Predicating The Crop Coefficient of Eggplant from Crop Evapotranspiration and Atmometer (ETgage)

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ABSTRACT

The objectives of the study are to predicate crop coefficient (Kc) for eggplant using watermarks gypsum blocks and atmometer (or ETgage) devices during the growing season and to compare the predicating values of the crop coefficient with FAO recommended Kc and with local study values. The study was conducted in the field within Al-Yusufiya Township, 30km south of Baghdad under semi- arid weather conditions. The watermarks and atmometer were used to measure crop evapotranspiration (consumptive use) and reference evapotranspiration respectively. Watermarks wereinserted in the root zones of eggplant staring from the time of planting till harvest time, with the same time the atmometer was installed in the same field after evaluation and comparison was done with the FAO-56 modified Penman – Monteith equation. Comparison between the predicating crop coefficient that obtained from crop evapotranspiration and reference evapotranspiration and the recommended FAO for Kc values showed thatthe relative error was29.61%, and with mean absolute error was0.2. Moreover, root mean square difference was 0.25. Additionallythe comparison between the predicating crop coefficient with the local study for Kc values showed a relative error of 36.91% and with mean absolute errorwas 0.26.Moreover, the root mean square differencewas 0.31.

Keywords: crop coefficient, crop evapotranspiration, soil moisture sensor.

أستنباط معامل نبات الباذنجان من الاستهلاك المائي للنبات ومن جهاز الاتموميتر (لقياس الاستهلاك المائي الكامن)

الخلاصة

يهدف هذا البحث الى أستنباط معامل نبات الباذنجان بأستخدام متحسسات الجبس لقياس رطوبة التربة وجهاز الاتموميتر (لقياس الاستهلاك المائي الكامن) خلال الموسم الزراعي, ومقارنة القيم المستنبطة مع القيم المسجلة لدى منظمة الزراعة والغذاء العالمية ولقيم محلية الاستخدام.الدراسة تمت في حقل ضمن منطقة اليوسفية التي تبعد 30 كم جنوب بغداد تحت ظروف جوية شبه جافة. أستخدمت متحسسات الرطوبة

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الجبسية وجهاز الاتموميتر لقياس الاستهلاك المائي للنبات والاستهلاك المائي الكامن على التوالي. تم وضع المتحسسات ضمن الطبقة الجذرية لبنات الباذنجان أبتداءا من وقت زراعة النبات ولغاية وقت الحصاد, وبنفس الوقت تم نصب جهاز الاتموميتر في نفس الحقل وبعد ان تم تقييم ومقارنة القيم المستحصلة مع معادلة بنمان – مونتيث (منظمة الزراعة والغذاء رقم 56). أظهرت نتائج المقارنة بين القيم المستنبطة لمعامل النبات مع قيم منظمة الزراعة والغذاء أن قيمة الخطاء النسبي كانت 29.61% ومعدل الخطاء المطلقكانت 0.2. بينما كان معدل الجذر التربيعي للفرق 0.25. كذلك أظهرت نتائج المقارنة بين القيم المستنبطة لمعامل النبات مع القيمالمحلية المستخدمة أن قيمة الخطاء النسبي كانت 36.91% ومعدل الخطاء المطلق كانت 0.26و كان معدل الجذر التربيعي للفرق 0.31.

INTRODUCTION

Estimating of crop evapotranspiration for specific crops is important for irrigation scheduling and agricultural water management[1]. Close agreement between alfalfa reference evapotranspiration (ETr) values measured with ET gage or computed using the 1982 kimberly – Penman equation. A strong correlation was found between the watermark sensor readinds and water content[2]. Crop water use information can be used to schedule irrigation systems. Crop water use is directly related to evapotranspiration (ET). The ET information must be adjusted to correspond to the crop and climate. Reference evapotranspiration (ETo) is measurement of the water use for that reference crop. The crop coefficient (Kc) takes into account the crop type and crop development to adjust the ETo for that specific crop. The water requirement of a crop must be satisfied to achieve potential yields. The crop water requirement is also called crop evapotranspiration and is usually represented as ETc. As ETcvaries with plant development stage and weather conditions, both the amount and timing of irrigation are important. The water balance method of irrigation scheduling is one method of estimating the required amount and timing of irrigation for crops [3]. Crop coefficient was developed based on irrigation scheduling protocols for cotton grown in the Southeastern ofUnited States. The model was uses a simplified water balance approach to track plant – available soil water during the growing season of cotton[4].The FAO – 56 procedures for estimating the crop coefficient was a function of fraction of ground cover and crop height [5]. Formalization for the FAO - 56 procedures was done using density coefficient and multiplied by the crop coefficient to represented full cover conditions to produce the actual conditions of ground coverage [6].In order to apply reference evapotranspiration results to all other non-standard crops, multiplier crop coefficients (Kc) have been developed to convert the reference data to each alternate crop and growth stage[7]. The most common forms of these smart technologies are evapotranspiration (ET)-based controllers. In recent years a relatively simple type of modified Bellani plate atmometer under the brand name (ET gage), has gained increasing popularity[8]. An atmometer is one of the alternative tools that can be used to measures the amount of water evaporated to the atmosphere from a wet, porous ceramic surface, atmometer is an “atmospheric meter,” and it measure evaporation rates affected by weather conditions and plant transpiration [2], this information can be utilized for irrigation scheduling. Based on the study conducted by [9,1] to determine the water demand of ornamental plants and affected by its roots and the availability of water available during the growth stages between that it is possible, an atmometer (ETgage) tool can be used to calibrate a nursery or landscape microclimate against a nearby weather data.Farmers have been using the ETgage to estimate the crop evapotranspiration, for better irrigation management practices through proper scheduling of their irrigation.ET gage is an accurate and reliable way to observe potential evapotranspiration. A comparison of observations for Egage with pan evaporation method, indicated that ET gage has similar trends but slightly higher than pan evaporation [10]. Crop evapotranspiration can be observed and measured by monitoring soil moisture content, when no rainfall and irrigation are added to the soil. Soil water status can be measured directly with sensors such as gypsum block, tensiometers, and capacitance probes. The choice of sensor will depend on soil water range to be measured, cost effectiveness, easiness to maintain, and the sensor's performance reliability type of soil, climate, plant root zone depth, soil salinity, and soil temperature[11].

MATERIALS AND METHODS

Location of the field study

The research field for this study is located within AL-YUSIFIYAH township, AL-QASIR region which lies north of ALMAHMODIYA district, 30 km away from south of Baghdad. The field is located at (Latitude~ 36 62 18 N and Longitude ~ 43 09 16 E Altitude ~ 30m), Figure (1) shows Google map for the field site location.The main source of the water for the Yusufiya River is fed from the Euphrates River through Fallujah channel. The usual method used to irrigate the field study is the flood irrigation. The approximated total field study area is 12500 m^2.Eggplant is used in the study; the field area is about 870 m^2.

The laboratory analyzes of the soil samples are conducted in the laboratories of the National Center for Water Resources (NCWR) in Ministry of Water Resources (MOWR). The objective of the analysis is to verify the physical characteristics of the soil in order to determine the texture of the soil and all physical properties. The soil texture is loamy clay.

Devices and Equipment

The followings are specifications and description of devices and equipment are used in the study field work.

1.Atmometer or ETgage

An atmometer, the brand name (ETgage), has gained increasing popularity(Manufacture by C&M Meteorological Supply, Colorado Springs, CO, USA). It is one of the alternative tools that can be used to measures the amount of water evaporated to the atmosphere from a wet, porous ceramic surface as shown in Figures 2 and 3.

The atmometer consists of a canvas-covered ceramic evaporation plate mounted on a distilled water reservoir. The reservoir capacity is 300 mm as water depth. The fabric covering creates a diffusion barrier (resistance) that controls the evaporation rate and ranging from (112–294) s m^{-1} similar to that found in healthy leaves in a well-watered plant community.

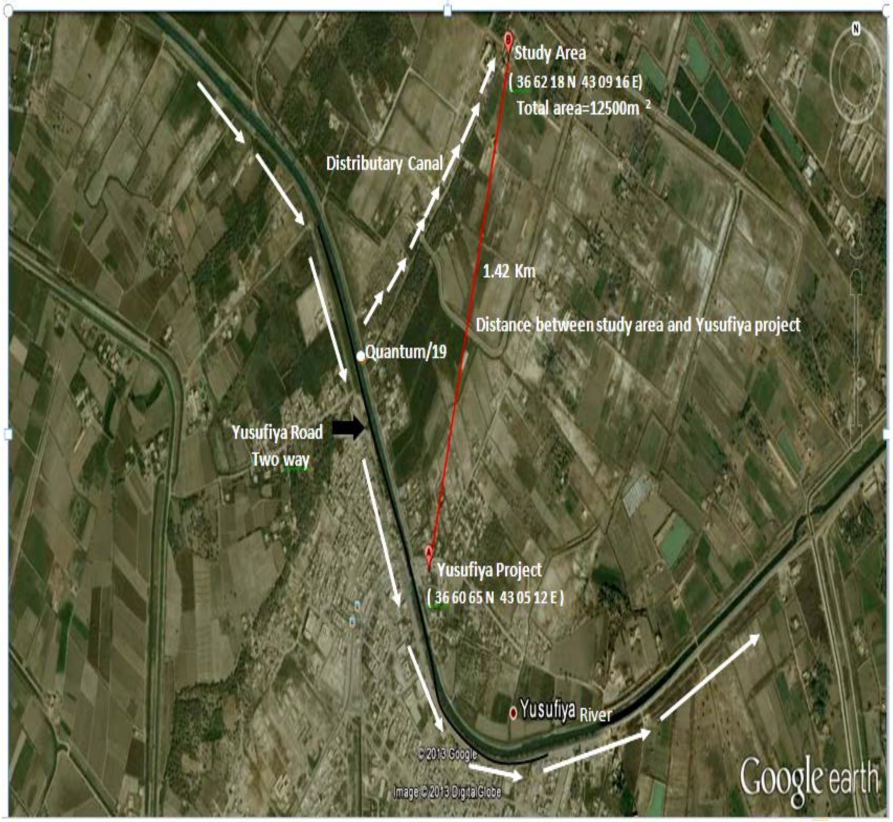

Figure (1) Google map for the research site.

The green canvas cover that surrounds the ceramic plate mimics the crop al bedo so that solar radiation absorption by the ET gage will be similar to the solar radiation received at the crop canopy. In theory, the diffusion barrier of the canvas cover and the stomata resistance of healthy, actively growing, green, and well- watered grass vegetation is assumed to be similar. The cover over the ceramic plate can be changed to simulate the ET rate for alfalfa-reference ET (ET_r or ET_o). The standard model with Number 54 green canvas cover is recommended for estimating ETr similar to modified Penman- Monteith (ET_o).In the ETgage system, water is provided to the ceramic cup by suction through a glass or plastic supply tube and check valve consisting of a diaphragm mounted in a section of silicon tubing attached at the lower end of the glass supply tube. A white poly-tetrafluoroethlylene (PTFE) membrane has been introduced to be placed between the canvas cover and the evaporating surface (ceramic plate), replacing the check valve to prevent entry of rainwater into the system. The shape of the evaporating surface also helped in easier fabric mounting and maintained better contact between the canvas cover and the ceramic plate.

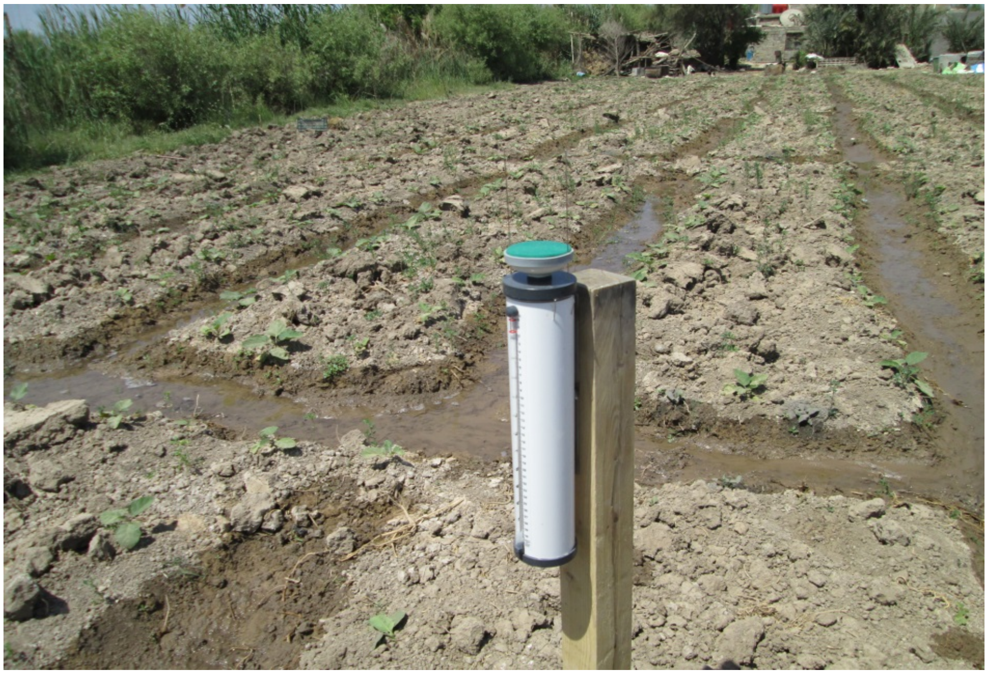

Figure (2) Location of atmometer in the field when the eggplant was in the initial stage.

Figure (3) Development stage for eggplant with the location of atmometer device in the field.

The ETgage reservoir is ventilated by two (1.5 mm diameter) holes drilled at the upper end of the clear polyvinyl chloride pipe. Distilled water is always used in the ETgage reservoir to prevent accumulation of solutes in and on the plate that can reduce the porosity of the plate and affects the evaporation rate a sight glass on the water reservoir allows the water levels in the reservoir to be read manually. Accuracy of daily ET data by reading the plastic sight tube is limited. The ETgage is easy to install and requires little maintenance which is typically mounted on a wooden post along with a rain gage with the evaporation surface approximately 1 m above the ground surface. It should not be installed near tall trees, buildings, or tall crops that may prevent full exposure of the gauge to prevailing winds and other environmental factors affecting evapotranspiration. The bird spike that is mounted on the top of the gage is placed to discourage birds from perching on the plate. It should be located at a site representative of the field conditions for easy access. The atmometer was evaluated in the same site field; comparison was done with the reference evapotranspiration calculated from modified Penman – Monteith equation. Good correlation was observed.

Watermarks (soil moisture sensor)

Watermark sensors are widely available and have a number of favorable technical characteristics for on farm use, due to its low cost, ease of installation and durability.These sensors typically require site calibration of the threshold soil-moisture content to which the soil will be allowed to dry before irrigation will be permitted.The threshold value is determined relative to field capacity, the permanent wilting point, and the management allowed depletion between irrigation events.The patented watermark sensor (manufactured by the Irrometer Co. of Riverside, CA,model 200SS) is a solid-state electrical resistance sensing device that is used to measure soil water tension.This type of sensor consists of two electrodes embedded in a reference matrix material, which is confined within a corrosion-proof and highly permeable case (unit range from (0-wet-to 200cb-dry). The matrix material includes gypsum to buffer against the effects of salts and fertilizer, but these sensors do not dissolve like gypsum block sensors. Soil moisture is constantly absorbed or released from the sensor as the surrounding soil moisture conditions change. As the soil moisture changes, the sensor moisture reacts as reflected by the change in electrical resistance between the electrodes.Granular matrix sensors operate on the same electrical resistance principle as gypsum blocks. As the moisture level increases, conductivity increases, andthe sensor is calibrated to output the moisture level in terms of soil tension [9].

When soil water content increases, either by rain or irrigation, water penetrates the block, allowing more granular matrix (gypsum, which approximates compressed fine sand) to go into the solution. Similarly, as evapotranspiration decreases soil moisture, the electrical resistance increases. Thus, these moisture blocks give an idea of the amount of energy with which water is held in the soil, and an understanding of water availability to the crop. Total of five numbers of watermarks sensors are used in the field area within the root zone of eggplant at depths 15, 30, 45, 75 and 95 cm.

CALCULATION AND PROCEDURES

Modified or predicated crop coefficients for Eggplant is calculated from water consumption by dividing daily measured crop evapotranspiration (ET_c) by reference evapotranspiration (ET_o) which measured from the atmometer as follows:

$$Kc = \frac{ETc}{ETo} \quad \text{.....(1)}$$

Where:

Kc = estimated or predicated crop coefficient,
ETc = crop evapotranspiration (mm/day), and
ETo = reference evapotranspiration (mm/day).

Crop coefficient (ETc) is calculated from watermarks sensors reading, when there is no irrigation and rainfall. Reference evapotranspiration (ETo) is calculated from atmometer (or ETgage). The crop coefficient for the Eggplant is predicated for each growing stages (development, improvement, mid of season and harvesttime or end of season) and starting from the date of planting till harvest time.

Statistical Analysis Methods

Comparison between predicated Kc, local crop coefficient and FAO values are made on daily basis, monthly and growing stages. For error analysis the following statistics are used:

$$RMSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(yi - xi)^2} \quad \text{.....(2)}$$

$$RE = \frac{RMSD}{xav} * 100 \quad \text{....(3)}$$

$$MBE = \frac{\sum_{i=1}^{n} |yi - xi|}{n} \quad \text{... (4)}$$

Where:

RMSD = root mean square difference,
n = number of observations,
yi = predicated crop coefficient,
xi = local or FAO crop coefficient,
xav = average value of crop coefficient (from local or FAO values),
RE = relative error (%), and
MBE = mean bias error.

RESULTS AND DISCUSSIONS

The local crop coefficients (Kc) for eggplant (crop coefficients values were done by Russian study in early of 1980's under Iraqi weather conditions) are presented monthly starting from March, while the crop coefficient used by FAO are depend on the growing season of the plant (initial, mid of season and late of season), the initial stage represent April and May, while June and July represent mid of the season. August is representing end of the season. The predicating Kc is calculating according to the daily measurements of the soil water content when there is no irrigation and rainfall. Figure (4) shows the comparison of crop coefficient for eggplant between predicating, local (Russian) and FAO values.

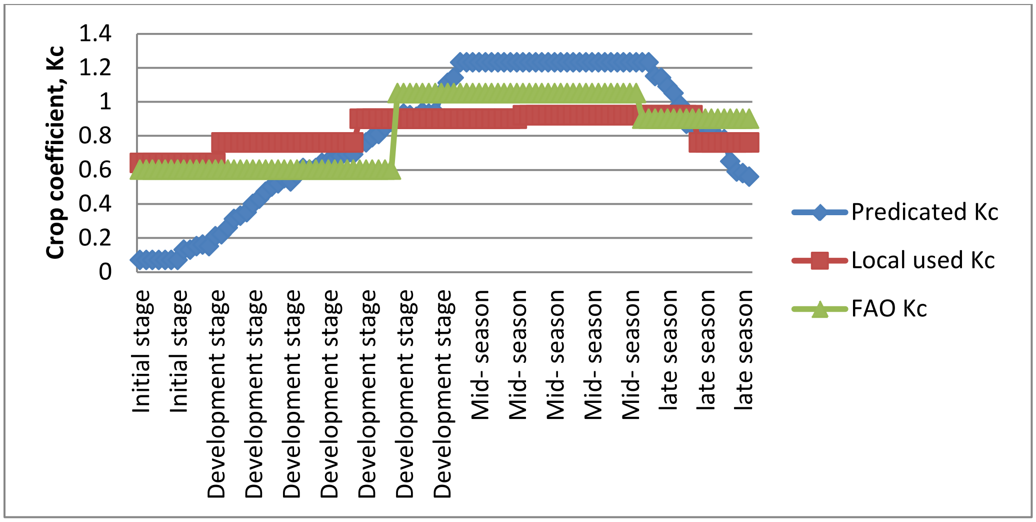

Figure (4) Comparison of Kc for eggplant between predicating, local (Russian) and FAO values.

The predicating values of the crop coefficients in the early stages of the growing season and up 19th. of May are low numbers, starting from 0.07 to 0.57, which is less than the local and FAO values (0.76 and 0.6 respectively), because the plant is in the early growing stage (crop development stage) and where the root zoneis less than 40 cm in depth. In early days of June, the predicating Kc values are begin to be increased and to be equal to local values (Kc = 0.9) and less than FAO (Kc = 1.05). After 17th. of June the improvement of the plantand the mid of the season is starting, the predicating Kc values are starting to be more than the local and FAO values, the root zone depth is about 70 cm and water demand is increasing (mid- season stage). The average value of Kc is about 1.23, comparing with the local value of 1.09 and the FAO value of 1.05. This high value of the predicating Kc is due to the highly water demand in this stage of the plant. Then the predicating values of Kc are began to decreased due to harvest time (or end of season) to reach a value of 0.56, which is normal and acceptable due to the plant is in end of the season and the water demand will be decreased to be as minimum as possible, while the local and FAO Kc values are 0.76 and 0.9 respectively.

Table(1) shows the root mean square difference, relative error and the mean absolute error for the predicating Kc and the local values. The error and the statistical analysis for the comparison between the predicating Kc and the local values show that the root mean square difference is ranged between 0.53 for May to 0.12 for August which is less than 1.0, while the mean absolute error ranged between 0.53 for May to 0.96 for August which is less than 1.0. Moreover, the relative error is ranged between 83.3% in May to 15.5% in August.

Table (1) Root mean square error, relative error and mean absolute error for the comparison between predicating Kc and the local (Russian) values.

Month	RMSD	RE (%)	Mean Absolute Error
April	0.53	83.28	0.53
May	0.29	37.65	0.25
June	0.23	25.01	0.18
July	0.28	30.44	0.26
August	0.12	15.48	0.096
Average	0.31	36.91	0.26

Table (2) shows the root mean square difference, relative error and the mean absolute error for the predicating Kc and the FAO values. The error and the statistical analysis for the comparison between the predicating Kc and the FAO values show that the root mean square difference is ranged between 0.49 for May to 0.17 for May and June which is less than 1.0, while the mean absolute error ranged between 0.49 for May to 0.13 for May which is less than 1.0. Moreover, the relative error is ranged between 82.2% in May to 17.81% in June.

Table (2) Root mean square error, relative error and mean absolute error for the comparison between predicating Kc and the FAO values.

Month	RMSD	RE (%)	Mean Absolute Error
April	0.49	82.20	0.49
May	0.17	27.99	0.13
June	0.17	17.81	0.16
July	0.19	19.14	0.18
August	0.22	24.23	0.19
Average	0.25	29.61	0.20

CONCLUSIONS

The conclusions for this paper are:

1-The predicating crop coefficient for eggplant is more accurate than the local and FAO values due to: first is the direct measuring for the crop evapotranspiration by using watermarks soil water sensors within the root zones.No crop stress was observed, and the allowable depletion values are always below 45%, and second is the direct reading of referenceevapotranspiration from the atmometer without using the weather station or complicated equations and meteorological information.

2- As recommended by FAO, the crop coefficients values are only an approximation, because these values under standard climatic conditions and typical irrigation management and soil wetting conditions. Accurate values can be adopted for most applications related to irrigation planning, design, and management.

3- Accurate estimating of crop coefficient for specific crops is important for irrigation scheduling, good agricultural water management, productivity and water saving.

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