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Effects of Subsurface Water Retention Technology on Crop Coefficient and Crop Evapotranspiration of Eggplant

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ABSTRACT

In this paper, the effects of subsurface water retention technology (SWRT) on crop coefficient (k_c) and crop evapotranspiration (ET_c) of eggplant were investigated in sandy loam soil. For this purpose, two treatments plot (with SWRT and without using SWRT) were adopted during 93 days of cultivation. The study was conducted in open field within Al-Fahamah Township, Baghdad, Iraq during summer growing season 2017. The accumulated ET_c of eggplant was 403.3 and 515.2 mm for SWRT treatment and control plot, respectively by reduction percentage 21.7 %. The average values of ET_c during the growing season were 4.3 and 5.5 mm/day, respectively. The crop coefficients value during the growing stages for initial, development, mid-season and late season stages was 0.15, 0.41, 0.81 and 0.78 in SWRT treatment plot for the respective stages and for the control plot one 0.2, 0.46, 1.13 and 0.9, respectively.

Key Words: subsurface water retention technology, evapotranspiration, crop coefficient, eggplant.

تأثير تقنية الاغشية الحافظة للماء تحت السطح على معامل النبات والاستهلاك المائي للباذنجان

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الخلاصة

في هذا البحث تم التحقق من تاثير الاغشية الحافظة للماء تحت السطح على معامل النبات k_c والاستهلاك المائي ET_c للباذنجان في تربة رملية مزيجية. لهذا الغرض، فأن نوعين من المعالجات الزراعية (بأستخدام الاغشية الحافظة للماء تحت السطح وبدون استخدام الاغشية) اعتمدت خلال 93 يوم من الزراعة. تمت الدراسة في حقل مفتوح ضمن منطقة الفحامة، مدينة بغداد- العراق للموسم الزراعي الصيفي 2017. كان الاستهلاك المائي التراكمي لنبات الباذنجان 403.3 و 515.2 ملم لتقنية الاغشية الحافظة للماء تحت السطح وغير الحافظة، على التوالي وبنسبة نقصان قدره 21.7 %. كان معدل القيم للاستهلاك المائي خلال موسم النمو كانت 4.3 و 5.5 ملم/يوم لتقنية الاغشية الحافظة للماء تحت السطح والمسيطر، على التوالي. كانت قيم معاملات النبات خلال مراحل النمو: الابتدائية و التطور و منتصف الموسم و مرحلة نهاية الموسم 0.15، 0.41، 0.81 و

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0.78 على التوالي في تقنية الاغشية الحافظة للماء تحت السطح للمراحل المتوالية وقيمة معاملات النبات للالواح المسيطر عليها كانت 0.2، 0.46، 1.13 و 0.9 على التوالي.

الكلمات الرئيسية: تقنية الاغشية الحافظة للماء تحت السطح، الاستهلاك المائي، معامل النبات، الباذنجان.

1. INTRODUCTION

Eggplant (*Solanum Melongena L.*) is a member of the Solanaceous family. It grows widely, and it requires warm soil and air for good production, and can be grown in all types of soil, but works well in fertile soils having easy drainage and rich in organic matters. Eggplant is an annual and economically important plant, produced as 35300000 tons from 1900000 hectares worldwide, 7% of the eggplant production occurs in Africa, Europe, and America, while 93% is produced in Asia, **Ghaemi,** and **Rafiee, 2016**. During the growing period, crop water requirement varies due to variation in weather condition and crop canopy and related to both irrigation systems and cropping technique. Water requirement for irrigation represents the difference between the crop water requirement and effective rainfall. **Pidwirny, 2006** stated that the crop evapotranspiration (ET_c) is defined as the amount of removing water from a soil surface due to evaporation and transpiration processes. Application of nutrient and irrigation frequency can affect ET_c by decreasing or increasing plant water demand and by changing the level of soil water depletion. Units of evapotranspiration are expressed as depth of water per unit time to assure compatibility with the calculation of hydrologic budget, **Hall, 2001**. Crop evapotranspiration can be estimated indirectly using crop coefficient (K_c) associated with the estimates of reference evapotranspiration (ET_o), **Mendonca, 2007**. **Daniel, et al., 2012** determined the evapotranspiration and crop coefficient for eggplant during 134 days of cultivation in Seropédica-RJ, Brazil, under two cropping systems (no-tillage and conventional soil preparation) and stated the maximum evapotranspiration is 285.15 and 323.44 mm for the no-tillage and for the conventional one, respectively. Additionally, the crop coefficient for the no-tillage system are 0.83 in the initial stage of growth, 0.77 in the development stage, 0.9 in the middle stage and 0.97 in the late stage, while the crop coefficient for the conventional soil preparation is 0.81 in the initial stage of growth, 1.14 in the development stage, 1.17 in the middle stage and 1.05 in the late stage. **Hikmat, 2014** investigated crop coefficient values for eggplant in open field and state the crop coefficient values are 0.15 in the initial stage of growth, 0.71 in the development stage, 0.92 in the mid-stage and 0.58 in the late stage. **Allen, et al., 1998** shows crop coefficient values for 34 strategic crop that are mostly collected from the FAO database and studies. The crop coefficient values from FAO for the eggplant for initial, mid and late of the season are 0.6, 1.05 and 0.9, respectively. These values are calculated under sub-humid conditions and typical irrigation management and soil wetting conditions, where the minimum relative humidity is 45% and wind velocity is 2 m/s. **Hamza, 2015** predicted the crop coefficient values and crop evapotranspiration for cucumber inside greenhouse for two consecutive seasons and stated that the mean values of K_c for the first season are 0.16 in the initial stage of growth, 0.87 in the development stage, 1.23 in the middle stage and 0.87 in the late stage, while the mean values of k_c for the second season are 0.17 in the initial stage of growth, 0.68 in the development stage, 1.09 in the middle stage and 0.88 in the late stage. Additionally, the total calculated values of crop evapotranspiration were 218.2 and 281.9 mm, respectively for the first and second season. The objectives of this study were to evaluate the effects of subsurface water-saving membranes installed at depth 35 cm below ground surface in a sandy loam soil, on crop evapotranspiration (ET_c) and crop coefficient (K_c) values of eggplant in open field.

2. MATERIALS AND METHODS

2.1 Experimental Condition and Location of the Field Study

The experimental work was conducted within Al-Fahamah Township, Baghdad, Iraq for the summer season of eggplant from the month of April 9th to July 10th, 2017. The experimental work was carried out in the small open field located at Latitude: 33°25' N, Longitude: 44°20' E, and altitude: 36 m. **Fig. 1** shows a Google map of the study area. The main source of water was from a farm reservoir charged continuously from Tigris River. Two soil samples from the field of eggplant were taken at depth (0-50 cm). Analyses of soil sample were conducted at the laboratories of the Agricultural Research Directorate of Ministry of Science and Technology. The goal of the analysis was to identify the physical characteristics of the soil in order to determine soil texture and physical properties of the soil which included apparent specific gravity, soil texture, field capacity (FC), and permanent wilting point (PWP). The average analysis of the soil texture for the two samples of the field is classified as sandy loam soil. Also, FC and PWP were estimated to be 16.3 and 7.4 % (by volume), respectively. **Table 1** shows the average values of the physical properties parameters for the soil sample.

2.2 Treatments, Experimental Design and Crop Material

The total area of the study was 27 m^2 (9 m long and 3 m wide). **Fig. 2** shows the layout of the field study area. Trickle irrigation system was used because it is a suitable method for water application. **Fig. 3** shows the layout of the trickle irrigation system. The system consists of two double irrigation lines each was 9 m long of diameter 15 mm, and each trickle line contains 18 emitters along its total length. The emitters were spaced at 0.5 m apart. The average flow rate of each emitter was 20 ml/min. Eggplant crop (*Solanum Melongena L.*) was planted on 0.5 m distance between plants on both sides. In each irrigation process, soil water content before irrigation, date, the flow rate from the emitter, and time of the irrigation was recorded when possible. Two treatment plots were selected for the research work, treatment no.1 (T1) using subsurface water retention technology (SWRT) was installed below the soil surface and treatment no.2 (T2) was control plot (without using SWRT). SWRT consists of subsurface low-density polyethylene membrane thickness 175µm installed at depth 35 cm below ground surface with aspect ratio 3:1 (length to height). The installation of the membrane was done manually and all the excavation work was done by hands, no special machine was used in this process. The width of the membrane was 36 cm with both side heights was 12 cm. **Fig. 4** shows the layout of the polyethylene membrane under the soil profile.

3. CALCULATION AND PROCEDURE

Estimated crop coefficient (K_c) values for the eggplant crop for T1 and T2 were calculated from water consumption by dividing daily measured crop evapotranspiration (ET_c) by reference evapotranspiration (ET_o) as follows, **Allen, et al., 1998.**

$$Kc = \frac{ETc}{ETo} \tag{1}$$

where:
K_c= estimated crop coefficient,
ET_c= crop evapotranspiration (mm/day), and
ET_o= reference evapotranspiration (mm/day).

Crop evapotranspiration (ET_c) for eggplant was calculated based on daily readings or between day and another through the growing season based on applicable equation conducted by **Israelsan,** and **Hansen, 1979** as follows:

$$ET_c = (\theta_p - \theta_n) \times RD \qquad (2)$$

where:
θ_p= soil moisture content in the previous reading day (% by volume),
θ_n= soil moisture content in the next reading day (% by volume), and
RD= rooting depth (mm).

Crop evapotranspiration (ET_c) for eggplant was calculated by measuring the soil water content using the gravimetric method when there is no irrigation and precipitation. Reference evapotranspiration (ET_o) was provided from Abu-Ghraib weather station (Latitude: 33°32' N, Longitude: 44°23' E, and altitude: 30 m) away from the study area of about 16 km. **Table 2** shows the values of the ET_o during the growing season. The crop coefficient (K_c) for the eggplant was estimated on daily basis for each growing stage: 1- initial, 2- development, 3- mid-season, 4- late season stage, and starting from the date of transplanting till harvest time.

4. RESULTS AND DISCUSSION

4.1 Effect of SWRT on Plant Water Consumption

Crop evapotranspiration values were calculated by using **Eq. (2)** for treatment plots T1 and control treatment T2. The irrigation schedule for both treatment plots was started from mid of April 9, 2017, and ended on mid of July 10, 2017. Water was applied when the depletion percentage reached 45% from the available water, no crop's water stress was allowed. **Fig. 5** shows the daily variation of ET_c values for eggplant in T1 and T2. The accumulated measurement of ET_c during eggplant cultivation was 403.3 and 515.2 mm for SWRT treatment T1 and control plot T2, respectively. The average values of ET_c during the growing season were 4.3 mm/day and 5.5 mm/day, respectively for treatment T1 and treatment T2. The installation of polyethylene membrane under soil surface have provided saving in using the water for irrigation of 21.7 % compared to control treatment (T2) because there was no barrier to keep water in the soil, and consequently, this effect was reflected in the calculated values of crop coefficient values.

4.2 Determination of the Crop Coefficient Values

Crop coefficient values were calculated by using **Eq. (1)** for treatment T1 and control treatment T2. Periods of crop development for each growing stage of the eggplant according to **Allen, et al., 1998** depended on and was shown in **Table 3**. The growing stage (initial, development, mid and late of the season) of the eggplant were based on the observation of the development of the crop which was similar to the study conducted by, **Daniel, et al., 2012** and, **Hikmat, 2014**. Also, the crop coefficient used by **Allen, et al., 1998** depended on the growing season (initial, mid and late of the season), the initial stage represents April, May, and June represents mid of the season, while July represents the end of the season. **Table 4** shows the average eggplant's crop coefficient values for the growing stages conducted by different approaches. **Fig. 6** shows the crop coefficient values of eggplant conducted by different approaches. The overall average percentage in K_c stages values difference between T1, T2, **Hikmat, 2014, Daniel, et al., 2012** and **Allen, et al., 1998** approaches were: 25, 10, 93 and 19 %, respectively. The main parameter that K_c value depends on in Eq.1 was ET_c and ET_o, therefore when ET_c value reduced due to saving water, the K_c value will be reduced accordingly. Values of K_c in the treatment T1 were close to K_c values conducted by **Hikmat, 2014** due to both types of research work were carried out in open field with the same weather parameters and in the same city. In the present work, a reduction in values of K_c was shown clearly in initial, development and mid of season stages. Additionally, weather parameters and location of the field were also affected by K_c values.

5. CONCLUSIONS

The installation of polyethylene membrane under the soil surface and within crop's root depth affected the daily variation of the ET_c values due to the reduction of soil water saved which was low in T1 compared with T2. The total measured value of ET_c was 403.3 and 515.2 mm for T1 and T2, respectively; the saving in irrigation water in T1 was 21.7 % of the total water used for irrigation. The polyethylene sheet was sufficiently improved in saving water in the crop root depth and ET_c value was reduced without any crop water stress was observed. The calculated values of crop coefficient values for the T1 plot for initial, development, mid and late of season growing stages were: 0.15, 0.41, 0.81, and 0.78, respectively. While the crop coefficient values for the T2 plot were: 0.2, 0.46, 1.13, and 0.9, respectively. The overall average K_c value difference between T1 and T2 plots was 25%. Additionally, the difference in K_c value between T1 and Hikmat, Daniel, et al., and Allen, et al., were: 10, 93 and 19 %, respectively. K_c values affected by crop evapotranspiration, weather parameters, the location of the field, and even whether the field was open or inside greenhouses.

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NOMENCLATURE

ET_c = crop evapotranspiration, mm/day.
ET_o = reference evapotranspiration, mm/day.
FC = field capacity, % by volume.
K_c = crop coefficient.
PWP = permanent wilting point, % by volume.
RD = rooting depth, mm.
SWRT = subsurface water retention technology.
θ_p= soil moisture content in the previous reading day, % by volume.
θ_n= soil moisture content in the next reading day, % by volume.
T1 = Treatment no. 1
T2 = Treatment no. 2

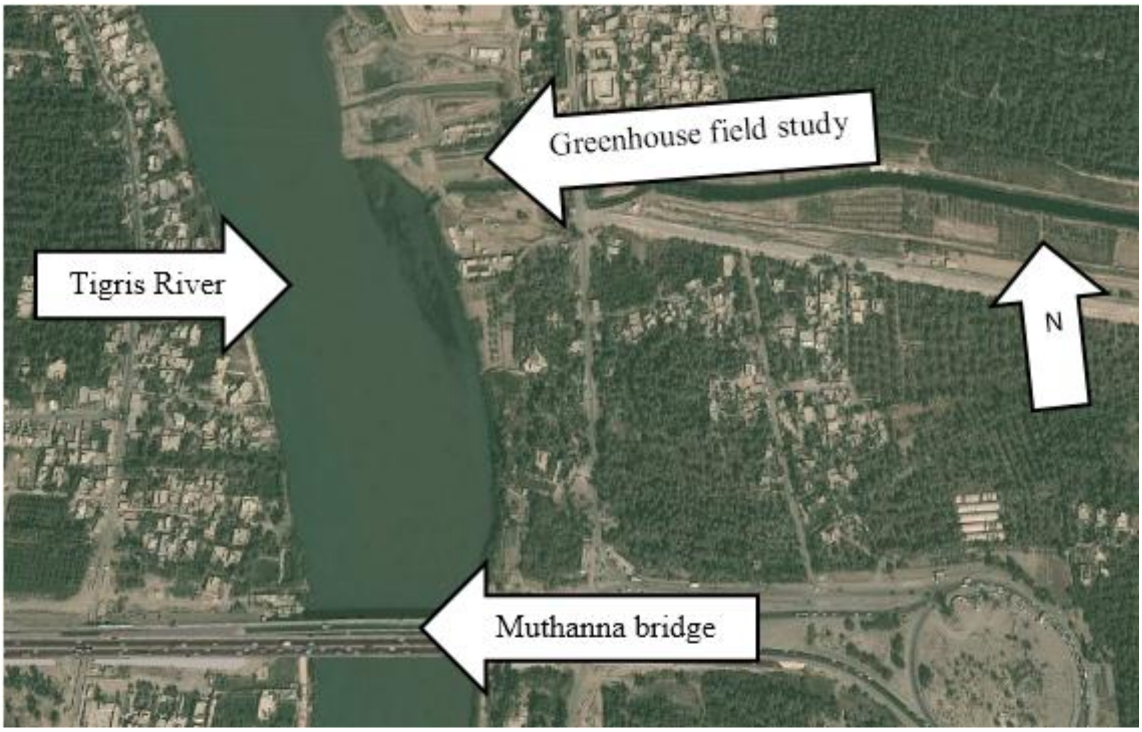

Figure 1. Google map for the research site work.

Figure 2. Study field area.

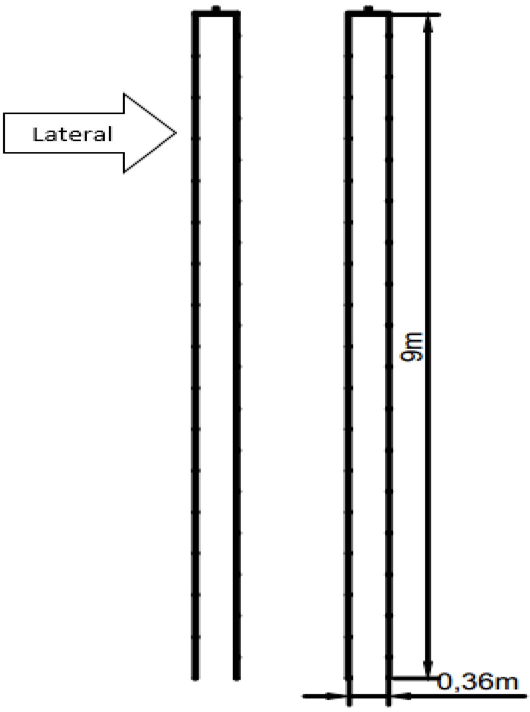

Figure 3. Layout of the trickle irrigation system.

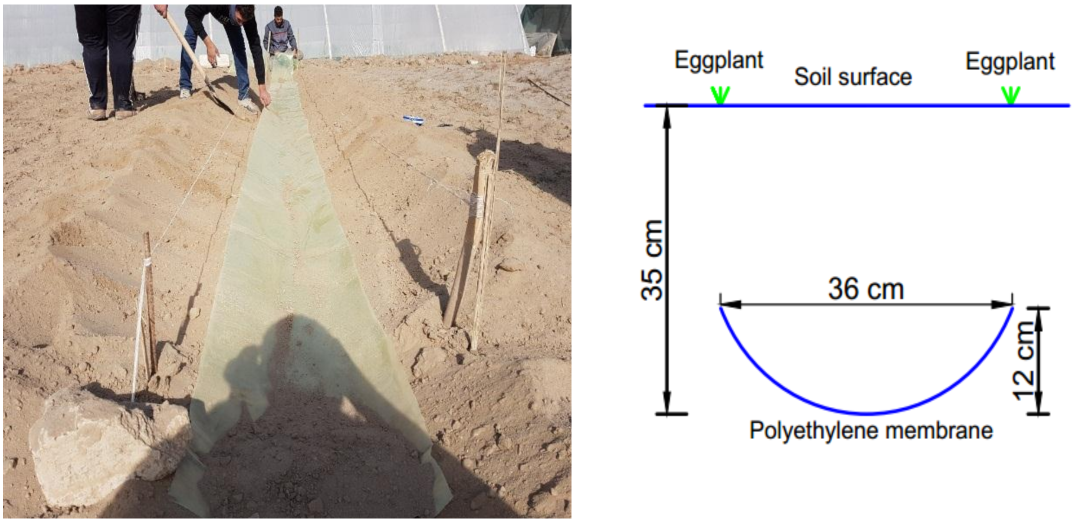

Figure 4. The layout of the polyethylene membrane under the soil profile.

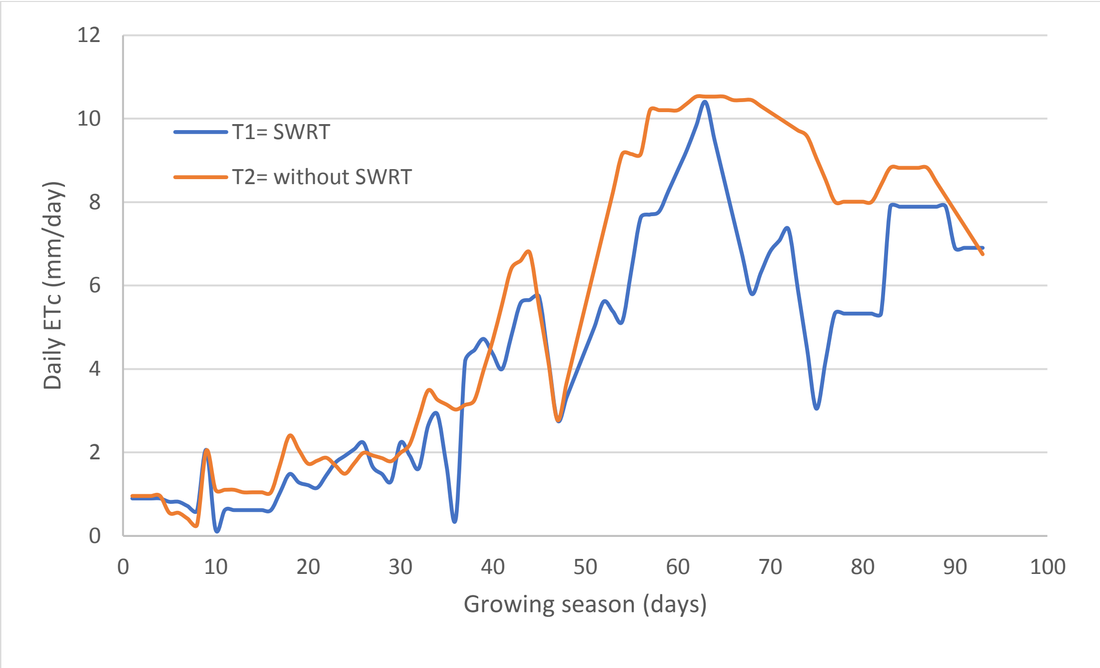

Figure 5. Daily variation of the ET_c values of eggplant.

Table 1. Physical properties of the soil.

Type of the test	Specifications of the soil Average for the depth (0-50 cm)
Apparent specific gravity	1.23
Soil texture	Sandy loam
Water content at field	16.30

capacity (% by volume)	
Water content at permanent wilting point (% by volume)	7.40

Table 2. Reference evapotranspiration (ET_o) values during the growing season.

Date	ETo (mm/day)	Date	ETo (mm/day)	Date	ETo (mm/day)
09-Apr.	5.1	10-May	8.4	10-Jun.	8
10-Apr.	4.7	11-May	7	11-Jun.	8.7
11-Apr.	5.7	12-May	8.2	12-Jun.	8.1
12-Apr.	5.8	13-May	7.9	13-Jun.	7.6
13-Apr.	7.4	14-May	8	14-Jun.	9
14-Apr.	6.5	15-May	8.9	15-Jun.	7.9
15-Apr.	3.5	16-May	8.4	16-Jun.	7.7
16-Apr.	5.4	17-May	7.9	17-Jun.	7.2
17-Apr.	5.1	18-May	8.5	18-Jun.	8.3
18-Apr.	5.8	19-May	9	19-Jun.	8.8
19-Apr.	5.5	20-May	7.5	20-Jun.	8.6
20-Apr.	5.4	21-May	6.6	21-Jun.	8.6
21-Apr.	6	22-May	6.2	22-Jun.	8.6
22-Apr.	6.8	23-May	7	23-Jun.	9.6
23-Apr.	5.7	24-May	6.6	24-Jun.	9.2
24-Apr.	6.2	25-May	6.9	25-Jun.	10.3
25-Apr.	6.5	26-May	7.4	26-Jun.	10.2
26-Apr.	6.5	27-May	7.9	27-Jun.	9.9
27-Apr.	4.5	28-May	7.5	28-Jun.	11.4
28-Apr.	7.4	29-May	6.7	29-Jun.	8.6
29-Apr.	7.7	30-May	7.8	30-Jun.	8.9
30-Apr.	8.1	31-May	8.6	01-Jul.	8.2
01-May	7.6	01-Jun.	7.2	02-Jul.	7.2
02-May	6.4	02-Jun.	7.7	03-Jul.	7.6
03-May	6.8	03-Jun.	7.7	04-Jul.	8.1
04-May	6.4	04-Jun.	8.8	05-Jul.	9.3
05-May	6.7	05-Jun.	8.6	06-Jul.	10.2
06-May	7.5	06-Jun.	8.2	07-Jul.	9.1
07-May	7.6	07-Jun.	9	08-Jul.	8.8
08-May	7.5	08-Jun.	8.6	09-Jul.	10.7
09-May	7.8	09-Jun.	8.7	10-Jul.	10.6

Table 3. Estimation of the period and percentage of the growing stage of eggplant.

Stage and period	Initial	Development	Mid-season	Late season	Total
Growing stage (%)	23	31	31	15	100
Stage period (day)	21	29	29	14	93

Table 4. Average eggplant's K_c values for the growing stages estimated by different approaches.

Models and approaches	Growing stages-K_c			
	Initial	Development	Mid-season	Late-season
Present study (T1)	0.15	0.41	0.81	0.78
Present study (T2)	0.2	0.46	1.13	0.9
Hikmat, 2014	0.15	0.71	0.92	0.58
Daniel, et al., 2012	0.81	1.14	1.17	1.05
Allen, et al., 1998	0.6	-	1.05	0.9

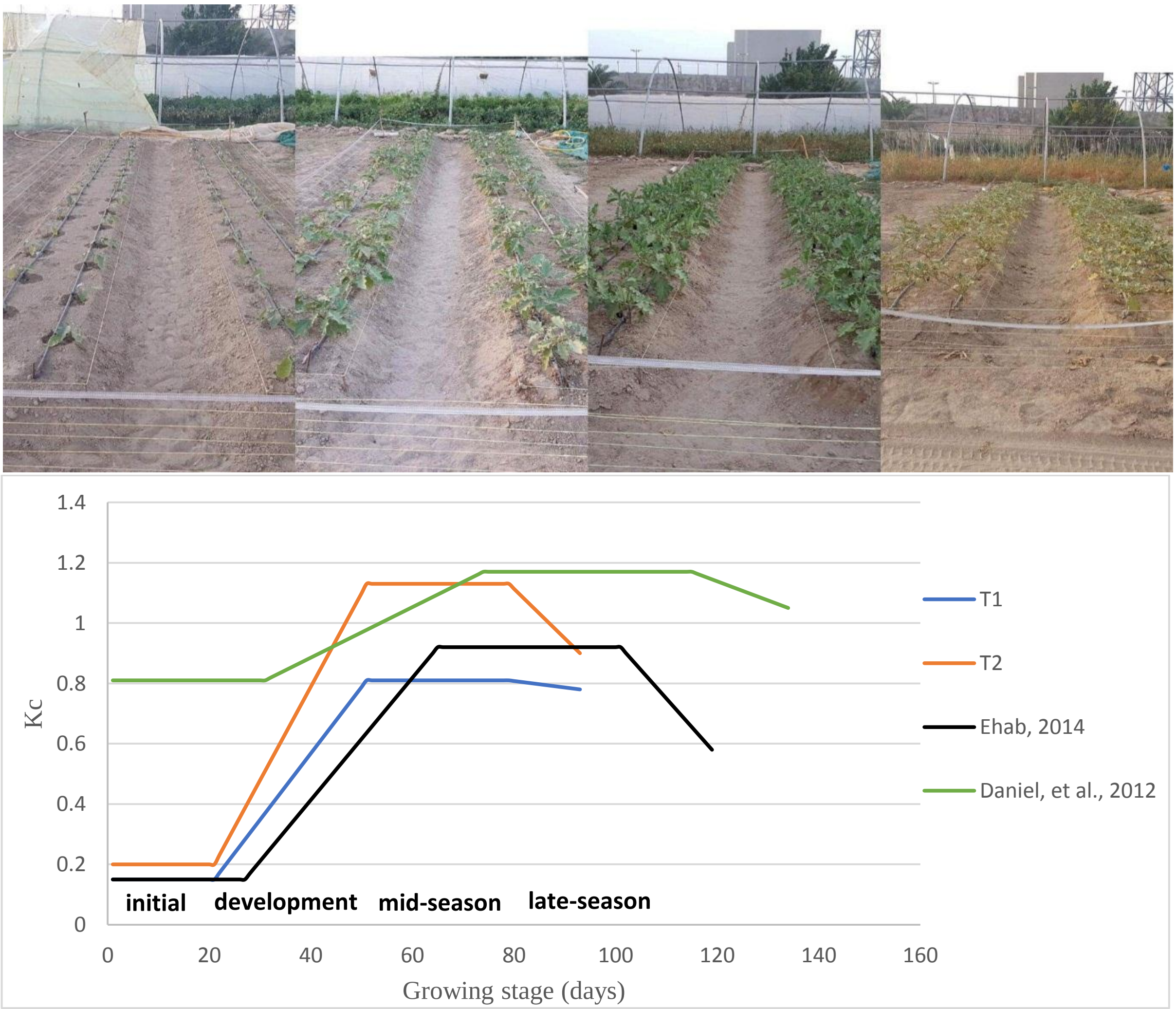

Figure 6. Comparison of the crop coefficient values for the eggplant.