6)$$

where,

d: water depth (m). A: irrigated area (m^2).

Q: discharge (liter hr^{-1}). t: time (hour).

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

$$ET_a = d \quad (7)$$

The reference evapotranspiration was calculated by substituting Equation (5) into Equation (6) according to the following equation [FAO (1998)].

$$ET_o = \frac{ET_a}{Kc} \quad (8)$$

where,

ET_a: evapotranspiration (mm day^{-1}). ET_o: evaporation-reference transpiration (mm day^{-1}). Kc: yield coefficient.

The irrigation time was determined by finding the amount of water evaporated from the American evaporation basin, class A, according to the following equation [FAO (1998)].

$$Epan = \frac{ET_o}{Kp} \quad (9)$$

where,

ET_o = 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 Al-Hadithi (2010) 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 should be added to the soil as requirements for salt washing, which is 6.05% was calculated according to the equation mentioned by Dorota (2000) of modern irrigation systems, including drip irrigation and the following:

$$LR = \frac{Ec_{iw}}{2\left(MAX_{E_{c_e}}\right)} \times 100 \quad (10)$$

where,

LR: Amount of leaching requirement (%).

EC_{iw}: The electrical conductivity of the irrigation water, m1-decimens

MAX_{ECe}: The highest electrical conductivity, dSm^{-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 [Ayers and Westcot (1976)].

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 leaf area was estimated by the gravimetric method (dry weight) by taking a fully developed leaf (the fifth leaf) for five random plants and for each experimental unit. The leaves were punctured for three locations by a tube with a diameter of 0.01 m with 15 discs and dried in an oven at a temperature of 65 Celsius until the weight was stable. The leaf area was calculated according to the equation mentioned by Wein (1997).

Table 1: Some 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	—
2	Silt			112		13	(EC)		1.67	Ds.m^{-1}
3	Clay			661		14	Positive ions	Ca_2^+	5.23	Mmol.L^{-1}
4	Texture				Silty Loam			Mg_2^+	3.92	
5	Bulk density			1.26	Mg m^{-3}			Na+	5.77	
6	Hydraulic conductivity			5.3	Cm h^{-1}			K+	0.54	
7	33	27.9	Volumetric moisture of the soil (kpa)	%						
	1500	9.1								
8	Infiltration Base Rate			7.2	Cm h^{-1}	15	Negative ions	SO_4^{2-}	7.63	
9	Mean Weight Diameter			0.41	mm			HCO_3^-	1.53	
10	$(CaSO_4)$			1.1	G kg^{-1}			CO_3^{2-}	NIL	
11	$(CaCO_3)$			213.3				Cl^-	6.65	

Table 2: Chemical properties of irrigation water.

Class	SAR	NO_3 = ppm	Dissolved Ions meq L^{-1}								pH*	EC* dS.m^{-1}
			$CO_3^=$	HCO_3^-	SO_4^{-2}	Cl^-	K^+	Na^+	Mg^{+2}	Ca^{+2}		
C3S1	1.02	0.09	Nil	0.81	1.5	6.08	0.15	2.71	3.55	3.48	7.6	0.9

$$Leaf\ area\left(dm^2\ plant^{-1}\right)=\frac{Leaf\ area\ of\ tablets\times dry\ weight\ of\ leaves}{Dry\ weight\ of\ tablets} \quad (11)$$

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

$$Total\ product\left(meg\ g\ ha^{-1}\right)=\frac{Average\ yield\ of\ 5\ plants\,(kg)\times 20200\ plants.hectare^{-1}}{100} \quad (12)$$

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 [Al-Sahoki and Waheeb (1990)].

3. Results and Discussion

3.1 Bulk density for depth 0-15 cm

The results of Table 3 showed a significant difference in the average values of the bulk density values for depth 0-15 cm using subsurface drip irrigation methods. The PRD irrigation treatment showed the lowest average bulk density values of 1.28 mcg m^{-3}, while it was 1.31, 1.33 mcg m^{-3} for the two treatments SBI and SDI Irrigation sequentially. The reason was attributed to the water added at frequent intervals and in appropriate quantities that help to keep the soil moist, which leads to an increase in the activity of microorganisms in the surface layer of the soil that works to form a network of hyphae that surround the soil particles. As well as they help to degrade the organic materials that act as carminates for soil particles lead to increase the stability of the aggregates in the soil and improve their structure, which agrees with Al-Dulaimi (2011).

There was no significant effect of moisture depletion and its interaction with the irrigation method at the bulk density values, as the rate of moisture depletion treatment 25% equal to 1.3 mcg m^{-3} compared to 1.31 mcg m^{-3} for 50% moisture depletion treatment. The lowest value was 1.27 mcg m^{-3} for $PRD_{0.25}$ irrigation treatment compared to $SDI_{0.50}$ irrigation which was 1.34 mcg m^{-3}.

3.2 Bulk density for depth 15-30 cm

The results of Table 4 indicate a considerable difference in the average values of bulk density for depth 15-30 cm using subsurface drip irrigation methods. The PRD irrigation treatment gave the lowest rate of 1.32 mcg m^{-3}, while it was 1.35,1.38 mcg m^{-3} for SBI and SDI irrigation treatments respectively. Regarding the effect of moisture depletion, significant differences were observed in the average values of bulk density, where the 25% moisture depletion treatment gave the lowest rate of 1.33 mcg m^{-3} compared to 1.37 mcg.m^{-3}, for the 50% moisture depletion treatment. The reason could be due to the fact that the increasing in the moisture depletion rates leads to increase the drying of soil and the sudden wetting causes the destruction of the soil aggregates and rearrange the particles and their disjointed aggregates. The results also showed that the interaction between irrigation method and moisture depletion does not considerably affect the bulk density values.

3.3 Mean weighted diameter for depth 0-15 cm

The results of Table 5 showed a significant difference in the mean values of the weighted diameter for the depth 0-15 cm using subsurface drip irrigation method. The PRD gave the highest average of 0.39 mm, while it was 0.17 and 0.15 mm for SBI and SDI irrigation treatments, respectively. Which could be attributed to the low soil moisture content in the superior treatments. As a result, the dry part works to extract an amount of moisture content from the irrigated part, which increases the speed of the alternation of drought and humidification cycles and thus increases the stability of soil aggregates, which led to accumulation of salts and binding materials within the root zone, which is consistent with the findings of Al-Obaid and Al-Issawi (2019).

While, the same table indicates that there are significant differences in the average values of the weighted diameter rate due to the effect of moisture depletion. The 25% moisture depletion treatment gave the highest rate of 0.28 mm, compared with 0.19 mm for the 50% moisture depletion treatment. This could be due to the high values of bulk density through wet

Table 3: Effect of irrigation method and moisture depletion on bulk density in mg-3 for depth 0-15 cm.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	1.32	1.34	1.33
SBI	1.30	1.31	1.31
PRD	1.27	1.29	1.28
LSD $_{0.05}$	N.S		0.032
Average moisture depletion	1.30		1.31
LSD	N.S		

Table 4: Effect of irrigation method and moisture depletion on bulk density, Mg-3 for depth 15-30 cm.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	1.36	1.41	1.38
SBI	1.33	1.37	1.35
PRD	1.29	1.34	1.32
LSD $_{0.05}$	N.S	0.04	
Average moisture depletion	1.33	1.37	
LSD	0.034		

and drying processes from repeated irrigation with longer durations for irrigating depletion with 50% of the ready water and an increase in the amount of water added per irrigation compared to irrigation at 25% depletion of the ready water. That result is consistent with what Mahdi (2019) found. The same table also showed that the interaction between irrigation method and moisture depletion has no major effect at the average weighted diameter values.

3.4 Mean weighted diameter for depth 15-30 cm

The data in Table 6 showed a significant difference in the values of the average weighted diameter for depth 15-30 cm using subsurface drip irrigation methods. PRD irrigation treatment gave the highest mean of the average weighted diameter values of 0.29 mm, while the average values of the average weighted diameter were 0.2 and 0.13 for SBI and SDI treatments sequentially. The reason might be attributed to the

Table 5: Effect of irrigation method and moisture depletion on average weighted diameter mm for depth 0-15cm.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	0.19	0.10	0.15
SBI	0.21	0.12	0.17
PRD	0.43	0.35	0.39
LSD $_{0.05}$	N.S		0.021
Average moisture depletion	0.28		0.19
LSD	0.017		

Table 6: Effect of irrigation method and moisture depletion on average weighted diameter mm for depth 15-30 cm.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	0.12	0.14	0.13
SBI	0.23	0.17	0.2
PRD	0.33	0.25	0.29
LSD $_{0.05}$	0.013		0.009
Average moisture depletion	0.22		0.19
LSD	0.007		

indirect improvement of soil construction by adding the level of irrigation water at the field capacity for close periods, which helps to create the appropriate conditions for good root growth. And hence, the root and microbial secretions will increase as a resin and threads that work to preserve the soil aggregates from deterioration and link with each other, as a result, it is positively affected on the values of the weighted diameter ratio. This result agrees with Darren (2005). In terms of moisture depletion, we notice that there are significant differences in the average values of the weighted diameter rate. Where 25% moisture depletion treatment gave the highest rate of 0.22 mm compared to 0.19 mm for the 50% moisture depletion treatment, which may be attributed to the high levels of irrigation that led to destruct the soil aggregation and deposit the fine particles in the soil pores, which caused an increase in the bulk density and thus affected the stability of the soil aggregates, which is consistent with Al-Janabi (2012). The results of the interaction between irrigation method and moisture depletion showed that there was a significant difference in the values of the average weighted diameter. $PRD_{0.25}$ irrigation gave the highest value of 0.33 mm, compared to $SDI_{0.25}$, which was 0.14 mm. The reason may be due to the fact that the fragmentation of the irrigation depth gives a greater opportunity to maintain an appropriate moisture content for a longer period and the soil will not be exposed to a drought condition between irrigations [Al-Dulaimi (2011)].

3.5 Potato plant height

Table 7 shows the effect of the subsurface drip irrigation method and moisture depletion on the average values of potato plant height, which is shown that the PRD irrigation treatment was significantly superior to the SBI and SDI irrigation treatments, as it gave the highest average values of 45.4 cm compared to 44.5 and 44.3 cm, respectively. The reason for this may be due to the fact that moisture in the superior treatment is available at its best levels in the root zone, which leads to the plant cells under the PRD method being less susceptible to moisture tension compared to what the rest of the irrigation methods are exposed to. Moreover, the subsurface irrigation provides fertilizers and nutrients to the plant very efficiently, which increases the activity and vitality, and this is consistent with what was mentioned by Kang *et al.* (2001) and Al-Obaidi (2001).

However, for moisture depletion, the 25% moisture depletion treatment significantly outperformed the 50% moisture depletion treatment, as the 25% moisture depletion treatment gave the highest average plant height values about 45.1 cm compared to 44.4 cm for the 50% depletion treatment. Increasing the percentage of moisture leads to increase the rate of total absorption of minerals, and increasing the vegetative growth, and then increasing the plant height compared to other irrigation treatments and this is consistent with what Elhani *et al.* (2019) have found.

For the interaction between irrigation method and moisture depletion treatments, the highest value of potato plant height was 46.1 cm for $PRD_{0.25}$ irrigation treatment, which is significantly superior to all other interaction treatments. While the lowest value of potato plant height was 44.1 cm for $SDI_{0.50}$ irrigation treatment,

Table 7: Effect of irrigation method and moisture depletion on potato plant height cm.

Drip irrigation methods	Moisture depletion (%) 25%	50%	Average irrigation methods
SDI	44.50	44.10	44.30
SBI	44.70	44.20	44.50
PRD	46.10	44.80	45.40
$LSD_{0.05}$	1.30		0.90
Average moisture depletion	45.10		44.40
$LSD_{0.05}$	0.70		

and perhaps the reason is due to the partial drying method of the root zone compared to other irrigation methods. The experimental results have shown that it increases the efficiency of irrigation and thus provides moisture at its best levels in the root zone, which means that the plant cells are not exposed to high moisture tension. Also, increasing the humidity will lead to increase the rate of total absorption of minerals and this agrees with Elhani *et al.* (2019).

3.6 Potato leaf area

Table 8 shows the effect of the subsurface drip irrigation method and moisture depletion their interaction on the average leaf area values. We noticed that the PRD irrigation treatment was significantly superior to the SBI and SDI irrigation treatments, as the average leaf area values were 39.5 dm^2 compared to 34.9 and 33.9 dm^2, respectively. The reason for this may be attributed to the fragmentation of the irrigation depth and the efficiency of this method in maintaining adequate moisture for the plant, and thus increasing the leaf area, which is consistent with what was stated by Liu *et al.* (2006).

However, for moisture depletion, depletion treatment significantly outperformed the depletion treatment. The 25% treatment gave an average of 38.33 dm^2, while it reached 33.83 dm^2 for 50% treatment, and this is consistent with Amanullah *et al.* (2010).

In other hand, the interaction between irrigation method and moisture depletion treatments, $PRD_{0.25}$ treatment showed the highest value of leaf area was with 40.5 cm^2, which is significantly superior to all other interaction treatments. While, the lowest value was 30.9 cm^2 for $SDI_{0.50}$ treatment. Which is the sequence of

Table 8: Effect of irrigation method and moisture depletion on leaf area dm^2 of potato plant.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	36.80	30.90	33.90
SBI	37.70	32.10	34.90
PRD	40.50	38.50	39.50
$LSD_{0.05}$	2.00		1.40
Average moisture depletion	38.33	33.83	
$LSD_{0.05}$	1.10		

Table 9: Effect of irrigation method and moisture depletion on leaf area dm^2 of potato plant.

Drip irrigation methods	Moisture depletion (%)		Average irrigation methods
	25%	50%	
SDI	27.674	24.610	26.142
SBI	28.458	27.974	28.216
PRD	29.753	28.681	29.217
$LSD_{0.05}$	N.S		1.444
Average moisture depletion	28.628	27.088	
$LSD_{0.05}$	1.179		

drought and hydration cycles that results in urging the roots to absorb and making the necessary elements in the soil bed more easily to absorb by the plant grown by employing the partial drying system of the root zone and this is what Iqbal *et al*. (2020) referred.

3.7 Total yield (Mha^{-1})

Table 9 shows the effect of irrigation method and moisture depletion and their interaction on the yield. It is clear that the irrigation treatment was significantly superior to the SDI and SBI irrigation treatments. PRD shows the highest average with 29.217 Mgram ha^{-1}, followed by SBI treatment with an average of 28.216 Mgram ha^{-1} and SDI with 26.142 Mgram ha^{-1}. The reason may be due to the lack of moisture in the soil as a result of the addition of PRD, which is less in total with the added water compared to SBI and SDI irrigation, which significantly affected the yield, and this is what Al-Issawi (2010) found. Whereas, for the moisture depletion rate, the 25% depletion treatment with a rate of 28.628 mcg ha^{-1} was significantly outperformed the 0.50 depletion treatment that has a rate of 27,088 mcg ha^{-1}. The reason was because of adding water in a close period and which helps to provide the nutrients in the area of root collections when needed. Also, its maintaining the appropriate humidity preventing water leak outside the root zone, which is reflected on the yield.

There was no significant effect of the interaction between irrigation systems treatments and moisture depletion. The highest yield was 29.753 mcg ha^{-1} for $PRD_{0.25}$, while the lowest yield was 24,610 mcg ha^{-1} for $SDI_{0.50}$ treatment. The reason is attributed to decrease the amount of added water which led to a decrease in the yield rate due to exposing the potato plant to water stress, which led to decrease the vegetative growth indicators of the plant, which then reflected on the total yield. All of that might be due to the negative effect of water stress at 50% depletion on biological processes, carbon metabolism, transport of nutrients and carbohydrates, enzymatic activity, plant hormones and elongation the cells and their division. Which led to a reduction in the number of tubers, their weight and the total yield. In addition to providing water and nutrients in the root system area when the plant needed.

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