Evaluation crop evapotranspiration and crop coefficient of squash (zucchini) with subsurface water retention technology(SWRT) and without SWRT

تقييم تبخر نتح المحصول لنبات القرع (كوسا) ومعامل المحصول مع استخدام تقنية حجز المياه تحت سطح التربة وبدونها

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Abstract

In this days because of the water scarcity world trends to reduce the water losses and increase the yield to fill lack of water and food by using modern technologies to reduce the evapotranspiration and deep percolation of water with pesticide, fertilizer and nutrient that percolate to ground water and pollute the environmental of ground water. Therefor many countries go to apply new technology by utilizing polyethylene membrane sheet called mulch on soil surface to prevent the evaporation, in addition to utilize polyethylene membrane sheet to prevent the deep percolation which called subsurface water retention technique (SWRT). Additionally, calculation of actual crop water consumptive(actual crop evapotranspiration) to estimation the actual crops water amount and not profusion by the water via measuring crop evapotranspiration (ET_c) for each crop and cropping pattern. This method considered best method for water rationing and reduced the waste (squandering) via using modern technique. This research was sited in Sadat-Alhindyia township in Babylon governorate in middle of Iraq about squash crop (zucchini) that planted in plots (lines) irrigated by drip irrigation. The research carried out on two treatment, first treatment using membrane sheet(SWRT) under root zone of squash crop (zucchini) (TA) as ratio 2:1 (width: height) and the second treatment plot using without SWRT technique (TB). The results that the average and accumulated crop evapotranspiration to TB was more than TA by 18.3%. This indicates that the using SWRT technique assisted on reduce crop consumptive amount and reduce of losses by deep percolation. . Number of irrigation was in plot TA less than TB by 12 %.

Keywords: squash (zucchini), crop evapotranspiration (ETc), SWRT technique, crop coefficient.

الخلاصة :

يتجه العالم في هذه الايام بسبب الشحة المائية نحو تقنين المياه، تخفيض الضائعات المائية وزيادة انتاجية المحاصيل لسد نقص الماء و الغذاء بواسطة استخدام التقنيات الحديثة لتساعده على خفض التبخر والتغلغل العميق للمياه تاخذ معها المبيدات ،الاسمدة والمغذيات التي يتغلغل الى المياه الجوفية دون الاستفادة منه ومسببة ضررا على بيئة المياه الجوفية. ذهبت بعض البلدان الى التقنيات الحديثة باستخدام تقنية غشاء بولي اثلين الملش(mulch) على سطح التربة لمنع التبخر واضافة الى استخدام اغشية البولي اثلين لمنع التغلغل العميق التي تسمى تقنية حجز المياه تحت السطح التربة (SWRT). بناءاً على ذلك يتم حساب الاستهلاك المائي الفعلي للمحاصيل(تبخر النتح المحصول الفعلي) لغرض تخمين كمية المياه الفعلية وعدم الاسراف فيها عن طريق قياس تبخر النتح الحقيقي لكل محصول مع كثافة المحصول الزراعية. اجري هذا البحث في سدة الهندية محافظة بابل في وسط العراق حول نبات القرع (الكوسا) المزروع بخطوط تسقى بالري بالتنقيط. التجربة انجزت بطريقتين، الطريقة الاولى استخدام تقنية(SWRT= TA) بنسبة 2:1(عرض: ارتفاع) والطريقة الثانية بدون استخدام SWRT (TB). نتائج معدل تبخر النتح الحقيقي وتبخر النتح التراكمي للمعالجة TBاكبر من TA بـ18.3%. وهذا يدل على ان استخدام تقنية SWRT ساعدت على تقليل كمية الاستهلاك المائي مع تقليل الضائعات بواسطة التغلغل العميق. عدد مرات السقي في الطريقة الاولى (TA) اقل من الطريقة الثانية (TB) بنسبة 12%

الكلمات المفتاحية: القرع (الكوسا)، تبخر نتح للمحصول(ETc)، تقنية SWRT، معامل المحصول.

Introduction

The expansion in using modern technology in cultivation of crops and rationing and reduce of deep percolation by subsurface water retention technology(SWRT) so as to reduce the losses of water which goes to deep percolation under root zone will use polyethylene membrane sheet under root zone of crops at depth of root zone and setup by U shape and multi aspect ratio (horizontal: vertical)(2:1,2.5:1,3:1,5:1,10:1). This technology helps to save of water, fertilizer and pesticides in root zone. The SWRT membranes increase soil water and nutrient contents in plant root zones and require less irrigation water to half and triple maize, cotton and horticultural crops in Iraq, Iran, China and the USA**[1]**. Water loss was reduced even more when surface mulch was added to soils equipped with SWRT membranes. Soil temperature reductions at various depths in SWRT membrane treatments plus straw surface mulch were greater than when SWRT membranes were installed without straw mulching of the soil surface **[2].**

Searcher[3] evaluating the use of membrane sheet(SWRT) to two type of crops (hot pepper and okra) in two sites in Sadat Al-Hindyia , Babylon of Iraq. He utilize trickle irrigation in greenhouses and obtain on on increasing of yield, water use efficiency (WUE) and water productivity WP in treatment T1. The field water use efficiency (FWUE) of hot pepper in T1 was more than T2and T3 by 50 % and 59 %, respectively and the FWUE of okra in T1(SWRT) was more than T2and T3 by 25 % and 149 %, respectively.

Searchers [4] in search use SWRT which install under the soil surface below root zone of crops for retaining water in order to fill lack of water. SWRT sat up below root zones of crops to enhance the yield, conserve water and give high field water use efficiency and crop water use efficiency. **Searchers[5]** study about the crops of zucchini squash (Cucurbita pepo L.) is widely grown under unheated greenhouse conditions for off-season production. weather conditions influencing both radiation and water utilize are mainly limited by the seeding dates. The relation between the radiation and the water utilize with weather variables is important for the quantification of crop yield and for enhancing field water utilize efficiency(FWUE) and radiation utilize efficiency (RUE). The crop coefficient (Kc) during the spring–summer period ranged from 0.10 to 1.15, while for the summer–fall season the Kc ranged from 0.12 to 0.80. the weather condition were daily solar radiation (Rs), daily air temperature (TA) and daily vapor pressure (VPD). **Searchers[6]** study many of crops in sumer and winter by FAO56 searches. In search study about squash (zucchini) found the start plant of zucchini in May and harvest after 90 day (three months). The initial growing season take 20 days and development have 30 days but mid of season have 25 days and late of season have 15 days. The crop coefficient in initial stage do not give but the development, mid of season and late of season were 1.0, 0.8 and 0.4, respectively. The root of zucchini crops was 0.6-1 m. the allowable deplation fraction was 50% and allowable electric conductivity was 4.7ds/m. **searchers[7]** state about The increasing value of the water productivity of three treatment (T1 compared with plots T2 and T3) was 46 and 170 %, respectively. Using membrane sheet of SWRT under the soil surface resulted in an increase in the value of yield, field water use efficiency and water productivity. also, saving water and reduced the water losses by deep percolation. **searchers[8]** mention about subsurface water retention technology is modern method for retention irrigation or rainfall water under surface soil in root zone depth so as to save water in soil profile for long period. In this study water use efficiency and water productivity for hot pepper inside greenhouse were calculated and compared using in three treatments plots planted with hot pepper using: subsurface water retention technology (T1), organic matter (T2) and tillage (T3).

2- Materials and Methods

2-1 Location of the Field Study

The research field for this study was located within Sadat Al-Hindiya Township, in the Governorate of Babylon 70 Km south of Baghdad. Sadat Al Hindiya barrage reached 2Km from field. The latitude was 32 º 42’ 23”N , longitude 44º 36"E and altitude: 31m. **Fig. (1)** shows the Google map for the site of the research study.

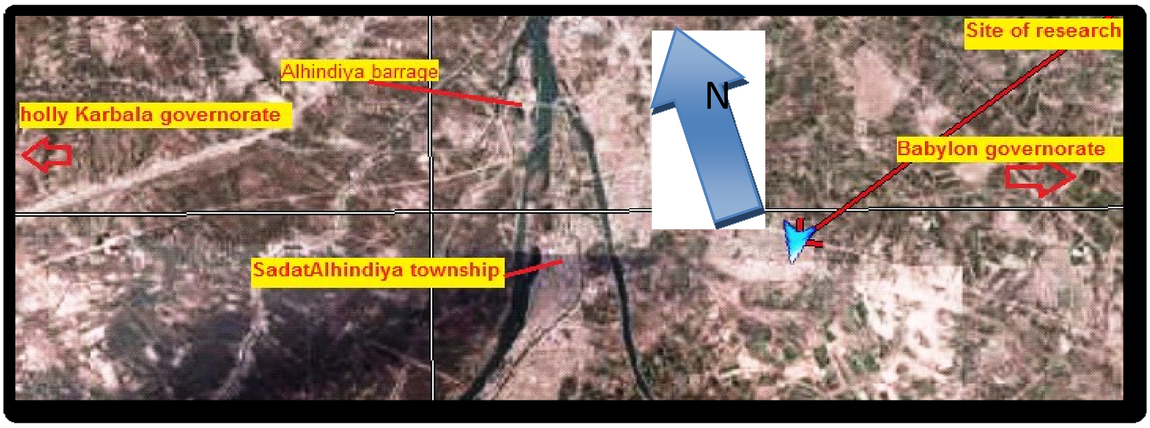

Figure (1) shows Google map for the site of the research study.

The irrigation water source from a tap that was taken from network of drinking water which took the water from Shat-ALHilla. The analysis was conducted to get on the physical properties of the soil in order to get soil texture and physical characteristic of the soil that represent apparent specific gravity(As), soil texture, field capacity(F.C), and permanent wilting point(P.W.P.). The soil texture was loamy sand soil. The F.C was 12.9% by volume and P.W.P. was 6.94 % by volume, As of loamy sand soil was 1.45 and allowable depletion of squash was 50% (**Allen et al., 1998**). The high effective root zone was 50 centimeters. Weather temperature for the site taking by Mini Environmental Quality Meters. Date of planting the crop was started at 10 May 2017 and the harvest date was mid of August 2017. Electric water pump was utilized for the drip irrigation system of maximum flow rate equal to 30 l/min with maximum head equal to 30 m and rated at power equal to 0.37 kw (0.5 HP).

Figure (2) Installation of the SWRT in site as ratio 2:1(width to height).

2-2 Treatments, Experimental Design and Crop Material

Two treatments were used: the first treatment was TA was utilized SWRT that set up below soil surface at root zone that put on partial from root of plant which save water and nutrient of crop, but in second treatment (TB) was without use membrane sheet only control on irrigation. The treatment area of TA and TB was as length of 8.3m and width was 1m so the total area at any treatment was 8.3 m^2. The SWRT was of 8.3 m and of width 45 cm set up in soil as U shape which has the aspect ratio 2:1 (width to height) installed at depth 30 cm under the root zone of crops the thickness of SWRT of the membrane sheet was 90 µm. The installation process of the membrane sheet carry out by manual work as shown in **Fig. (2)**. **Fig. (3)** showed cross section through the site of the SWRT as ratio of installing 2:1 (width: height). Zucchini squash (*Cucurbita pepo L.*) was seeded in the field at a distance of 20 cm plant spacing (St) between two plants of lines TA, TB. The emitters spacing (Se) in plots was 20 cm in TA and TB plots. The date of seeding was beginning of May 2017 and finished date in middle of August 2017. The total area equal 30 m^2. The drip irrigation system has single line 8.3m length. Each line contains of one drip tape. The row distance (Sr) between the two line was 1 m and lateral distance(Sl) was 1m. each plant provided with one emitter of average flow rate of 32 cm^3/min. The percentage wetted area(Pw) was 34% . **Fig. (4)** shows the squash(zucchini) crop at different growing stage **Fig. (5)** shows daily variation of the zucchini's ET_c values for treatment plots TA and TB and **Fig.(6)** shows daily variation of the zucchini's ET_o values measured by atmometer in field closed by concrete wall 3m height. **Fig. (7)** shows accumulated ET_c values of zucchini crop through the growing season in both treatment plots TA and TB. **Fig. (8)** shows daily and average predicted crop coefficient values of zucchini crop in initial, development, mid and late of season stage in treatment TA. **Fig. (9)** shows daily and average predicted crop coefficient values of zucchini crop in initial, development, mid and late of season stage in treatment TB. **Fig. (10)** shows basic components of the atmometer apparatus. **Fig. (11)** shows Mini Environmental Quality Meters.

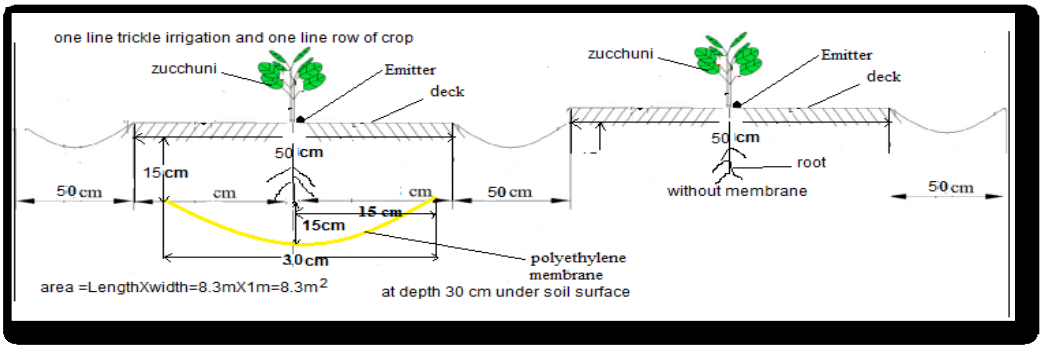

Figure (3) Cross section through soil deck and the site of the SWRT.

2-3 Estimation of Crop Evapotranspiration for the squash (zucchini) crop.

Daily crop (or actual) evapotranspiration (ETc) values for the **squash (zucchini)** were calculated when no irrigation water was applied and according to the following equation (**Israelsan and Hansen, 1979**).

$ETc = (\theta_P - \theta_n) * RD$ …………………………… (1)

where:

θ_P: soil moisture in the previous reading (% by volume),

θ_n :soil moisture in the next reading (% by volume), and

RD: rooting depth (mm).

The max. rooting depth in mid- season was 500mm

2-4 Depth of Applied Water

Applied depth of irrigation water was calculated by using the following equation:

$Q * T = dg * A$ ………………………………… (2)

where:

Q: applied discharge from the drip system (cm^3/min.),

T: time of irrigation (min.),

A: wetted area (cm^2), and

*d*g: applied depth of water (cm).

Calculation of reference evapotranspiration (ET_o) from the meteorological parameters

In this study the reading from the atmometer apparatus were recorded every day. Modified Penman-Monteith model was utilized data in the weather station to estimate the reference evapotranspiration (ET_o) in open field **(Allen et al., 1998)**:

$$ET_o = \frac{0.408*\Delta(R_n - G) + \gamma\frac{900}{T+237}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (3)$$

Where:
ET_o: reference evapotranspiration (mm /day),
R_n: net radiation at the crop surface (MJ/m^2 /day),
G: soil heat flux density (MJ/ m^2 /day),
T_{mean}: mean daily air temperature at 2m height (^{o} C),
U_2: wind speed at 2 m height (m/s),
e_s: saturation vapor pressure (kPa),
e_a: actual vapor pressure (kPa),
e_s-e_a : saturation vapor pressure deficit (kPa),
Δ: slope vapor pressure curve (kPa/^{o} C), and
γ: psychrometric constant (kPa/^{o} C).

$$\Delta = \frac{4098\left[0.6108\, exp\left(\frac{17.27Tmean}{Tmean+237.3}\right)\right]}{(Tmean+237.3)^2} \quad (4)$$

$$\gamma = 0.665 * 10^{(-3)} * Pa \quad (5)$$

where:

Pa = atmospheric pressure [kPa].

Crop Coefficient Values

The advantage of utilizing the crop coefficient (K_c) values was for calculating the irrigation requirement and scheduling the irrigation process through the growing stages. The crop coefficient is basically according to **(Allen et al., 1998):**

$$K_c = \frac{ET_c}{ET_o} \quad (6)$$

Crop coefficient values for squash (zucchini) were predicted for all crop's stages (initial, development, mid and end of seasons) through the growing seasons.

Calculation of Soil Water Content

The soil water content was expressed using gravimetric method. The mass of water was divided by dry weight of the soil sample. The percent water content by dry weight was estimated by utilizing the following formula from applied soil physics book (**Hanks and Ashcroft, 1985**):

$$\theta_m = \frac{m_w}{m_s} * 100 \quad (7)$$

where:
θ_m: percent of soil water content by dry weight (%),
m_w: mass of water content (gm), and
m_s: mass of dry soil (gm).

The soil water content percentage by dry weight was converted to volumetric percentage by multiplying the percentage by dry weight by apparent specific gravity of the soil (As)

$$\theta_v = \theta_m * As \qquad (8)$$

where:

θ_v: percent of soil water content by volume (%), and
As: apparent specific gravity of the soil.
The example of eq.(7) and eq.(8)
Total weight of soil (mt) was= 100.22gm and mass of dry soil ms = 93.19gm subtract the ms from mt to get on mass of water (m_w) = 100.22-93.19=7.03gm from eq.(7)

$$\theta_m = \frac{7.03gm}{93.19gm} * 100 = 7.54\% \text{ by dry weight}$$

from eq.(8) get on $\theta_v = 7.54\ \% * 1.45 = 10.93\%$ by volume while the field capacity was 12.9% by vol. and P.W.P was 6.94% by vol. also the allowable deplation of squash was 50% get on ready available water was 9.92 % by vol.

Table (1) Month, depth of applied water and frequency of irrigation of zucchini in treatment plots TA and TB for the growing season 2017.

Month	Depth of applied water (mm) in plot TA	irrigation Number TA	Depth of applied water (mm) in plot TB	irrigation Number TB
May	85	8	104.8	9
June	105.58	8	115.05	9
July	127.28	9	150.66	10
Total	**317.8**	**25**	**370.5**	**28**

Total volume of irrigation water of TA and TB were 0.39, 0.47 m^3, respectively.

3- Results and Discussions

Daily squash (zucchini) crop evapotranspiration values were measured by using watermarks sensors through the root zone depths starting from the date of planting to the end of the season, where Eq. (1) was applied. Moreover, for the date of irrigation process,depth and volume of water applied were calculated by applying Eq. (2). Table (2) and Table (3) showed the month, depth and volume of applied. Table (4) shows the month, ETc of TA, ETc of TB, ETo, Kc of TA, Kc of TB.

4. CONCLUSIONS

The following conclusions were resulted from the experimental work of this study:

1- The total ET_c of zucchini through the growing season of TA and TB were 245, 263 mm, respectively. The total growing days was 97 days. But the total depth of applied water in plot TA was 317.8mm and plot TB was 370.5mm

2- Identical ET_c values were found in zucchini crop of TA less than TB. The existing of membrane sheet was effected crop's ET_c.

3- The predicted K_c values for zucchini during the initial, development, mid and end of season in plots TA was 0.15, 0.57, 0,68 and 0.46 in initial, development , mid of season and late of season , respectively while TB was 0.18, 0.65, 0,72 and 0.49 in initial, development , mid of season and late of season , respectively. The value of K_c in TA and TB were approximately similar.

4- The total depth of applied water for zucchini crop in treatment plot TA was 14.2 % less than that applied in plots TB. Number of irrigation was in plot TA less than TB by 12 %.

5-RECOMMENDATION

For further studies, the following recommendations were suggested:

1- using SWRT for light soils in area of rainfall together with supplementary irrigation.
2- To search the possibility of using SWRT for strategic crops such as wheat, barley, maize and rice for various soil.
3- To study the influence to install the SWRT below the soil surface under different depths and widths.

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NOMENCLATURE:

- SWRT= subsurface water retention technology.
- TA, TB = treatment plots.
- ET_c = crop evapotranspiration (mm/day).
- ET_o = reference evapotranspiration (mm/day)
- K_c = crop coefficient (dimension less).

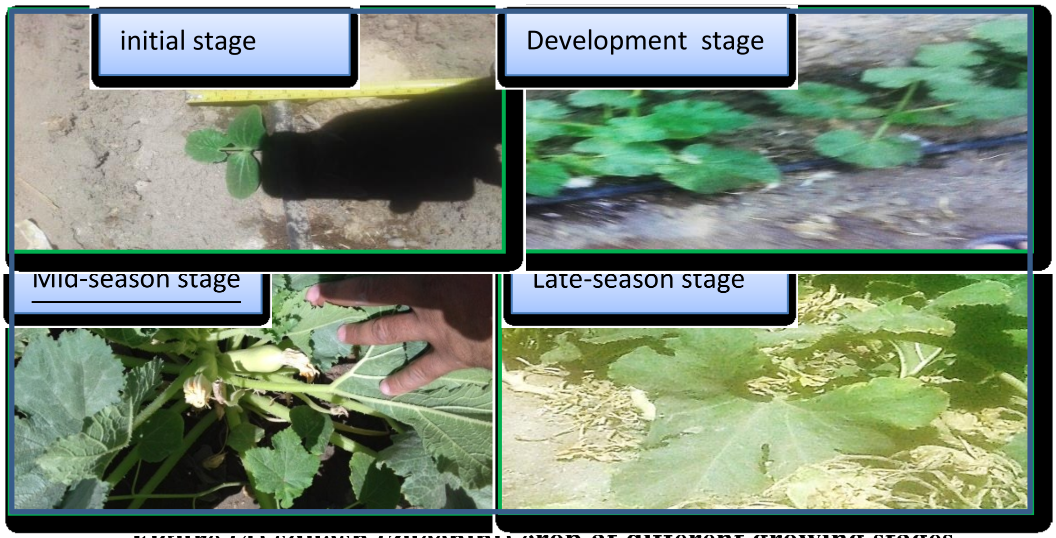

Figure (4) squash (zucchini) crop at different growing stages.

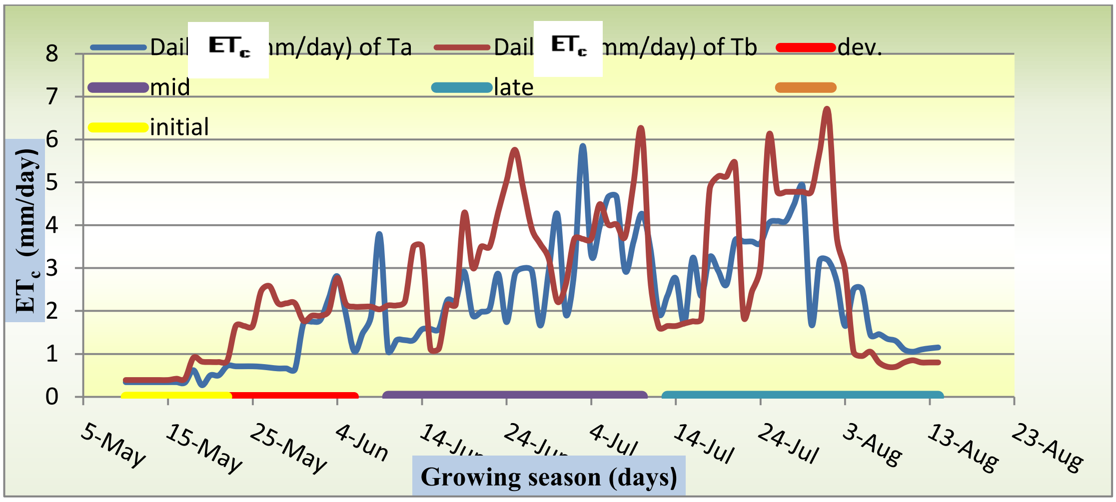

Figure (5) Daily variation of the zucchini's ET_c values for treatment plots TA and TB.

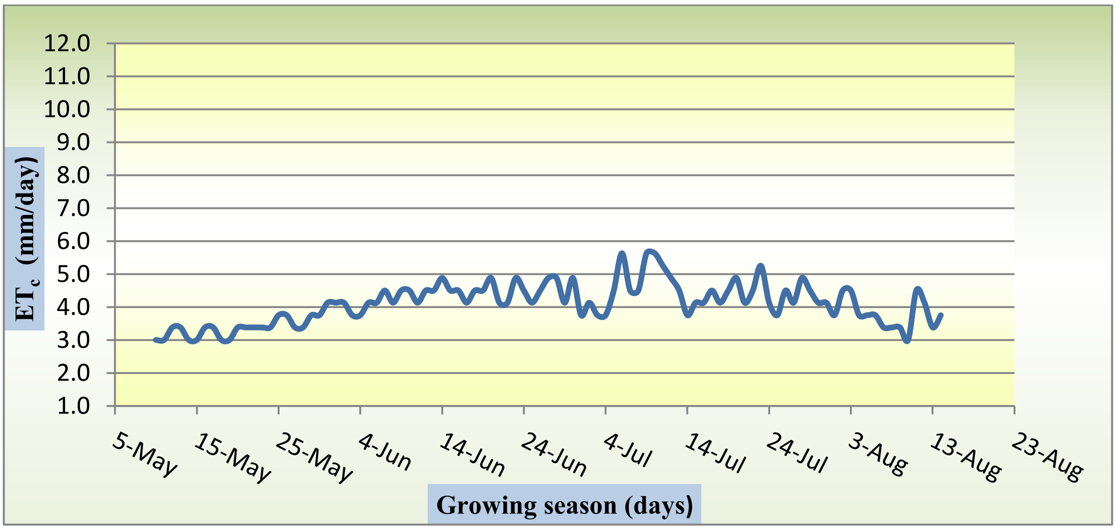

Figure (6) Daily variation of the zucchini's ET_o values measured by atmometer in field closed by concrete wall 3m height .

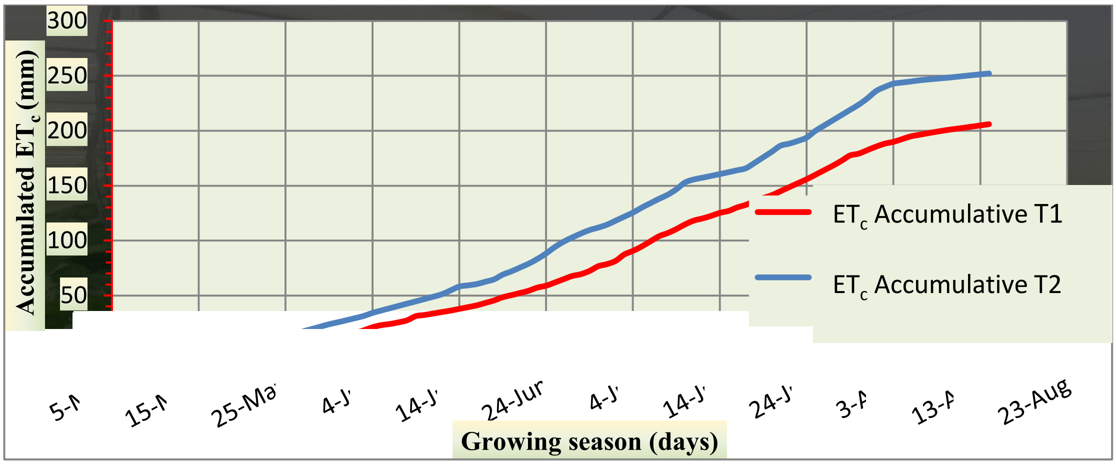

Figure (7) Accumulated ET_c values of zucchini crop through the growing season in both treatment plots TA and TB.

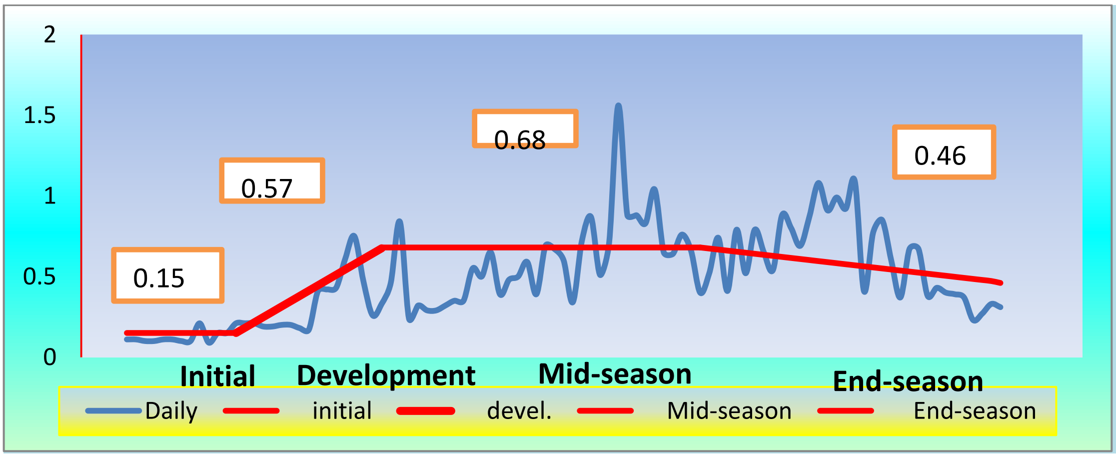

Figure (8) Daily and average predicted crop coefficient values of zucchini crop in initial, development, mid and late of season stage in treatment TA.

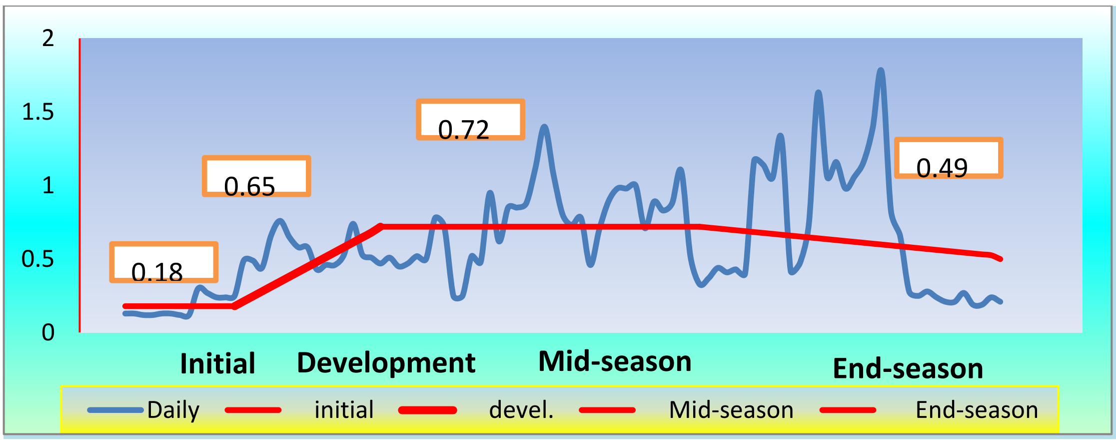

Figure (9) Daily and average predicted crop coefficient values of zucchini crop in initial, development, mid and late of season stage in treatment TB.

Table (2) Average predicted squash's K_c values for the growing stages carried out via various local models and approaches.

Models and approaches	Growing stage- K_c				Total period time (day)
	Initial	Develop.	Mid-season	Late-season	
Present work in plot TA	0.15	0.57	0.68	0.46	97
Present work in plot TB	0.18	0.65	0.72	0.49	97
FAO56	---	1	0.8	0.40	90

The reduction of Kc in TA and TB from the FAO56 because of the changing of metrological data (wind speed was near to zero and the region was closes by concrete wall 3m height therefore the radiation (sun shine) was very less because of shadow from walls from four side.

Table (3) Percentage of crop's growing stages and period duration of zucchini crop through the growing season.

Percentage of growing stage	Initial	Development	Mid-season	Late -season	Total
Average growing stage (%) of TA and TB	12.5	16.5	38	33	100
Stage period (days) of TA and TB	12	16	37	32	97

Table (4) Month, ETc of TA, ETc of TB, ETo, Kc of TA, Kc of TB.

Month-Year	ETc of TA (mm/month)	ETc of TB (mm/month)	ETo (mm/month)
May-2017	25	28	39.25
June - 2017	**79**	**87**	**55.90**
July- 2017	**117**	**122**	**167.65**
August-2017	**24**	**26**	**135.40**
Sum (mm)	**245**	**263**	**398.2**
Average (mm/day)	**2.6**	**2.8**	**4.1**

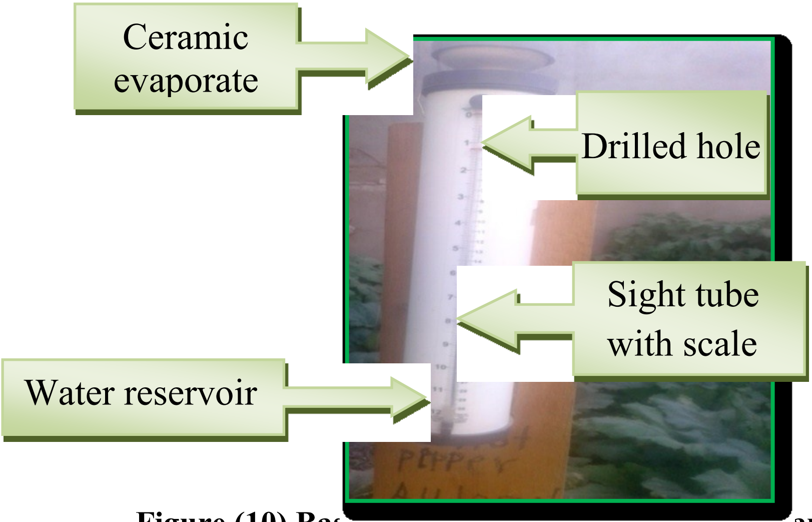

Figure (10) Basic components of the atmometer apparatus.

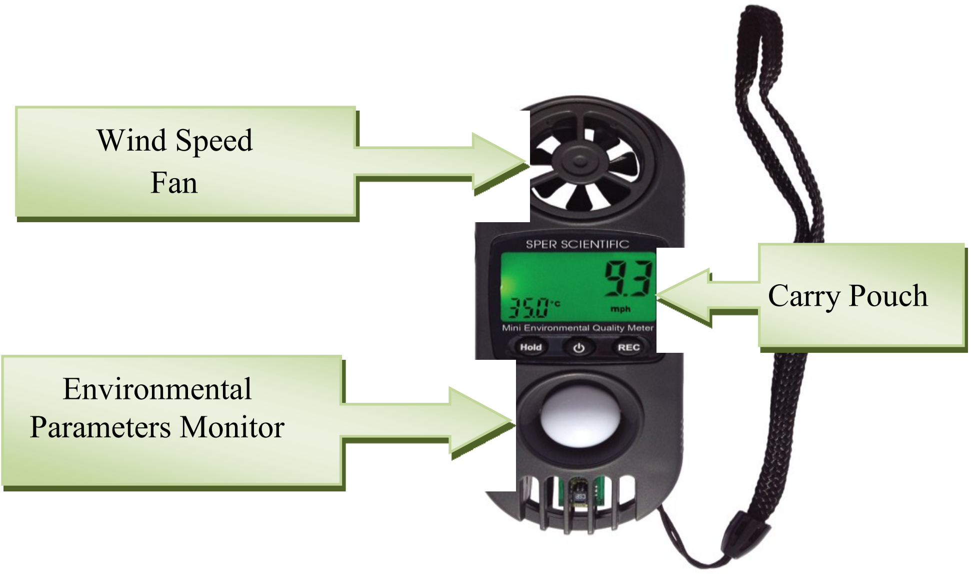

Figure (11) Mini Environmental Quality Meters.