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EFFECT OF DIFFERENT IRRIGATION SYSTEMS ON IRRIGATION WATER USE EFFICIENCY, GROWTH AND YIELD OF POTATO UNDER BAZIAN CLAY LOAM SOIL CONDITION

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ABSTRACT

A field experiment was conducted at Bazian Agricultural Research Center, Sulaimani governorate in clay loam soil to investigate the effect of different irrigation systems (Furrow "F", Sprinkler "S", Drip "D", and Sub-surface drip irrigation system "SD" with three different depths (10cm-SD_{10},25cm-SD_{25}, and 40cm-SD_{40}) on irrigation water use efficiency, growth and yield of potato (SYLVANA c.v). Results showed that the total amount of water delivered from the source was significantly smaller for (SD_{25}) and (SD_{40}). Maximum water used by potato root and the higher application efficiency were observed by (SD_{25}). There are no significant differences between (SD_{25}) and (SD_{40}) in irrigation water use efficiency IWUE, while the both systems were superior significantly on the other irrigation systems in this trait.

(SD_{25}) recorded the highest value and significantly dominated on other irrigation systems in many growth characteristics of potato. As well as this irrigation system (SD_{25}) was significantly increased potato yield and the percentages of yield increase were 35.5% and 27.6% compared to (F) and (S) respectively. There were no significant differences between (SD_{25}) and (D) in the average of tuber weight, while both treatments were superior significantly on the other irrigation systems. No significant different recorded between (S) and (F) for all growth and yield characteristics. Generally (SD_{25}) gave better results in water use and potato production.

***KEYWORDS**:* Irrigation System, Subsurface-drip, Water use, Potato growth, Yield

INTRODUCTION

Development of irrigated agriculture depends not only on sufficient water available, but also on the suitable irrigation system selection. Selecting an appropriate irrigation method has an effect on economic return through maximizing crop yield while minimizing the irrigation water used. Seckler et al. (Seckler, Amarasingle, Molden, Silva, & Barker, 1998.) Concluded that by developing irrigation processes 50% of the water demand increase can be covered by 2025. There are many well-known irrigation systems, such as border strip, furrow, sprinkler, drip and subsurface drip irrigation system. With increasing water demand sprinkler and drip irrigation methods are play a great role in improving irrigation. In recent years the application of drip irrigation in Iraq has grown up due to installation cost decrease (Badr, Abou Hussein, Al-Tohamy, & Gruda, 2010).

Subsurface drip irrigation system SD is one of the modern irrigation techniques used around the world. In subsurface drip irrigation system irrigation water is applied directly to the root zone, reducing losses due to surface runoff and evaporation. There is also no losses due to deep percolation while a small part of soil will be wetted. Nowadays, due to continues water resource decreases, subsurface drip irrigation required evaluation in order to improve water use efficiency. Installing drip laterals at deeper depth results in the reduction of soil evaporation, in contrast the deep percolations will increase. In sandy loam soils, downward movement of water occurs considerably because gravity force is larger than capillary force. Therefore, it is recommended to place drip laterals at a depth of (10 cm) for potato crop to reduce water losses due to deep percolation (Kumari, 2012).

Subsurface drip predominated surface drip irrigation significantly for potato yield in fields with sandy soil (Ati, Iyada, & Najim, 2012) and maximum average yield was recorded with subsurface lateral drip installed at 15 cm depth compared to 30 and zero cm depths. (Neelam &

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T.B.S., 2006). According to (Bozkurt and Mansuroğlu) the highest lettuce yield was obtained from drip laterals placed at 10 cm depth over zero and 20 cm drip line depth (Bozkurt & Mansuroğlu, 2011) . Onder et al. (Onder, Caliska, Onder, & Caliskan, 2005) concluded that in early potato productions under Mediterranean conditions the subsurface drip did not show considerable preferences on surface drip irrigation, however subsurface drip irrigation method was more expensive and difficult to replace. Ati et al (Ati, Iyada, & Najim, 2012) studied the effect of different irrigation methods and potassium fertilizers on the yield of potato and from the results both furrow and drip irrigation methods didn't have significant effects on tuber yield.

Potato is considered as a major food crop in many countries. It has a shallow root zone with most of its root system lying in the upper 40 cm zone of soil, also the root may extend to (1m) of soil depth. (Ati, Iyada, & Najim, 2012). Potatoes have a lower toleration for water scarcity than most other crops. When the applied irrigation water equaled to the exact water required depending on soil water tension measurement, potato plants had a higher quality/quantity product than if they were under/over irrigated. (Kang, Wang, Liu, & Yuan, 2004)..

The effects of irrigation methods have been widely studied for potato (Kumar, Asrey, Mandal, & Singh, 2009) (Onder, Caliska, Onder, & Caliskan, 2005), (Camp, 1998). In Kurdistan-Iraq, insufficient information about the irrigation water use efficiency and potato yield is available. The application of pressurized irrigation systems in Kurdistan-Iraq is limited. Subsurface drip irrigation system as a special case of drip irrigation system also had not got interest. The vast majority of Iraqi potatoes are furrow irrigated (USAID Iraq). New strategies are required to promote water saving and irrigation system improvement. Moreover under conditions of continuous decreasing of water sources, techniques based on best irrigation method and higher potato yields seem to be reasonably appropriate.

The objective of this study was to assess and compare the effects of different irrigation systems (furrow irrigation, sprinkler irrigation, drip irrigation and subsurface drip irrigation with different depth of drip line placement) on irrigation water use efficiency (IWUE), growth and yield characteristics of potato under Bazian and clay loam soil condition.

MATERIALS AND METHODS

A field experiment was conducted at Bazian Agricultural Research Center during (March to July 2014) located about (20 km) south west of Sulaimani governorate- Kurdistan - Iraq, with latitude (45˚ 07' 54"), longitude (35˚ 36' 31") and an altitude of (842m) above sea level, to evaluate the effect of different irrigation systems from both engineering and agronomic viewpoints. Soil samples were taken from the depth of (0-30 cm) at the location and analyzed in Directorate of Agricultural Research Center, Bakrajo. Some basic soil physical and chemical properties are given in Table (1).The experiment location characterized by Mediterian climate (Al-Ansari, 2013), the meteorological data during the growing season were collected and summarized in (Table 2).

Table(1):- Some physical and chemical properties of the experiment soil

Soil texture	E.C. ds.m^{-1}	PH	N%	Available P Ppm	Soluble K^+meq.l^{-1}	Soluble Na^+ meq.l^{-1}	Soluble Ca^+meq.l^{-1}	Soluble Mg^+ meq.l^{-1}	Cl meq.l^{-1}	O.M. %	$CaCO_3$ %	HCO_3 meq.l^{-1}	CO_3 meq.l^{-1}
Clay loam	0.28	7.7	0.14	15.18	0.10	0.17	1.9	3.6	0.4	2.06	27.1	1.7	0.3

Table(2): Some meteorological data of the experiment location during the study period

Month	Average Temperature (˚C)	Average relative humidity (%)	Average wind speed (Km. h^{-1})	Average sunshine duration (h)	Rainfall (mm)
March	13.65	55.3	1.78	5.6	24.4
April	17.94	50.5	1.31	7.9	19.2
May	25.90	26.3	1.45	8.9	3.3
June	27.90	20.9	1.65	11.8	1.4

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July	31.76	11.2	1.96	12.2	0

Water used for irrigation was taken from a local well. The irrigation water was tested and the results (Table 3) showed that its quality was within the acceptable limits.

Table (3): Irrigation water test results

E.C. (ds.m^{-1})	PH	SolubleK^{+} (meq.l^{-1})	SolubleNa^{+}(meq.l^{-1})	Soluble Ca^{+}(meq.l^{-1})	SolubleMg^{+}(meq.l^{-1})	HCO_3 (meq.l^{-1})	CO_3 (meq.l^{-1})
0.4	7.2	0.012	0.12	3	1.2	4.5	0.7

The field was plowed twice across each other and the experimental plots were prepared manually. Each plot measured 8.10 m^2 (3.00 * 2.70 m) and contained 30 plants spaced (0.90 * 0.30 m), plots were separated 2 m from each other. The potato cultivar used was SYLVANA, originating from the Netherlands. The tubers were planted manually, at a depth of 15 cm on March 3, 2014, and harvested on July 1, 2014. Standard agricultural practices such as fertilization, weeding, disease and pest control were carried out uniformly during the growing season for all treatments. All plots received basic application of 260 kg.ha^{-1} Urea (46% N), 160 kg.ha^{-1} Di-ammonium Phosphate (18% N and 46% P_2O_5) and 180 kg.ha^{-1} Potassium Sulfate (50% K and 17% S). Before the potatoes emerge, the same amount of water with the same frequency were applied to all of the treatment plots in order to guarantee a uniform germination (Wang, et al., 2011).Irrigation done depending on available water holding capacity using Tensiometers installed at (30) cm soil depth and used to monitor soil moisture content. All irrigations scheduled to be start when the moisture content drops below (50%) of available water holding capacity.

The experiment consisted of (6) treatments:

(F): Traditional furrow irrigation system, irrigation done by traditional surface irrigation method which is considered as control treatment.

(D): Drip irrigation system, the drip line was placed in the experimental plot on the soil surface. The lateral pipes were 20 mm in diameter. The drippers were twin wall, 30 cm dripper spacing, and (6 ℓ. h^{-1}) flow rate.

(SD_{10}), (SD_{25}) and (SD_{40}): these treatments are consisted of drip irrigation system with drip lines buried to depths of (10, 25, and 40 cm) respectively, this method is symbolized as (SD) for irrigation type and (SD_{10}, SD_{25}, and SD_{40}) referring to lateral line depths of (10, 25, and 40 cm) respectively.

(S): Solid set sprinkler irrigation method with one lateral line. The sprinkler spacing was about %40 of wetted diameter. The sprinkler used was characterized as (H-RB20, Nozzle 2.4 mm, operation head 2.5 bar, application rate 20 mm. h^{-1}). Sprinkler are set on riser of (70) cm height.

Experimental design was Randomized Complete Block Design (RCBD) with three replications. Data were analyzed by a computer program (XLSTAT Pro 7.5.3. 2005) and the comparisons among means were carried out by Duncan's Multiple Range test at $P \leq 0.05$ (Al-Rawi & Khalafulla, 1980). Each replication consisted of six experimental units and treatments were arranged randomly.

Measurements have been made in two aspects, engineering and agronomic. The following measurements for engineering aspect were done (delivered water from the source, total evaporation, deep percolation, water used by crop root, application efficiency and irrigation water use efficiency).

The field application efficiency was calculated by dividing water depth that is consumed by a crop relative to the depth of applied water (Bekele & Tilahun, 2006).

$$E_a = \frac{Water\ depth\ used\ by\ crop\ root\ (cm)}{Water\ depth\ applied\ in\ the\ field\ (cm)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Irrigation water use efficiency (IWUE) was calculated by dividing the yield obtained per unit of irrigation by total water applied, The IWUE was calculated from the following equation: (Ati, Iyada, & Najim, 2012):

$$\text{IWUE} = \left(\frac{\text{Total yield (kg)}}{\text{Total water applied } (m^3)}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

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For agronomic analysis; the following parameters were recorded from five plants and the means were recorded: root length (cm), plant height (cm), Stem diameter (mm), number of leaves per plant, leaf area (cm^2), leaf Chlorophyll content (mg. g^{-1} fresh weight), number of tubers per plant, tuber weight (g), yield (g $plant^{-1}$).

RESULTS AND DISCUSSION

Effect of different irrigation systems on different water use measurements of potato are given in (Table 4) and (Figure 1). The experiment resulted in significant ($P \leq 0.05$) difference in all irrigation systems on all measured parameters. The total amounts of water delivered from the source during the growing season were significantly higher for furrow (F) and sprinkler irrigation systems (S) with values of (2100 and 1850 liter) respectively, while the lowest amount was measured by (SD_{40}) and equaled (1010 liter) which was not differed significantly with (SD_{25}).Water losses due to evaporation was large for furrow (F) and sprinkler irrigation systems (S), since the furrow irrigation system has no potential to save irrigation water by reducing wetted soil surface and sprinkler drops are exposed to sunlight and wind. Moreover adding small amount of water prevented deep percolation except in furrow irrigation due to large amount of irrigation water added (Trautmann & Porter , 2012). Number of irrigations for the total growth season were maximum for furrow (F) and sprinkler systems (S) and minimum Drip irrigation systems. There were no significant differences between the irrigation systems (Drip "D", Sub-surface drips "SDs" and Sprinkler "S") in the depth of water used by potato roots while all of them superior significantly on the furrow system. There are not significant differences between all drip (D) and subsurface drip irrigation systems (SDs) in the application efficiency, while they were superior significantly on the furrow (F) and sprinkler irrigation systems (S) in this trait. The higher application efficiency was observed by (SD_{25}) which was equal to 88% and the lowest value gave by furrow system (F) which was equal to 52%. The subsurface drip irrigation system (SD_{25}) resulted in the highest value of IWUE (12.387 kg. m^{-3}) which was superior significantly over furrow, drip and sprinkler irrigation systems, whereas the percentage of increase was (161, 55.5 and 115.5%) respectively. A sample of IWUE calculation is given in the following (Furrow method given as an example):

$$\text{Total yield per plot (kg/plot)} = \text{Average yield per plant} * \text{Number of plants per plot}$$

$$\text{Average yield per plant} = 375.1\,\frac{\text{gm}}{\text{plant}}\ \text{from Table (6)}$$

$$\text{Average yield per plant} = 0.3751\,\frac{\text{kg}}{\text{plant}}$$

$$\text{Total number of plants per plot} = 30\ \text{plants/plot}$$

$$\text{Total yield per plot (kg/plot)} = 0.3751 * 30 = 11.253\ \text{kg/plot}$$

$$\text{Total water applied} = 2100\ \text{Liter, from Table (4),}$$

$$\text{Total water applied} = 2.1\ m^3$$

$$\text{IWUE} = \left(\frac{\text{Total yield (kg)}}{\text{Total water applied } (m^3)}\right)$$

$$\text{IWUE} = \left(\frac{11.253(\text{kg})}{2.1\ (m^3)}\right) = 5.36\ kg/m^3$$

Table(4):- Different water used measurements for different irrigation systems

Irrigation systems	Delivered water from the source (ℓ)	Total Evaporation (cm)	Deep percolation (cm)	Number of Irrigations	Water used by crop root (cm)	Application efficiency (%)	IWUE kg.m^{-3}	IWUE Increase of SD_{25}%
F	2100 a	25.1	4.8	12	40 b	52 c	5.363 d	161
D	1480 b	0	0	10	49.1 a	60 a	9.123 bc	55.5
SD_{10}	1350 bc	0	0	11	47.4 a	74 a	9.213 b	52
SD_{25}	1100 cd	0	0	9	49.3 a	88 a	14.007 a	0
SD_{40}	1010 d	0	0	9	48.2 a	87 a	12.387 a	13.8
S	1850 a	15.3	0	12	46 a	66 b	6.50 cd	115.5

Means with different letters are significantly different according to Duncan's multiple ranges test at P≤0.05

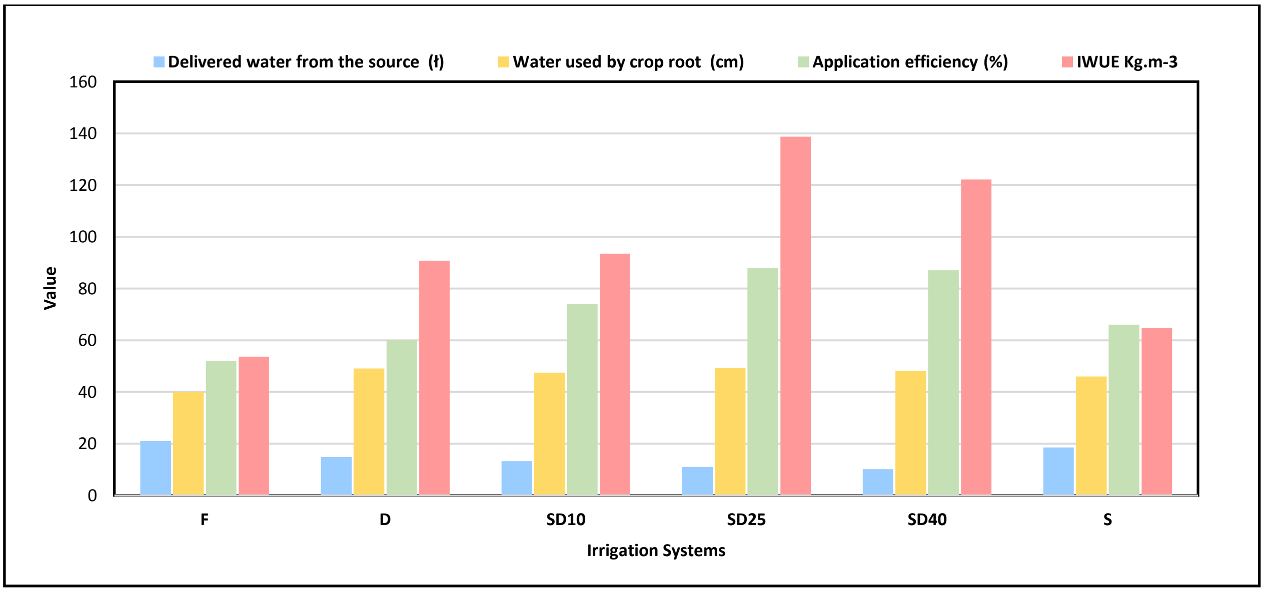

Fig. (1): Comparing parameters for different irrigation systems-For the purpose of clarifying; Delivered water from the source was divided by (100) and IWUE was multiplied by (10)

Comparing the results of agronomic characteristics, Table (5) shows that there were differences among different irrigation systems for potato plant growth. Subsurface drip irrigation system (SD_{25}) was superior significantly over furrow system (F) in root length, plant height, stem diameter and number of leaves per plant by (33.9, 31.7, 60.4 and 25.2%) respectively. while, mean of leaf area was not affected significantly by different irrigation systems. Drip irrigation system (D) gave the highest value of total chlorophyll content in leaves (44.87 mg.g^{-1}) and dominates significantly over furrow (F) and sprinkler irrigation systems (S) by (20.7 and 19.7%) respectively. Sprinkler irrigation system (S) was not different significantly from the furrow system (F) with regard to in all growth characteristics.

Table (5):- Effect of different irrigation systems on potato growth (SYLVANA c.v)

Irrigation Systems	Root length (cm)	Plant height (cm)	Stem diameter (mm)	No. of leaves plant^{-1}	Leaf area (cm^2)	Leaf chlorophyll content (mg g^{-1})
F	50.10 b	79.10 c	10.10 c	145.2 c	54.37 a	37.17 b
D	63.20 ab	91.77 b	14.20 ab	168.2 b	52.60 a	44.87 a
SD_{10}	54.30 b	84.20 bc	10.30 c	159.3 b	51.13 a	39.91 ab
SD_{25}	67.10 a	104.20 a	16.20 a	181.8 a	57.60 a	39.21 ab
SD_{40}	53.20 b	85.10 bc	11.10 bc	171.0 ab	53.33 a	40.33 ab
S	51.20 b	80.20 c	10.10 c	138.8 c	49.07 a	37.47 b

Means with different letters are significantly different according to Duncan's multiple ranges test at P≤0.05

Table (6) represented the influence of different irrigation methods on yield parameters of potato. The data revealed that subsurface drip irrigation system (SD_{25}) was significantly increased potato yield if compared to all other irrigation methods, whereas the percentages of yield increase were 35.5% and 27.6% compared to furrow (F) and sprinkler irrigation systems (S) respectively. The ability of (SD_{25}) to improve tubers yield could be attributed to the better performance under subsurface drip that can maintain a favorable soil water status in the root zone, which in turn helped the plants to utilize moisture as well as nutrients more efficiently from the limited wetted area. Moreover an advantage of burring the lateral drip lines at 25 cm is that the lateral depth is sufficient to avoid damage from tillage or other equipment but shallow enough to wet the root zone without wetting the soil surface (Abou Lila T.S. et al, 2013) .

Subsurface drip irrigation (SD_{25}) has led to increase the mean of tubers weight (101.6 g), due to the role played by this irrigation system to improving the root and vegetative growth of plants (root length, plant height, stem diameter, number of leaves, leaf chlorophyll content and leaf area of the plant) which are leads to increases ability of the plant to form tubers more larger sizes and then increasing the plant yield. Sprinkler irrigation system (S) was used to record the largest number of tuber per plant (6.1) which it is not differ significantly with other irrigation systems except drip irrigation (D). Also, sprinkler irrigation method (S) was not different significantly from the furrow system (F) in all yield traits.

Table(6): -Effect of different irrigation systems on potato yield (SYLVANA c.v)

Irrigation Systems	Yield (g plant^{-1})	Tubers weight (g)	No. of tubers plant^{-1}
F	375.10 c	66.97 b	5.7 ab
D	447.30 b	99.40 a	4.5 b
SD_{10}	412.50 bc	73.60 b	5.6 ab
SD_{25}	508.40 a	101.60 a	5.0 ab
SD_{40}	411.40 bc	77.60 b	5.3 ab
S	398.40 c	66.40 b	6.1 a

Means with different letters are significantly different according to Duncan's multiple ranges test at P≤0.05

Depending on the results and discussions of this field study, it can be concluded that the (SD_{25}) method offers considerable advantage for both yield and IWUE of potato. It seems to optimize the use of water in potato production under situations of water shortage then could be recommended for irrigation of potato crop under the Mediterranean climate of Kurdistan-Iraq with the possibility to reduce supply of limited water availability.

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