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ORIGINAL ARTICLE

USING DIFFERENT MEASUREMENT METHODS TO ESTIMATE WATER CONSUMPTION WITH SOME WATER STANDARDS, GROWTH AND YIELD OF STRAWBERRIES UNDER SURFACE DRIP-IRRIGATION

Saad Enad Harfoush* and Mohammed Salim Jumaah

Department of Soil Sciences and Water Resources, Faculty of Agriculture, University of Anbar, Iraq.
E-mail: saad.harfoush@uoanbar.edu.iq

Abstract: A field experiment was conducted in Anbar Governorate, Ramadi, Sufia area in the spring of 2018. It aimed to study the effect of using different methods to measure water consumption in some water standards, plant growth and yield indicators, and some soil physical characteristics under drip irrigation. The field was divided into three replicates including the following methods: evaporation basin (EB), Ghabari equation (GE) and Gravimetric moisture (GM). Analysis was carried out according to Randomized complete block design (RCBD) using SPSS.24. The results showed that the water consumption of the strawberry crop was 29.17, 34.50 and 40.57 cm for the GM, EB and GE respectively. The crop coefficient was 0.37, 0.75 and 0.48 for the beginning, middle and end of the growth stage respectively. The weighted moisture method significantly increased the efficiency of water use by 1.88 kg^{-3} compared to 1.62 and 1.43 kg^{-3} for EB and GE respectively. While the rate of plant height showed a significant differences, which amounted to 23.25 cm for the GE compared to 19.33 and 21.00 cm for the GM and EBs, respectively. The length of the roots had significant differences, which amounted to 33.40 cm for the treatment of weighted moisture compared to 30.00 and 28.50 cm for the EB and GE, respectively. The variation analysis table showed significant differences in the dry weight of the vegetative part, where it reached 19.25 g for the GE compared to 15.50 and 17.65 g for the GM and EB respectively and there was no significant difference in the overall yield rate.

Key words: Growth, Yield of strawberries, Water consumption, Surface drip irrigation.

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1. Introduction

Water resources protection is one of the most important challenges facing the world nowadays. Water occupies a privileged position, as it is correlating to food security, which has become a priority in recent years. In order to achieve the highest efficiency of irrigation, this requires scheduling of irrigation, which is meant for timing of appropriate irrigation and supply the plant of quantity required of water. This will provide a large amount and horizontal expansion of irrigated area. The use of drip irrigation to irrigate vegetable crops may outweigh other irrigation methods in terms of irrigation efficiency and reduce the growth of bushes and grass and soil erosion. One of the good management methods is to control the amount of water given in each irrigate according to the susceptibility of the soil to absorb the water and the plant requirement in its various stages of growth and to reach high productivity with minimal water losses. The most prominent of these methods is the drip irrigation, which is one of the most suitable way to add net irrigation depth. In addition, the limitation of fresh water availability has led researchers to develop new methods in the field of irrigation. The most prominent of which is the exposure of plants during the stages of growth to water stress using drip irrigation systems, which does not necessarily cause a significant reduction in the crop if the conditions of the soil and plant are observed scientifically, thus can save the

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amount of water and its exploitation for agricultural expansion.

Water consumption factor is important in the regulation and quantification of irrigation water, which involves the process of evaporation and transpiration, which is a factor in the determination of water balancing and irrigation scheduling. Soil moisture within the root zone affects the amount of evapo-transpiration, as plant roots absorb moisture from the soil depending on the amount of water ready to absorb and evaporation rates begin to decline when the soil moisture is increased. Water consumption is defined as the amount of water consumed by the plant system. It includes the amount of evaporation water from the surface of the soil and transpiration by the plant and the amount of water used in the construction of the plant's own tissue. The amount of water in the plant at the end of the agricultural season does not exceed 1% of the total evaporation loss that occurs over the course of the season. The measurement of the water consumption of any crop is either indirect depends on climatic data or direct methods such as the use of Lysimeters, soil moisture study, the method of integration and the method of water balance. Each of these methods has negative, positive and deterministic uses. Therefore, its ability to determine water consumption is different. It is necessary to choose the optimal and most efficient method. Strawberry is a member of the Rosacea family and it is called Fraise in French and this name was taken and used in Arabic. It is a small fruit with a wide spread due to its ability to adapt and grow under different environmental conditions and has many nutritional and medical benefits. Most sources point out that the original habitat of this plant is North America.

Strawberry is one of the twenty most valuable plants in the world. Its cultivation spread in many areas characterized by different climatic conditions due to its biological flexibility in adapting to different environmental conditions when ventilation, humidity and light are available. It almost can be cultivated in all areas of the Arctic to the tropics. Human has known shilake plant for a long time, which is characterized by its high ability to adapt and grow under different environmental conditions. Strawberry cultivation is still limited to some northern areas (Nineveh, Erbil) in scientific experiments stations and some small-cultivated areas. It has economic importance, food and health and economic importance of many countries through the increase in production, and its importance of health comes from the role of fruits in protecting the human body from chronic diseases such as heart disease and cancer [Torronen and Maatta (2002)]. Strawberry is an important food source for its nutrients, vitamins, proteins, carbohydrates, phenolic compounds and other antioxidants. It is an important source of vitamin C and phenols, including anthocyanin.

2. Materials and Methods

Soil samples were taken at depth of 0-30 cm are dried in aerobic method and then grinding and passing through 2 mm diameter sieve. Physical analysis has been done according to Basu *et al.* (1986) (Table 1) and chemical analysis according to Page and Keeney (1982) (Table 2).

Soil was plowed crossly and leaved some days for aeration then grinded, leveled and divided into three blocks each one includes three experimental unites with 1.5 m distance between unites and 2.5 m between blocks using randomized complete block design (RCBD). The experiment was carried out on 8/3/2018. The experiment included 26667 plant of strawberry seedlings (Fern) type. The distance between plants was 0.25 m, planted on one side of the sub-line and 10 cm

Table 1: Some physical properties of soil before planting at depth (0-30 cm).

Soil particles Gm. kg^{-1}	Soil texture	Bulk density mega $gram.m^{-3}$	Particle density mega $gram.m^{-3}$	Porosity %	Gravimetric soil moisture 1/3 bar	Gravimetric soil moisture 15 bar	Available water %
427 Sand	Silty loam	1.21	2.62	53.82	12.20	35.02	22.82
526 Silt							
47 Clay							

Table 2: Some chemical properties of soil before planting at depth (0-30 cm).

PH	EC $ds.m^{-1}$	Hco_3 Meq. L^{-1-}	Co_3^-	So_4^{-2}	Cl^-	Na^+	K^+	Mg^{+2}	Ca^{+2}
7.26	1.5	1.88	Nil	12.98	0.15	2.83	0.14	4.91	7.12

on the dotted. The crop service operations were performed, including fertilization according to the recommendation of fertilizers, control of fungal diseases using the systemic pesticide Dorado, also was used a pesticide (Comodoro) that is a pesticide for the prevention of insect infections, which is applied after germination. The irrigation was done by the Euphrates River's water. The experiment included the following methods: GM, basin (EB) and (GE).

The following characters were taken:

Bulk density and porosity: The bulk density was calculated in the way of the Core Sample according to the method mentioned in Basu *et al.* (1986) and the real intensity using the pycnometer, the porosity was calculated according to the following equation.

$$P = \left(1 - \frac{\rho_b}{\rho_s}\right) \times 100 \quad (1)$$

P = porosity, percentage, ρ_b = bulk density mega gram.m^{-3}, ρ_s = particle density mega gram.m^{-3}.

Gravimetric moisture method (GM): The irrigation process was carried out based on the percentage of soil moisture when 30% of the available water was exhausted during the first irrigation period, which was given in full to deliver the moisture to the field capacity. The depth of the added water depends on the depth of the roots during the growth stages which was calculated according to the equation mentioned by Kovda and Angun (1973).

$$d = \{\theta_{F.C} - \theta_{bi}\}D \quad (2)$$

d = Depth of water added (cm).

$\theta_{F.C}$ = volumetric soil water content at field capacity (cm^3.cm^{-3}).

θ_{bi} = volumetric soil water content before irrigation (cm^3.cm^{-3}).

D = root zone depth (cm).

Irrigation efficiency was 0.86 according to **Al-Esawi** (2010).

The stages of growth were divided according to the continuous follow-up of the experiment (Table 3).

Depending on the soil moisture description curve, the plant ready water (AW) was determined according to the following equation.

$$\theta_{AW} = \theta_{FC} - \theta_{PWP} \quad (3)$$

θ_{AW} = Prepared water to the plant %

θ_{FC} = Volumetric moisture at field capacity.

θ_{PWP} = Volumetric moisture at permanent wilt point.

Soil moisture was calculated at irrigation (wi) for the approved depletion rate of 30% of the available water. The strawberry plant does not tolerate the high depletion rates of the prepared water using the following equation

$$\theta_{wi} = \theta_{FC} - (\theta_{AW} \times \text{dep}) \quad (4)$$

θ_{wi} = Volumetric moisture of soil at irrigation %.

Prepared water to the plant %

Moisture depletion %.

Evaporation basin method (EB): Water consumption is calculated in this way by the following equations

$$ETP = E_{Pan} \times K_p \quad (5)$$

ETP= Reference water consumption (mm.day^{-1}).

E pan: pan evaporation (mm.day^{-1}).

K_p : pan coefficient which was (0.75) according to Aldulaimy *et al.* (2019).

$$ET = ETP \times K_C \quad (6)$$

ET = Actual water consumption (mm.day^{-1}).

K_C = Crop coefficient, which was adopted at the beginning of the growth stage 0.4 and the middle of the growth stage 0.85 and at the end of the growth phase 0.60.

The irrigation schedule for the growth season was calculated based on the measurement of evaporated

Table 3: Stages of growth, root depth and duration of the strawberry crop.

Growth stage	Date of beginning and end of stage	Duration of the stage (day)	Depth of roots (cm)
The beginning of the growth stage	8/3-31/3/2018	24	10
Mid-stage growth	1/4-19/4/2018	19	15
	20/4-15/5/2018	26	18
End of the growth stage	16/5-15/6/2018	31	25

water from the American Evaporation Basin Class A and offset Equation (7) in Equation (8) as follows

$$ETP = \frac{ET}{K_C} \tag{7}$$

$$E_{Pan} = \frac{ETP}{K_P} \tag{8}$$

When the evaporation from the evaporation pond reaches the resulting number from the equation above the irrigation will done.

Al-Ghabari equation method (GE): Water consumption was calculated through the (GE) from the Blini-Cridell equation mentioned in Al-Ghabari (2011) based on climatic data in accordance with the climatic conditions in Saudi Arabia and its proximity to the climatic conditions of Iraq. This equation was adopted and its mathematical formula is

$$ET = 4.5 \times K \times P(T + 17.8) \tag{9}$$

ET = Water consumption of crop (cm).

where,

P : Percentage of the number of daylight hours per month to their number per year during the period of growth obtained from the air station in Ramadi.

T : Average temperature during months' growth (°C).

K : A coefficient associated with both the coefficient of the crop and the temperature, calculated according to the following equation:

$$K = KT - K_C \tag{10}$$

where,

K_C : Crop coefficient for each stage of plant growth.

KT : A coefficient that reflects the effect of air temperature in water consumption for a short period on condition that it be greater than or equal to 0.30. It is calculated according to the following formula

$$KT = 0.24 + 0.3T \tag{11}$$

Crop coefficient: Crop coefficient is calculated according to Aldulaimy *et al.* (2019).

Water Efficiency: Water use efficiency is estimated according to the formula mentioned in Allen *et al.* (1998).

$$WUE = \frac{Y}{W_t} \tag{12}$$

where,

WUE : water use efficiency ($kg.m^3$).

Y : yield ($kg.\ ha^{-1}$).

W_t : The amount of water added ($m^3.ha^{-1}$).

Plant height: The height of five plants were randomly selected for each treatment and measured by the measuring tape from the contact area with the root to the top of the developing tip and then obtained the height ratio by dividing the total length of the five plants by their number [Al-Ethawi (2016)].

Root mass and length: The root area was washed by a quiet water stream after making a hole around the plant and then raising it and measuring the root length by measuring tape from the root contact point to the end of the active root, and then dried and weighed according to what was stated [Al-Khateeb and Al-Shaabani (2018)].

Dry weight of the vegetative part: At the end of the growing season, the plants were measured randomly by choosing five plants from each treatment and weighed after drying at 70°C for 48 hours until the weight was confirmed [Al-Sahaf (1989)].

Total yield: Strawberry yield was estimated for each treatment separately and the ratio of the yield to the hectare [Al- Ethawi (2016)].

3. Results and Discussion

3.1 Bulk density and porosity

Table 4 shows the effect of using different measuring methods for estimating water consumption under the manner of surface drip irrigation in the bulk density and soil porosity. The results indicate that there is no significant difference in the bulk density and porosity density at depth 0-15 cm. Treatment of GM had the lowest rate of bulk density and higher porosity, which was 1.35 $Mg.m^{-3}$ and 48.47% compared to 1.38 $Mg.m^{-3}$, 47.33% for the treatment of EB and 1.49 $Mg.m^{-3}$, 43.13% for GE treatment. It may be due to the heavy rains during the season growth. In addition, wetting and drying cycles result in the destruction of soil aggregates, which leads to the transformation of a number of large pores to smaller pores, which increase the bulk density and thus reduce soil porosity than before planting. In the case of bulk density and porosity of depth 15-30 cm, the results also indicate the same thing that happened to the two above. The treatment of GM was characterized by the lowest rate bulk density and

Table 4: The effect of using different methods to measure water consumption under the manner of surface drip irrigation in the bulk density and porosity.

Treatments	Depth (cm)	Bulk density $Mg.m^{-3}$	Porosity%
(GM)	0-15	1.35a	48.47a
(EB)		1.38a	47.33a
(GE)		1.49a	43.13a
(GM)	15 - 30	1.42a	45.80a
(EB)		1.45a	44.66a
(GE)		1.54a	41.22a

the highest porosity, reaching 1.42 $Mg.m^{-3}$ and 45.80% compared to 1.45 $Mg.m^{-3}$, 44.66% and 1.54 $Mg.m^{-3}$, 41.22% for the treatment of EB and GE respectively and for the same reason.

3.2 Water consumption

Table 5 shows the effect of using different methods for estimating water consumption under the surface drip irrigation, which reached 29.17, 34.50 and 40.57 cm for GM treatment, EB and GE, respectively. The depth of the water added at the beginning of the growth stage was 5.20, 6.55 and 8.48 cm, because of moderate temperature average during this stage. The middle of the growth stage was 12.72, 14.42 and 16.36 cm. This increase may be due to the evolution of the root and vegetative parts of the plant. At the end of the growths' stage was 11.25, 13.55 and 15.73 cm for the three transactions, it is possibly due to the reduced need of the plant for water to complete the composition of the tissue and dry proportion of parts. Eventhough, the high temperatures during this stage caused a slight decrease in water depth. This is agreed with Al- Khateeb and Al-Shaabani (2018).

3.3 Crop Coefficient

Table 6 shows how to calculate the crop coefficient in the moisture weight method of the strawberry crop under the manner of surface drip irrigation. It is noted that the crop coefficient varies according to the stages of growth it is related to the actual and reactive water consumption of the plant, which was 0.27, 0.75 and 0.50 for the beginning of the growth stage. Mid-stage growth and end-stage of growth, respectively. The coefficient of the crop was calculated by the actual water consumption of each phase ET, the evaporation of each stage of the American A-type evaporation basin multiplied by the KP basin coefficient to obtain ETP.

3.4 Water use Efficiency

Table 7 shows the effect of using different methods for estimating water consumption under the manner of surface drip irrigation in the efficiency of water use. The Table 8 of analysis of variance shows significant differences between the averages. The water efficiency rate in the GM was 1.88 $kg.m^{-3}$ and 1.47, 1.30 kg.m-3 for EB and GE respectively, which showed no significant differences. This may be due to the fact that the depth of water added by the GM is less than the other two methods, which improved some soil characteristics, thus got the highest efficiency of the use of water and this is in line with Al- Esawi (2010).

3.5 Plant characteristics

Table 8 shows the effect of using different methods

Table 5: The depth of the added water, the evaporated water and the number of irrigation for the strawberry crop during the growing season (cm).

Growth stages	Treatment	Depth of water added (cm)	Depth of evaporated water (cm)	Number of irrigation	Notes
First	(GM) (EB) (GE)	2.31+2.89 2.31+4.24 2.31+6.17	14.14 14.14 14.14	3+ first irrigation cycle 4+ first irrigation cycle + stage complete 4+ first irrigation cycle + stage complete	First irrigation cycle 2.31 cm to deliver moisture to the field capacity For all treatment by (GM)
Second	(GM) (EB) (GE)	12.72 14.42 16.36	22.62 22.62 22.62	4+ 6.7cm rain 5+ 6.7cm rain 5+ 6.7cm rain	At the beginning of the second stage was a depth of roots 15 cm.
Third	(GM) (EB) (GE)	11.25 13.55 15.73	30.10 30.10 30.10	4+ stage complete 5+ stage complete 5+ stage complete	On 19/4/2018 the root depth was measured and found 18 cm.

Table 6: Crop coefficient by gravimetric moisture for strawberry crop.

Stages of Growth by (GM)	E_{Pan} cm	ETP cm	K_P	ET cm	K_C
The beginning of the growth stage	14.14	0.75	10.61	2.31 First irrigation + 2.89	0.27
Mid-stage growth	22.62		16.97	12.72	0.75
End of the growth stage	30.10		22.58	11.25	0.50

Table 7: The effect of using different methods for estimating water consumption under the manner of surface drip irrigation in water use efficiency.

Treatments	Yield $kg.ha^{-1}$	Water volume $m^3.h^{-1}$	Water use efficiency $kg.m^{-3}$
(GM)	2859.20	1520	1.88a
(EB)	2942.13	2000	1.47b
(GE)	3054.14	2346.7	1.30b

Table 8 : Effect of using different methods for estimating water consumption under drip irrigation in some growth indicators and total yield.

Measured Indicators / Treatment	Plant height (cm)	Length of roots (cm)	Dry weight of roots (g)	Dry weight of the vegetative part (g)	Total yield kg. ha^{-1}
(GM)	19.33a	33.40a	2.00a	15.50a	2859.20a
(EB)	21.00a	30.00b	2.30a	17.65a	2942.13a
(GE)	23.25b	28.50b	2.70a	19.25b	3054.14a

for estimating water consumption under surface drip irrigation in some growth indicators and the total yield. The statistical analysis results indicated significant differences in plant height rate, which reached 23.25 cm for GE treatment compared to 19.33 and 21.00 cm for GM and EB respectively, due to the water volume was added to this treatment is greater than the rest treatments. Therefore, the plant can get the nutrients more easily. There were significant differences in the length of the roots, which reached 33.40 cm for the GM compared to 30.00 and 28.50 cm for the EB and GE, respectively. This may be attributed to the increase in the time between irrigations for the weighted moisture treatment, which led to the elongation of the root to reach the wet region. Moreover, most of the water absorbed by the roots is from the upper layer immediately after the irrigation and the tensile strength of this layer increases when its moisture content decreases so that the roots penetrate into the deeper layers that contain higher moisture. While, there was no significant difference in the dry weight of the roots, which reached to highest rate of 2.70 g for the GE treatment compared to 2.00 and 2.30 g for the (GM) and (EB), respectively. It is noted from the table that the length of the roots is inversely proportional to the dry weight due to the availability of moisture, which is have opposite relationship with the deepening of roots and therefore with the mass of roots and this is consistent with Al- Khateeb and Al-Shaabani (2018). There were significant differences in the dry weight of the vegetative part, which reached 19.25 g for the (GE) treatment compared to 15.50 and 17.65 g for the (GM) and (GE), respectively. This may be due to the same reason mentioned in the plant height above. On the other hand, there is no significant difference in the total yield, which amounted to 2859.20, 2942.13 and 3054.14 $kg.ha^{-1}$ for the (GM), (EB) and (GE), respectively, despite the disparity in the amount of water given during the growing season.

We conclude that the method of wet moisture led to saving the irrigation water and get the highest efficiency of water use compared to the rest of the transactions. As well as, improve some of the other soil characteristics, including bulk density, porosity and the depth, although there are no significant differences, thus it is the best method.

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