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DETERMINED OF WATER REQUIREMENTS FOR VEGETABLES UNDER DRIP IRRIGATION SYSTEM

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ABSTRACT

This work aims to calculate of water requirements for squash under drip irrigation in sandy soil at Al-Moulak area, Ismailia Government, Egypt. The average yield was 11.6 ton/fed for squash. The total water requirements was 379 mm (1591.8 m^3 / fed), The average of temperature of 28 – 32 °C in daily and in night of 16-18 °C at the average of relative humidity of 62 %.

The relationships between water requirement (E, mm/day) and deficits relative humidity (ds, mb) having the following formula:

$$? = a\, ds^{b}$$

Where, a, b - empirical coefficients of the regression equation.

At using experimental data through the season of Squash. That equal a = 1.89 and b = 0.64 then the relation become (? = 1.89 $ds^{0.64}$) and the correlation coefficient was 0.94 ± 0.0435. This means that in 94% of the water consumption of Squash variations in these conditions due to variations in deficit air humidity. For calculating Squash water requirement under drip irrigation was found as $? = ?_F K_C\ ?\ ds^{b}$ considering $?_F$ – Coefficient depending on wetting pattern in 1 m^2 under dripper and $?_C$ – Crop coefficient.

*The experimental data during calculation the crop coefficient of Squash through growth season was found as $?_C$ = 0,3565 + 1,6851*tr – 0,1455*tr^2 considering tr as relative time.*

Keywords: *Drip irrigation system, Water requirement, Squash*

INTRODUCTION

Water is fast become an economically scarce resource in many areas of the world and consider as a limiting factor in any agricultural expansion depending on its quantity, quality and methods of applied. In Egypt, land has been classified as arid region.

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Most of the Egyptian soils, out of the Nile Delta and valley, represent about 96 % of the whole area, (sandy soil). Agriculture uses the largest share of water, with peaks in excess of 90%, and uses it quite inefficiently since it is estimated that cases of efficiencies as low as 50% are not uncommon (Hamdy et al., 2001). There are three major groups of irrigation systems: surface, sprinkler and drip (micro-irrigation). Under sandy soil condition, drip irrigation is the artificial application of water to agriculture lands in order to insure adequate for crop growth. Also, Drip irrigation was characterized by a smaller amount of water applied to the soil system. (Cassel et al., 2001). It is considered as highly efficient system because it allows small but frequent application of water with minimum losses. Fertilizer or chemical amendment could be efficiently applied to plants. A knowledge of water requirement is necessary in planning farm irrigation system and improving efficient use of water and fertilizers, and the proper water management requires not only accurate determination of crop water requirements, but also we must know when and how much water should be applied.

Evapotranspiration data for agricultural crops has become increasingly important in irrigation management as well as in water resources management. It is dependent not only on the meteorological elements, but also on factors related to the crop and to the soil availability and soil environment.

The objective of this work is calculated of water requirements for Squash in sandy soil cultivated under drip irrigation system.

MATERIAL AND METHODS

Field experiment was carried out in sandy soil at the farm in Al-Moulak area, Ismailia Government, Egypt. Chemical, physical and hydrophysical properties of this soil were determined according to Black (1965), and shown in Table (1, 2, 3). Soil mechanical analysis was carried out using the international pipette method according to Jacobs et al (1971). The bulk density of soil was determined using undisturbed soil cores according to Klute (1986).

The drip irrigation system had the following characteristics, The distance between lateral lines was one meter, the distance between drippers was 50 cm, the kind of used drippers (GR) with discharge 4 Liters/hour.

Irrigation water was applied at rates based on (100 %) from the crop evapo-transpiration (ET_c) calculated according to Smith, 1992. Squash was planted on 1/6/2012 and chemical fertilizers were applied as following: super phosphate at rate of 150 kg/fed, ammonium sulphate at rate of 300 kg/fed and potassium sulphate at rate of 100 kg/fed.
Soil sampling for moisture content were taken from different sites locations around the emitter (0, 12.5 and 25 cm distance between emitters and laterals at 15, 30, 45, 60 and 75 cm depth).
Soil moisture values were measured after and before irrigation, through the three stages of squash growth season.

Table (1): Physical, chemical and hydrophysical properties of sandy soil in the experiment site.

Soil layer, cm	Particle size distribution* %			Texture class*	B.D**	$CaCO_3$	O.M	F.C	*** PWP
	Sand	Silt	Clay		g/ cm^3	%	%	%	%
0 –15	85.0	11.2	3.80	Loamy	1.37	0.76	0.34	9.3	2.2
15-30	95.4	2.50	2.10	Sand	1.63	1.12	0.23	8.7	1.8
30-45	98.6	0.30	1.10	Sand	1.68	1.33	0.22	8.6	1.8
45-60	98.6	0.43	0.97	Sand	1.60	1.24	0.26	8.7	2.0
60-75	98.5	0.93	0.57	Sand	1.63	1.24	0.26	8.7	1.8

*Classification of the International Society of Soil Science,
**B.D is the soil bulk density, ***PWP permanent wilting point.

Table (2): Chemical characteristics of the experimental soil.

C.E.C mol/kg	pH 1:2.5	EC (dS/m) at 25°C	Soluble anions (meq/l)				Soluble cations (meq/l)			
			CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mq^{++}	Na^+	K^+
9.5	8.2	0.26	—	2.1	2.0	2.0	1.8	0.8	3.1	0.4

Table (3): Chemical characteristics of irrigation water.

SAR	PH	EC (dS/m) at 25°C	Soluble anions (meq/l)				Soluble cations (meq/l)			
			CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mq^{++}	Na^+	K^+
2.65	8.4	0.49	—	2.90	0.53	1.91	1.47	0.78	2.82	0.27

In the experiment were measured components of the water balance equation of water balance experimental plots on which investigated soil moisture content is (mm):

$$\Delta W = I + P - ?Tc \pm Dp$$

Where: ΔW - Change of soil moisture content, ΔW = WF – WB

WF – Final soil moisture content, mm;

WB – Beginning soil moisture content, mm,

P - Precipitation, mm,

I – Irrigation, mm;

? Tc – Crop evapotranspiration, mm/day;

Dp - Deep percolation, mm.

Total water requirement was determined from the water balance equation as an unknown with the measured values, m and q. water balance (mm) that calculated a layer of soil (0-50 cm).

RESULTS AND DISCUSSIONS

The depth of water application is 379 mm (1591.8 m^3/Fed), while the average yield was 11.6 ton/Fed. The yield increments may be attributed to the increase of leaves number per plant which developed photosynthesis process. This leads to improve fruit number per plant. Also, Squash plant is classified drought sensitive crops, and so plants suffer from water stress (Table 4). This finding is in agreement with Raj Kumar and Kamia (1985).

Table (4): Water applied rates throughout the growing season of Squash.

Date	mm / period	Water applied m^3/Fed
1/6 – 20/6	73.8	309.8
21/6 – 20/7	177.4	745
21/7 – 15/8	127.8	537

The results in table 5 shows that the rainfall during the growing season in Egypt were reported to maintain soil moisture at 100% ETc, and the proportion of the wetting area the basis of $1m^2$ in experiment with squash in 2012 was the depth of ground water ? = 20 m, irrigation rate was 420 mm. While water requirement was 379 mm. Infiltration was 37.47 mm. and ? W (Change of soil moisture content) was 4.12 mm.

Table 5. Water balance (mm) calculated a layer of soil (0-50 cm)

Data	The intervals between irrigation (day)	Water Balance						
		Soil moisture content (mm)		The elements of water balance (mm)				
		W_B	W_F	? W	P	Dp	I	E (? ? /irri)
1 June	2	140.00	140.16	0.16	0	0.82	9	9
3 June	2	140.16	140.28	0.13	0	0.82	9	9
5 June	2	140.28	141.62	1.34	0	0.82	9	8
7 June	2	141.62	140.41	-1.21	0	0.82	9	11
9 June	2	140.41	140.60	0.19	0	0.82	9	9
11 June	2	140.60	141.96	1.36	0	0.82	9	8
13 June	2	141.96	140.75	-1.20	0	0.82	9	9
15 June	2	140.75	140.88	0.13	0	0.82	9	9
17 June	2	140.88	140.94	0.06	0	0.82	10	9
19 June	2	140.94	142.13	1.19	0	0.82	10	8
21 June	3	142.13	141.25	-0.87	0	1.46	16	15
24 June	3	141.25	141.35	0.09	0	1.46	16	15
27 June	3	141.35	141.51	0.16	0	1.46	16	15
30 June	3	141.51	143.74	2.24	0	1.46	16	13
3 July	3	143.74	144.51	0.76	0	1.46	16	14
6 July	3	144.51	141.72	-2.78	0	1.46	16	15
9 July	3	141.72	141.85	0.13	0	1.46	16	15
12 July	3	141.85	144.42	2.57	0	1.46	16	13
15 July	3	144.42	141.94	-2.47	0	1.46	17	15
18 July	3	141.94	144.15	2.21	0	1.46	17	13
21 July	3	144.15	142.13	-2.02	0	1.63	19	15
24 July	3	142.13	142.20	0.06	0	1.63	19	16
27 July	3	142.20	142.32	0.13	0	1.63	19	18
30 July	3	142.32	142.48	0.15	0	1.63	18	15
2 Aug.	3	142.48	143.19	0.72	0	1.63	18	16
5 Aug.	3	143.19	143.29	0.10	0	1.63	18	17
8 Aug.	3	143.29	144.28	0.99	0	1.63	19	16
11 Aug.	3	144.28	144.08	-0.20	0	1.63	18	17
14 Aug.	3	144.08	144.08	0.00	0	1.63	18	17
Total				4.12	0	37.47	420	379

Comparative analysis of actual water requirements of squash and calculated by different methods

Currently there are a significant number of computational methods for the determination of water requirements with Egypt's most widely used formula of the following authors: Blaney-Kridll - FAO56-Penman-Monteys (PM) - Turk - Jensen Hayes (HH) - Hargreaves (CH) - FAO meth. - Priestley Taylor (PT) - Ivanova NN and Pan.

Theses formulas was calculated water requirements of squash. The results and data of the experiments are shown in Figure 1. Analysis of Figure 1 shows that the root zone and soil moisture content affects the water requirements of squash.

Water requirements (Experimental data) appropriate soil moisture located within the boundaries of water requirements was calculated by known formulas. Between the experimental data and calculated according to the formula to make comparative analysis.

Method G. Blaney - V. Kridll for the entire growing season gives the deviation of water requirement by 9.0%. Deviation of 2-3 days are more significant reaching 34.2%. This technique is suitable for the calculation of water requirement under these conditions as a whole during the growing season. It is not suitable for the calculation of water requirement for the period 2-3 days because of the lack of precision and the lack of biological factors for the area and crop.

Method 56-FAO-Penman Monteys generally for vegetation under predicts 15.1% for the period 2-3 days deviation is 36.3%. This technique is suitable for the calculation of water consumption in the whole vegetation. And is not suitable for the calculation of the period of 2-3 days.

Ivanova NN method correspondingly gives deviation 12.6% and 58.8%. 26.8% and Turk 49.1%; Jensen Hays 14.2% and 37.8%. 13.1% and Hargreaves 31.00%, FAO, 6.9% and 33.7%. Priestley Taylor 0.6% and 32.2% and Pan 0.3% and 30.1%. These methods are not suitable for calculating water requirements of squash within growth season in Egypt under drip irrigation.

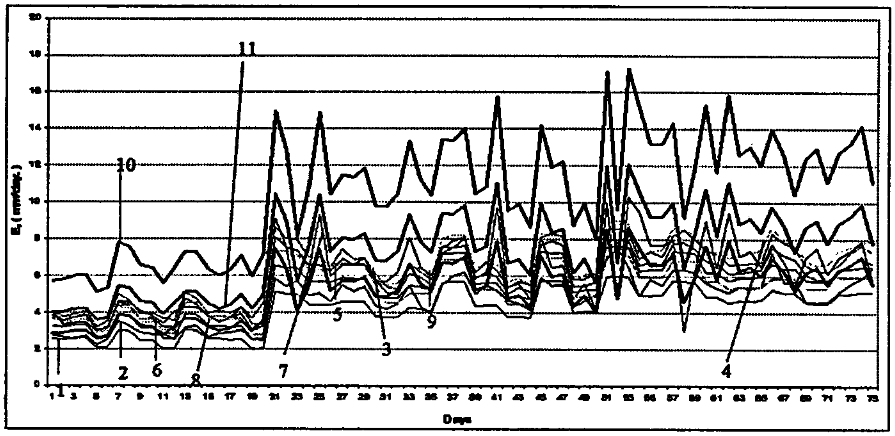

Fig.1. Comparative analysis of actual water requirements data of squash and calculated by different methods, 1- Priestley Taylor; 2- Turk; 3- FAO meth.; 4- Jensen Hayes; 5- Hargreaves; 6- Blaney-Kridll; 7- FAO56 Penman-Monteys; 8- Ivanova; 9- Pan; 10- Actual; 11- Calculated.

In the future to calculate the regime of drip irrigation we need to determine the water requirement for the periods 2-3 days. As the results of calculations and comparative analysis, none of these methods we have in Egypt, when grown squash and drip irrigation does not provide the required accuracy of the results. That is they do not take into account the root zone moisture content of the soil. In connection which there is a need to develop a methodology for calculating water requirement in Egypt under drip irrigation with the root zone soil moisture.

In [Konstantinov, A.R. 1968, Pchelkin V.V., Zimin F.M, 2003] analyzed the various forms of relationships between water requirement and temperature and relative humidity. The relationship showed a function having the following formula:

$$? = a\, ds^{b} \qquad (1)$$

Where:

E - Crop water requirement, mm / day;

ds – Deficits of air humidity, mb ,

a, b - Empirical coefficients of the regression equation.

By using experimental data through the season of squash (soil moisture content, temperature, relative humidity and the amount of average daily deficits humidity) by the method of mathematical statistics was obtained by the regression equation between water requirement and the amount of average daily deficits humidity

$$? = 1.89 \text{ ds}^{0.64} \qquad (2)$$

Empirical coefficients a and b

Crop	a	b
Squash	1.89	0.64

Correlation coefficient for this connection was 0.94 + 0.0435. This means that in 94% of the water requirement of squash variations in these conditions due to variations in deficit air humidity.

It should be noted that the static ranks include monitoring water demand periods when the squash were well developed and the soil moisture content was adequate (100% ETc) that is when water requirement is equal to the potential evapotranspiration. If these rules are included in the calculation of the data from 20 June to 01 August and excluded the value of water requirement beginning and end of the growing season.

The formula (2) was obtained for the calculation of water requirement of squash without their biological characteristics. Biological characteristics of agricultural crops in the fact that in the initial period of vegetation is not sufficiently developed root system and foliage. So prevalent physical evaporation from the soil surface above the transpiration. At the end of the growing season plants are aging and the intensity of water use falls.

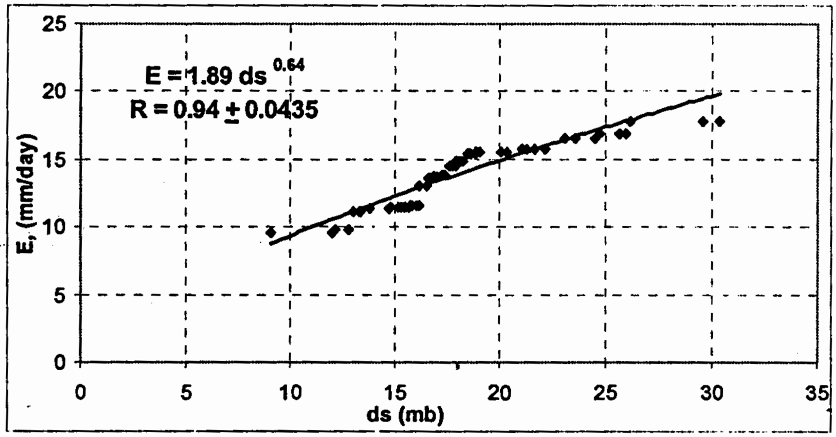

Figure 2. The relationship between water requirement and the amount of average daily deficits humidity.

At the beginning and end of vegetation dominated by physical evaporation of transpiration water requirement is lower than in the period when transpiration dominates. These biological features squash considered entering into formula (2) biological factors are determined from the equation:

$$Kc = \frac{E_{Act.}}{E_{Calc.}} \tag{3}$$

Where:

? Act. – Actual water requirements calculated by water balance, mm/day.;

? Calc. – Calculated water requirements calculated by formula (2).

As the results of the calculations the values of the biological factors depend on the phase of plant development. By using the experimental data for the biological factors squash between irrigation intervals were composed of 28 rows of static members to determine the relationship between the relative time and crop coefficient, the regression equation was obtained the equation for calculation crop coefficient of squash through growth season.

$$? _C = 0.3565 + 1.6851*tr - 0.1455*tr^2 \tag{4}$$

Where : tr – Relative time.

Correlation coefficient is equal to 0.87 ± 0.107 This shows the close relationship between the estimated and actual values of the crop coefficient. The results of calculations by equations (4) are summarized in Figure 3.

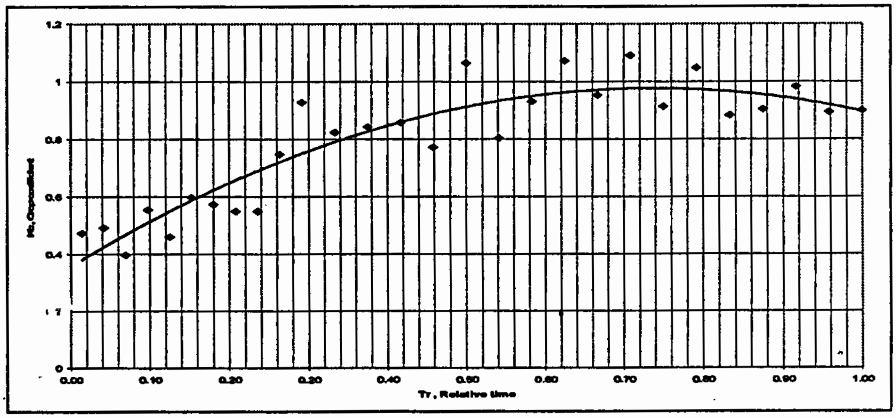

Figure 3. Relationship between Crop coefficient of Squash and relative time

When introduced into the formula (2) the importance of crop coefficient regression equation takes the form (mm):

$$? = K_C \, ? \, ds^{b} \qquad (5)$$

Where: K_C – Crop coefficient.

At actual is not all irrigated area is wetting under dripper in each square meter of the irrigated area in this case wetting about 0.392 m^2. It should be noted that the various drip irrigation have different diameters. Therefore in determining water requirements should be considered only the area that is in the field of concrete irrigation drip.

The wetting pattern under dripper will vary depending on their specifications. But it is impossible to develop the formula for the calculation of water requirement for each type of drippers. Based on this fact it was decided to enter into the formula (5) factor (K_F) which takes into account the wetting pattern per 1 m^2 under dripper.

The final formula for the calculation of water requirement for squash under drip irrigation system will be the following:

$$? = ?_F \, K_C \, ? \, ds^{b} \qquad (6)$$

Where:

E - Crop water requirement, mm / day;

$?_F$ – Coefficient depending on wetting pattern in 1 m^2 under dripper,

$?_C$– Crop coefficient.

CONCLUSION

In the future to calculate the regime of drip irrigation we need to determine the water requirement for the periods 2-3 days. As the results of calculations and comparative analysis none of these methods we have in Egypt, when grown squash and drip irrigation does not provide the required accuracy of the results. That is they do not take into account the root zone moisture content of the soil. In connection which there is a need to develop a methodology for calculating water requirement in Egypt under drip irrigation with the root zone soil moisture.

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$$? = ?_F K_C ? ds^b$$

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الملخص العربي

حساب الاحتياجات المائية لمحاصيل الخضر تحت نظام الرى بالتنقيط

عبد التواب متولى ابراهيم زيدان [١]   مجدى عبدالوكيل مطر [٢]

يهدف هذا البحث الى ايجاد طريقة مثلى لحساب الاحتياجات المائية لمحصول الكوسة تحت نظام الري بالتنقيط فى ارض رملية.

تم تنفيذ هذا العمل في التربة الرملية الحمراء في مزرعة في منطقة الملاك، محافظة الإسماعيلية، مصر.

كان متوسط الانتاج 11.6 طن / فدان وكمية الاحتياجات المائية كانت ٣٧٩ مم (1591.8م^{٣} \فدان) ومتوسط درجة الحرارة بالنهار(٢٨-٣٢ درجة منوية) وفي الليل (١٦-١٨ درجة منوية) ومتوسط الرطوبة النسبية ٦٢٪.

في اعمال [كونستانتينوف، 1968، بتشولكن , زيمين ، 2003] كان هناك تحليل مختلف لأشكال العلاقات بين الاحتياجات المائية ودرجة الحرارة والرطوبة النسبية وأظهرت العلاقة وجود الصيغة التالية:

$$? = a\, ds^{b}$$

حيث E - الاحتياجات المائية للمحاصيل، مم / يوم,

ds - مقدار العجز فى الرطوبة النسبية مم بار,

a، b - معاملات تجريبية من معادلة الانحدار.

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باستخدام البيانات التجريبية اثناء موسم النمو (الرطوبة الارضية و درجة حرارة الجو و الرطوبة النسبية و العجز فى الرطوبة النسبية) من خلال طريقة الإحصاء الرياضي من معادلة الانحدار بين الاحتياجات المائية للمحصول وكمية المتوسط اليومي لمقدار العجز فى الرطوبة النسبية تم الوصل الى معادلة لحساب الاحتياجات المائية لمحصول الكوسة .

$$? = 1.89\, ds^{0.64}$$

كان معامل الارتباط لهذة المعادلة 0.0435 ± 0.94 هذا يعني أنه في 94٪ من تقلبات الاحتياجات المائية بسبب التغيرات في العجز فى الرطوبة الجوية.

وتم الحصول على المعادلة النهائية لحساب الاحتياجات المائية لمحصول الكوسة تحت الرى بالتنقيط كالتالى :

$$? = ?_F K_C ? ds^b$$

حيث E - الاحتياجات المائية للكوسة، مم / يوم,

$?_F$ - معامل يعتمد على مساحة البلل تحت النقاط فى مساحة ١ متر٢,

K_C - معامل المحصول.

وتم الحصول على معادلة لتقدير معامل المحصول للكوسة خلال موسم النمو كالتالى :

$$?_C = 0{,}3565 + 1{,}6851 * tr - 0{,}1455 * tr^2$$

حيث tr – الوقت النسبى خلال موسم النمو.