Evaluation of mobile trickle irrigation and sub-surface nanotechnology trickle irrigation by irrigating bean (cv. Veto)

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Abstract. Water resources are suffering from scarcity and deterioration their quality due to environmental dilution. Trickle irrigation is the best efficiency systems because it focuses on the root space only, omitting surface runoff and minimizing deep percolation losses.
A field study was carried out in clay loam soil in Ramadi city (College of Agriculture- University of Anbar) during the fall season of 2018 using two trickle irrigation systems, mobile system and under surface drip irrigation by using Nano-Root guard drippers.
Current study aims to evaluate the physical properties effects, water consumption of bean (cv. Veto) and water use efficiency. for the purpose of comparing the yield of bean irrigated by these two methods.
Seeds of bean were sown on 20th of October 2018 and the harvest time was on 13th of March 2019. Evaporation pan was used to estimate the irrigation dates when the depletion of the soil reaches 50% of its water content. Bean productivity significantly increased under surface trickle irrigation with 7.71-ton ha-1 in comparison to 6.32-ton ha- 1 that was obtained from mobile trickle irrigation method. The crop water requirement was 446 mm according to evaporation pan data. Regarding the method of irrigation, they were affected. As a result, the soil water content average for the three replications along growing season was 21.75% under mobile device while it was 24.96% in the sub-surface drip irrigation.
Keywords: trickle irrigation, sub-surface trickle irrigation, mobile trickle irrigation.

1. Introduction

The issue of water scarcity has become one of the greatest challenges facing the world. In particular, water loss in irrigated agriculture has become one the major influences on water scarcity, and it is also expected to be a major challenge in the coming years. This is attributed to many factors such as the scarcity of usable water resources, and the increasing demand of water for agricultural activity. Therefore, the demand for water is directly proportional to the increase in the population [10]. Therefore, it has become necessary to use modern technologies in irrigation, with the aim of saving irrigation water, and enhancing the uniform distribution of moisture and nutrients in the root zone with preserving soil properties [1]. The relationship between crop productivity and water consumption is direct, as the productivity increases with the increase in water consumption in the last stages of crop growth due to the high humidity in the root zone of the plant [2]. These results are consistent with what was found by the mechanism [3] where he showed that there is an increase in the production of a crop. in addition, when the water consumption reached 487 mm, Season-1, the production started to decrease with the increase in water consumption [4]. However, when planting fava beans obtained an economy of the amount of water consumed during the growing season if using the mobile drip irrigation system, as the water consumption decreased to 266 mm season-1 as compared to 318 mm season-1 when using subsurface trickle irrigation), i. e. a decrease of 16.56 % [5].

2. Materials and Methods

A field experiment was conducted in the fields of the College of Agriculture – University of Anbar during the winter season 2017-2018, in mixed clay soil (clay loam) for the period from 20/10/2018 to 3/13/2019. It aims to compare the mobile surface drip irrigation method with subsurface drip irrigation with Nano scopes. (Nano-root guard) was obtained from the Turkish company GeoFlow, in some physical properties of the soil, water parameters, and plant growth, as well as the effect of wind on evaporation rates in both methods. The experiment was applied according to the design of complete random sectors. The soil was prepared after plowing using a tipping plow, leveling it using a leveling machine, smoothing with the simplicity of a punching plow, and then dividing the field into two transactions representing two sectors. The first treatment included the subsurface drip irrigation method using Nano scopes (Nano-root guard) with three replications. The seeds of (VETO) beans were planted on 10/20/2018 as an indicator of growth and production and the season ended on 3/3/2019. Soil samples were taken at the depth of 0.00-0.30 m and tested through a sieve of 2 mm for the purpose of conducting laboratory analyzes. Table 1 includes a summary of some physical and chemical characteristics of the study soil samples. All soil samples tests were done in Agricultural soil laboratory, university of Anbar, Iraq.

Table 1: Physical and chemical soil properties at depthe of 0-30 cm.

Chemical properties			**Physical Properties**		
Quantity	**Units**	**properties**	**Quantity**	**Properties**	
7.44		pH	38	Sand	Soil particles. %
4.69	ds m^{-1}	Ec	32	Silt	
2370	mg L^{-1}	Ca^{+2}	30	Clay	
988	mg L^{-1}	Mg^{+2}	Clay Loam		Texture
2532	mg L^{-1}	Na^{+}	48.5	0	Water content by wt.% at special tension. (bar)
109	mg L^{-1}	K^{+}	32.8	0.33	
3545	mg L^{-1}	Cl^{-}	12.6	15	
1046	mg L^{-1}	$HCO3^{-}$	20.2	Available water %	
98	mg L^{-1}	$CO3^{-2}$	1.37	Balk density Mg m^{-3}	
1310	mg L^{-1}	$SO4^{-2}$	2.63	Actual density Mg m^{-3}	
0.38	g kg^{-1}	O.M	47.90	Void ratio %	
	Cm/hr.		9.87	Hydraulic conductivity	

Seeds of bean (VETO Spanish) were planted at a rate of 25 kg dunam-^{1} adopted in Iraq in the irrigated areas according to [6], in the form of lines on both sides of the drip line alternately. The distance between lines was (80 cm) and between one plant and another was (35 cm). Phosphate fertilizer was added in the form of mono superphosphate (DAP) (P2O5 46%) at a rate of 120 kg Hc-^{1} at once according to [4]. The first irrigation was given on 10/20/2018 to bring the soil moisture content to the limits of the field capacity (matric potential is 33 kPa). Then, the irrigation scheduling was applied according to the depth of the roots with the stages of crop progress when 50% of the ready water was depleted. The bush control (weeding) process was carried out manually and as needed. The irrigation interval was based on the evaporation basin (American Class A) located within the site of the experiment.

Irrigation was done when 50% of the ready water was depleted, and it was adopted in scheduling irrigation based on the growth stages of the leguminous crop. These stages were divided into four stages according to [7]. The depth of the water to be added was calculated according to Equation 1 [16]

$$d = (\theta_{f.c} - \theta_{pwp}) /100*D \quad (1)$$

As: d: depth of added water (m) θ_{fc}: volumetric moisture content at field capacity (%) pwp: volumetric moisture content just before irrigation (%) D: root zone depth (m). The evaporation basin was adopted Class-A according to [8]. To calculate the depth of the added water

2.1. Trickle Irrigation Machine:

It is a modified axial sprinkler irrigation system that was manufactured locally [3], in which the sprinklers were replaced by metal tubes hanging to a height of (0.2 m) from the level of the ground level. The distance between these hanging tubes was brought closer to a distance of (0.8 m) between one pipe and another. The drippers were replaced by a valve to control the discharge of each hanging pipe according to the area that it irrigated. These tubes ended with a flexible plastic tube with a length of (0.50 m) drawn over the surface of the soil. The system consists of a fixed end (the center tower) installed on a concrete base, where the system is supplied with water from its source. The center tower consists of four columns linked together by horizontal pillars with a straight tube in its center. (Figure 1)

To connect the water to the moving part, an electrical control board containing the operating switches is installed on the tower. The system speed regulator, electric current meters, and the second part is the rotating arm from which the tubes hang. It ends with two frames, and an electric motion generator with a rotational speed converter (gearbox). The area irrigated by each point was calculated as shown in Figure 1.

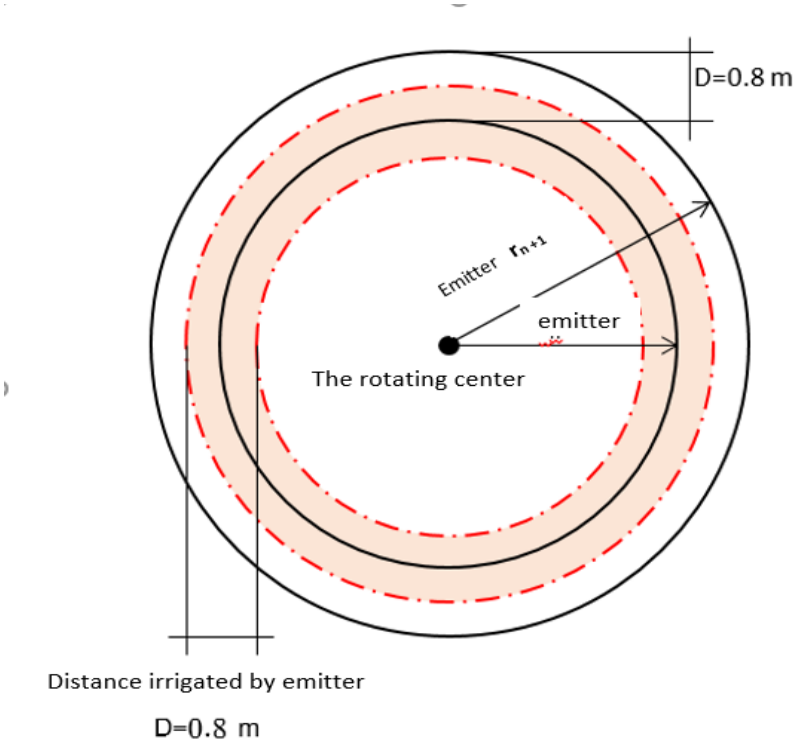

Figure 1: How to calculate the irrigated area

Whereas: A_n: The area that the point number n (m 2) irrigates R_n: after the n point from the center of the system. (M)

D: the distance between each two hanging tubes (m) π: the constant ratio (3.14) Figure 1

The proportionality coefficient between each of the two conjugations is calculated according to [10] from the following equation:

$$F\_((n, n-1)) = A\_n / A\_((n-1)) \quad 2$$

As: F _ ((n, n-1)): the coefficient of proportionality between the two points, A_n: the irrigated area at the point n. (M 2)

A _ ((n-1)): the area irrigated at the (n-1) drip (m2)

The volume of water is calculated from the first point of the system to the area of the first point during a capacity time (5.5 minutes) which represents the time of a complete cycle of the system using containers of (1 liter) after controlling the discharge to the minimum value.

Then, the discharge of other points is computed by multiplying the discharge by the proportionality factor according to [11] as follows:

$$Q_n = Q\_(n-1) \times F\_((n, n-1)) \quad 3$$

As: Q_n the discharge of the dotted (n),: Q_ (n-1), the discharge of the dotted preceding it,: F_ (n, n-1) the ratio coefficient between the two consecutive points.

2.2. Nano-Root guard

Figure 2: Nano-Root -Guard (ASSIF)

The Nano-drippers were obtained from the Turkish company GeoFlow. The latest form of the Nano-Root guard is the (VERD), ASSIF, GFPC, VARDIT, where each dripper is used with a type of plant What was used in the research is type (ASSIF) Figure 2, which is used for crops, their discharge varies according to the operating pressure. It usually operates at low operating pressures from (0.2 to 2 bar), and has a diameter of 16 mm. It contains a Nano-leachate membrane that contains 109 cm-2 holes and the distance between droplet and another is 0.35 m, calibrated. The dripper at a pressure of (0.2 bar) yields a 1.6 liter hour $^{-1}$.

2.3. Crop Consumptive Use:

The recorded daily evaporation was measured from the evaporation basin, and then the reference evaporation - transpiration was calculated using equation [12]

$$ET_o = Kp \times Epan \quad 4$$

ETo = evaporation - reference transpiration (mm day^{-1}), Kp = pan coefficient%, Epan = evaporation from the pond (mm day-1)

Kp (0.70) was adopted because the area is cultivated. The relative humidity is low, less than 40%, and the wind speed is moderate 2 - 5 m s-1 according to [9]. Then it is calculated according to the actual crop water consumption for both methods according to Equation (4) according to evaporation - actual yield according to the following equation (5).:

$$ET_a = ET_o \times Kc \quad (5)$$

ETa = evaporation - transpiration (mm day $^{-1}$), ETo = evaporation - reference transpiration (mm day - 1), Kc = yield factor%

The yield factor for legumes mentioned in (5) As follows:
Initiation of vegetative growth (germination) 0.3 - 0.4
End of vegetative growth 0.65 - 0.75
Flowering 0.95 - 1.05
Full maturity (dry ripeness) 0.85 - 0.90

2.4. Crop water use efficiency:

It is the ratio between crop yield (Y) to the amount of water used by the crop in the form of evaporation-transpiration (ET) according to the formula proposed by [13].

$$\text{Crop Water Use efficiency} = \frac{Y}{ET} \quad (6)$$

The statistical analysis of the obtained results of soil and plant samples was carried out using Excel program, and the lowest significant difference LSD was calculated at a significance level of 0.05.

3. Results and Discussion

3.1. Consumptive Use

Table (2) shows the amount of water consumption that was calculated based on the readings of the evaporation basin and the yield factor from previous research. It is noticed from the table that the rate of water consumption has a general trend. It started slightly and then increased until it reached it peak in the stage of productive growth. Then it increased again. In the stage of maturity, and according to this table (2), the value of seasonal water consumption reached 446 mm. This value will change according to the method of irrigation, its efficiency, the climate and the soil texture. As this value in the germination stage and its duration of 35 days, it reached 51.72 mm, which represents 11.59% of the actual water consumption. Then it increased with the increase in plant growth until it reached 133.45 mm during the vegetative growth phase of 40 days. Growth phase represents 29.92% of the actual total water consumption. While the consumption in the reproductive growth phase reached 148.89 mm, which is of a period of 30 days, which represents the proportion of 33.38% of the total actual water consumption. At the maturity stage of 40 days, the actual water consumption value was 112.21 mm, which represents a ratio of 25.15%.

Table 2: Consumptive use for four plant growing stages**.**

Consumptive use mm				
1st stage	**2nd stage**	**3rd stage**	**4th stage**	**summation**
51.7	**133.4**	**148.8**	**112.2**	**446.1**

3.2. Soil water distribution:

The following equation was constructed to find the values of soil moisture at any depth and distance, which were analyzed statistically according to SPSS program, as the correlation coefficient (R^2) in fixed drip irrigation ranged between 0.68 and 0.76, and in mobile drip irrigation, it ranged between 0.90 and 0.94, which is in the following form:

$$w = a\, e^{b\,X}\, e^{c\,Y} \qquad 7$$

Whereas: W = humidity (%), Y = depth (cm), X = dimension (cm), a, b, and c = constants (varying by stage)

e = mathematical constant [13], [14].

Table 3 shows the value of the correlation coefficient for the moisture data after analyzing it with SPSS program. It shows that there are significant differences between the two methods, as it reached (0.9233) for mobile irrigation, while it reached (0.7200) for subsurface irrigation. This explains that the water descends from the soil surface in a homogeneous manner into the soil bed, unlike subsurface drip irrigation. It is noticed that the value of (C) in the moving drip is 0.004 and for all stages of the moisture distribution it has not changed. But in the subsurface drip irrigation and in the second stage, the value of (c) from 0.004 to 0.003. Perhaps the reason for this is that the water did not infiltrated into the soil in a homogeneous manner, unlike the surface moving irrigation. This means that subsurface irrigation is more efficient than moving drip irrigation as it maintains moisture in the area.

Table 3: R^2 values.

irrigation method	**1st stage of soil moisture distribution**	**2nd stage**	**3rd stage**	**The average**
Mobile method	0.94	0.9	0.93	0.9233
Subsurface method	0.76	0.68	0.72	0.72
0.0517				L.S.D

3.3. Effects of irrigation methods on the crop and field properties

3.3.1. *Plant height and productivity.* Plant height is one of the important field indicators, which include the size of the vegetative total. The results in Table 4 when compared to the effect of the two irrigation methods followed, showed that the treatment of subsurface drip irrigation showed a significant superiority in plant height reaching 89.73 cm, while it reached in the treatment of moving drip irrigation to 79.94 cm. It means that the subsurface drip irrigation treatment surpassed with an increase of 12.24% over the mobile drip irrigation treatment. This superiority may be due to the fact that the subsurface drip irrigation method contributed to creating more favorable conditions for plant growth from aeration. In addition to not having a significant effect on the properties of the physical soil, in particular the bulk density and total porosity. Furthermore, the humidity of the moving drip was more susceptible to weather factors, including the wind factor. These results are consistent with what was found [2], which he attributed to the fact that the method of subsurface drip irrigation provided more suitable conditions for. The most important of the plant growing is a good ventilation and appropriate moisture distribution in the root zone, this reduced the plant's stress.

Table 4: Irrigation methods effects on crop properties.

Crop Properties	Subsurface trickle method	Mobile trickle method	L.S.D
Height cm	89.73	79.94	9
Production ton hc^{-1}	7.71	6.32	0.974

In addition, the difference in irrigation method has significantly contributed to the variation in production as the subsurface irrigation method achieved the highest productivity, reaching 7.71 tons Hc^{-1}, while the mobile drip irrigation method reached 6.32 tons Hc^{-1}.

Furthermore, an increase of 19.38%in production may be attributed to the provision of more moisture in the root zone than in the mobile drip irrigation method. This was observed from the nature of soil moisture distribution, and its decrease in the surface layer in surface drip irrigation. The later was affected by weather factors such as winds and temperatures more than the effect of subsurface irrigation method, which secured more moisture in the root zone for a longer period. Another factor was the physical properties of the soil, including aeration, and the bulk density that remained the best in the subsurface drip irrigation method. Thus, these results are consistent with their findings [15][16].

3.3.2. *Water use efficiency.* Table 5 shows that the highest water use efficiency occurred in the treatment of subsurface drip irrigation. It reflects a significant difference, as it reached 1.73 kg m-3 water when compared with the mobile drip irrigation treatment, which amounted to 1.41 kg m-3 water, with an increase of 22.7%. The reason in this might be [17] that the subsurface drip irrigation was distinguished by preserving the physical properties of the soil better than moving drip irrigation, in addition to the availability of a higher moisture content in the case of subsurface drip. These results are consistent with the findings of [18] and [19] who attributed the reason to homogeneity. Irrigation efficiency through precise addition to the root zone in the treatment of subsurface drip irrigation, in comparison with surface drip and despite the fact that the water consumption was the same [20],[21].

Table 5: Water use efficiency

Irrigation method	production (ton hc^{-1})	Irrigation water volume (m^3 hc^{-1})	Water use efficiency
Mobile method	6.320	4463.9	1.14
Subsurface method	7.710	4463.9	1.73
L.S.D			0.218

3.3.3. *Wind speed effects*. Figure 3 shows the effect of wind speed on the amount of evaporation from the soil. It was found that by increasing wind speed, evaporation increases from the surface of the exposed soil. Therefore, its effect was greater in surface moving drip irrigation than its effect on subsurface drip irrigation method, as shown in Figure 3.

This result is consistent with the findings of [22]. The results also showed that the amount of production decreased due to the influence of the wind factor, especially the person exposed to it in the

experiment treatments, and the soil moisture content is more affected by the irrigation method.

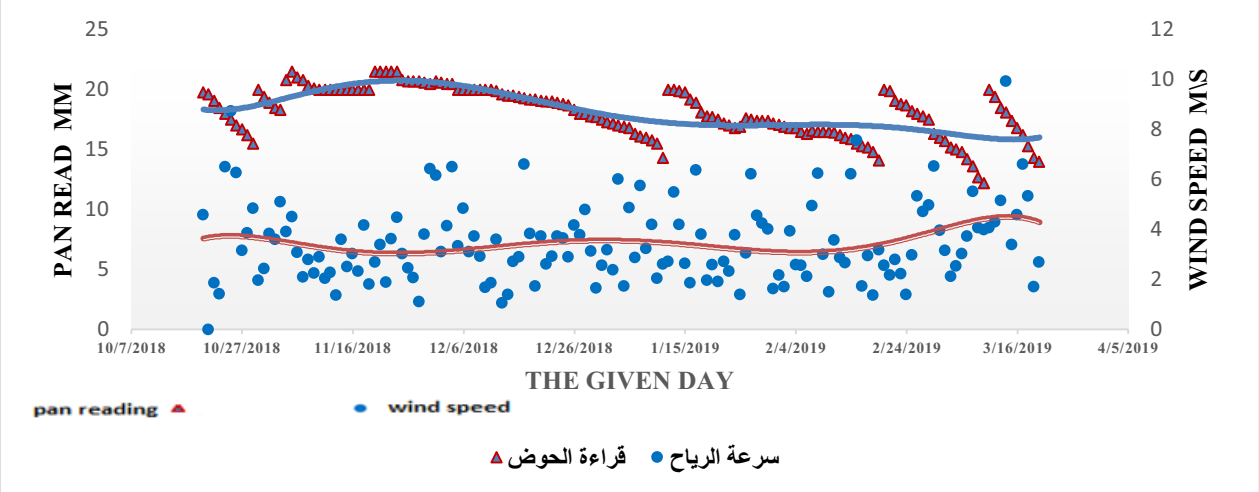

Figure 3: Wind speed effects on evaporation**.**

4. Conclusions:

1- The moisture distribution showed more uniformity when using subsurface irrigation.
2- The values of the studied physical properties were superior when using the subsurface drip irrigation system compared to the mobile surface drip system.
3- The growth, water use efficiency and yield characteristics were superior when using the subsurface irrigation system.
4- Water consumption of pea plants reached 446 mm Season^{-1}.
5- The amount of production decreased due to the influence of the wind factor especially under mobile surface trickle system.

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