Evaluating the Crop Coefficient for Cherries Plants in Michigan State

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ABSTRACT

Crop coefficient for cherries was evaluated by measure the water consumption in Michigan State to find its variation with time as the plant growth. Crop coefficients value (Kc) for cherries were predicated by Michigan State University (MSU) and also by Food and Agriculture Organization (FAO) according to consume of water through the season. In this paper crop coefficients for cherries are modified accordingly to the actual measurements of soil moisture content. Actual evapotranspiration (consumptive use) were measured by the soil moisture readings using Time Domain Reflectometers (TDR), and compared with the actual potential evapotranspiration that calculated by using modified Penman-Monteith equation which depends on metrological station and by using pan evaporation method. Absolut error techniques show that the predicated crop coefficient by MSU should be modified and changed from 1.0 to 1.20 during June, and from 1.02 during July and August to 1.2 to reduce the crop water stress and give better water management and perfect schedule for irrigation process.

Key words: crop coefficient, actual evapotranspiration, soil moisture, plant growth.

تقييم معامل نباتات الكرز في ولاية مشيكان

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الخلاصة

تم تقييم معامل نبات الكرز في ولاية مشيكان من خلال قيمة أستهلاك الماء لغرض ايجاد التغاير في قيم المعامل مع مراحل نمو النبات. أن معامل نبات الكرز (Cherries) والمستنبط من قبل باحثين في جامعة ولاية مشيغان و منظمة الغذاء والزراعة (فاو) يعتمد على مراحل أستهلاك النبات وانتاجه خلال السنة. من اجل الحصول على دقة أعلى لتقدير قيم معامل النبات ، تم في هذا البحث أعداد مقترح لتعديل معامل النبات وذلك من خلال القياسات الحقلية للمحتوى الرطوبي للتربة وبالتالي بالامكان معرفة الاستهلاك الفعلي للنبات وذلك باستخدام مقياس مجال وقت الانعكاس (TDR). تمت مقارنة النتائج مع القيم المحسوبة من معادلة بنمان – مونتيث المعدلة (Modified Penman-Monteith equation) والتي تعتمد على قياس المتغيرات المناخية لمحطة الانواء الجوية قرب منطقة البحث وكذلك قيم التبخر من حوض التبخير (Pan evaporation). أستخدمت تقنية الخطأ المطلق (Absolute Error) الاحصائية لايجاد الطريقة الافضل عند المقارنة ، فوجد أنه من المفضل تعديل معامل النبات والمستنبط من قبل جامعة ولاية مشيكان الامريكية لشهر حزيران من ١,٠ الى ١,٢، ومن ١,٠٢ الى ١,٢ لشهري تموز وأب، وذلك للتقليل من الجهد الرطوبي ، وأيضا للحصول على أدارة افضل للمياه وجدولة مثلى لعملية الري.

1. INTRODUCTION

Crop coefficient, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics results in different crop evapotranspiration (ET) levels in different types of crops under identical environmental conditions. Due to the differences in evapotranspiration during the various growth stages, crop coefficient for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages: dormant, bloom, fruit set and development, and late season, **Allen, et al., 1998.**

Once the reference evapotranspiration (ET_o) has been determined, a crop coefficient must be applied to adjust the reference ET_o value for local conditions and the type of crop being irrigated. Crop coefficients for Apples, Cherries, Pears and Grapes with cover crops have been segregated into months, **Water Conservation, 2001**.

The most important use of evapotranspiration information is in the irrigation scheduling where good water management requires that the irrigator apply only enough water to meet the needs for the crop plus some additional amount to compensate of the inefficiencies of the irrigation system, **Darrell, 20103.**

Crop coefficients that given by **FAO, 1998** resulted in an update of Kc values to be applied into Penman-Monteith method and procedures to arrive better estimates under various climatic conditions and crop height and expanding the range of crops and crop types, **Kassam,** and **Smith**, **2001**.

Proper irrigation is essential to maintaining, healthy and productive Cherry orchard. Over irrigation slows root growth, increase iron chlorosis in alkaline soils, and leaches nitrogen, and sulfur out of the root zone, **Brent**, **2008**. Drought stress will effect on the fruit development from the pit hardening to harvest, and typically occurs concurrently with the highest temperature of the season, **Brent**, **2008**.

In this study the crop coefficients for cherries which calculated by measuring crop evapotranspiration were compared with FAO, Utah State and Michigan State recommended values.

2. AREA OF THE STUDY

The study area is located north- west of Michigan State in United State of America, called Travers City, where research center of Michigan State University (MSU) is located. Cherry of 10 years ages is used which are spaced by 6.3×6.3m. Trickle irrigation is used and one emitter per crop of capacity 3.785 *l/hr* is considered, see **Fig.1**. Soil texture is Loamy sand and the groundwater is the source for the irrigation.

Time Domain Reflectometer (TDR) soil moisture tools, **Fig.2**, are used in the measurement of soil moisture every fifteen minutes per day and through the growing season. Determination of water content with TDR relies on the fact that the travel time of an electromagnetic pulse through stainless steel probe (the wave guided), embedded in the soil, and is a function of the soil's water content. Total numbers of twenty four of TDR are being used to cover the studied area, where at each location two numbers of the tools are used at depth of 915*mm* and 1220*mm*, and it is distant 200*mm* from center of the tree.

Pan evaporation class A is used for measurement of water evaporation, made of 20 gauges galvanized welded iron of size 1207mm in diameter and 254mm in depth. It is normally installed on a wooden platform set on the ground in a grassy location. The pan is filled with water within 60mm of the top edge.

3. METHODOLOGY AND PROCEDURE

The adopted methodology in this study is first: estimate the actual evapotranspiration from measuring soil moisture content, second: calculate the potential evapotranspiration by using pan evaporation and Enviro-Weather station methods, and finally third: calculate the actual crop coefficient from first and second steps.

3.1 Actual Evapotranspiration

Actual crop evapotranspiration (ET_c) may be estimated by measuring the soil moisture content, especially when the plant age is 10 years and the shaded area is large enough to reduce the evaporation from the ground surface. Average values of all the soil moisture measurements tools are recorded. The difference between the reading in the early day and the late hour of the day is the consumptive use of the plant, **Tables 1** and **2** show samples of soil moisture measurements for years 2010 and 2011. The estimated crop evapotranspiration can be calculated from the following **Eq. (1):**

$$ET_c = ET_o * Kc \qquad (1)$$

Where:

ET_c = Actual or crop evapotranspiration (mm/day),
ET_o = Potential or reference evapotranspiration (mm/day), and
Kc = crop coefficient.

3.2 Crop Coefficient (Kc)

Crop coefficient for cherries will vary over the growing season starting from April to October (growing season in Michigan State). **Fig.3** shows the comparison of the crop coefficient values developed by MSU, FAO and by Utah State University for cherries, **Brent, 2008**.

3.3 Potential (or Reference) Evapotranspiration

In this study potential evapotranspiration (ET_o) can be calculated by using the following methods:

1- Pan evaporation: cylindrical pan over covered ground surface is used through growing season in the area of the study.
2- Enviro-Weather station is used in the area near by the area of the study. Modified Penman-Monteith equation is used which developed by, **FAO, 1998**:

$$Et_O = \frac{0.408\,\Delta(Rn-G)+\gamma\left(\frac{900}{T+273}\right)U_2(es-ea)}{\Delta+\gamma(1+0.34U_2)} \qquad (2)$$

Where:

Et_o= potential or 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 daily air temperature at 2m height (C^o),
U_2= wind speed at 2m height (m/s),
e_s-$e_{s=}$ saturation vapor pressure deficit (kpa),
γ= psychrometric constant (kpa/C^o), and
Δ= slope vapour pressure curve .

4. RESULTS AND DISCUSSION

Values of Kc which developed by FAO and by Utah State are less in early growing stage and Kc developed by FAO is more in the bloom stage and fruit set and development stage from the measured values by MSU, when the plant's evapotranspiration is increased. While Kc developed by Utah State and by MSU is almost equal in these stages. On the other hand the developed Kc by FAO and by Utah State is less in the late of the season and after, when the plant's evapotranspiration is decreased.

Fig.4 shows the comparison between different calculations of actual evapotranspiration based on Kc equals to 1.02 as developed by MSU for year 2010. The actual evapotranspiration calculated from Modified Penman-Monteith (ET_2) gives values less than that measured values (ET_4), especially during July and early days of August, and almost equals in values in mid days of August.

Table 3 shows summary of absolute error for year 2010 and 2011. The absolute error $|ET4 - ET2|$ for crop coefficient developed by FAO is much better than the developed one by MSU. While Absolute error $|E\,T4 - ET3|$ for crop coefficient developed by MSU gives value less than crop coefficient developed by FAO, except for June 2011.

Fig.5 shows comparison between different calculations of actual evapotranspiration based on Kc equals to 1.20 as developed by FAO for year 2010. The potential evapotranspiration calculated from Modified Penman-Monteith equation (ET_2) gives values less than measured values (ET_4), especially during July and early days of August, and higher values during mid-days in August.

Figs.6 and **7** show comparison between different calculations of actual evapotranspiration based on different values of Kc (equals to 1.0 and 1.20) as developed by MSU and by FAO respectively for June 2011.
Absolute errors $|ET4 - ET2|$ and $|ET4 - ET3|$ are 11.42, 7.23 and 9.59, 5.01 respectively. That's mean Kc = 1.2 is the best in the comparison.

Fig.8 shows the absolute error when Kc equals to 1, 1.02, and 1.2. The absolute errors of $|ET4 - ET2|$ for July and August of years 2010 and 2011were less in values than the absolute errors of $|ET4 - ET3|$. On other hand the absolute errors of $|ET4 - ET2|$ for June of years 2010 and 2011 were higher than $|ET4 - ET3|$.
From actual evapotranspiration measured by soil moisture content ET_4 and from ET_2 and ET_3, modified crop coefficient (Kc) can be found by using the following equations, assuming that there is no deep percolation (drainage water):

$$Kc = \frac{ETc}{ETo} \quad (3)$$

The developed values of Kc from **Eq. (3)** were equal to 1.2 for June, July and August. **Table 4** shows comparison between Kc used by MSU and the modified values.

5. CONCLUSION

According to above results, crop coefficient developed by Michigan State University should be modified to be equal to 1.2 for month's stages June, July and August, which matches with values recommended by FAO. Therefore, schedule the irrigation process according to none modified crop coefficients may be harmful on the plant growth and production under water stress.

Recommendation for further research works is to use the crop coefficient developed by MSU and study the effect of water stress on the crop growth and production to minimize the irrigation process and save water. Also crop coefficient for early months could be included in future studies.

6. ACKNLODGEMENT

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7. REFERENCES

Allen, G. A., Perera, L. S., Raes, D., and Smith, M., 1998, *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirement FAO*. Irrigation and Drainage paper No.56, FAO, Rome, Italy.

Brent, B., 2008, *Orchard Irrigation: Cherry*. Utah State University, Cooperative extension, March.

Darrell, W., 2010, *Crop Water Use*, Crop Production Clinics Proceedings, University of Nebraska-Lincoln Extension.

FAO, 1998, *Crop Evapotranspiration-(Guidelines for Computing Crop Water Requirements*), Irrigation and Drainage Paper No. 56, Rome, Italy.

Farahani, H. J., Howell, T. A., Shuttleworth, W. J., and Bausch, W. C.,. *Evapotranspiration: Progress in Measurement and Modeling in Agriculture*. Transactions of the ASABE, Vol. 50(5), PP. 1627-1638

Kassam, A., and Smith, M., 2001, *FAO Methodologies on Crop Water Use and Crop Water Productivity*, Expert Meeting on crop water productivity paper No. CWP-M07, Rome, 3 to 5 December.

Suat, I., 2009, *Estimating Crop Evapotranspiration from Reference Evapotranspiration and Crop Coefficient*, Neb Guide, University of Nebraska-Institute of Agriculture and aural Resources, paper no. G 1994.

Water Conservation Factsheet, 2001, *Crop Coefficients for Use in Irrigation Scheduling*, British Columbia, Ministry of Agriculture, Food and Fisheries, October.

Table 1. Soil moisture content as in equivalent depth for year 2010.

Date	Soil moisture content (equivalent depth mm) for depth 915mm	Soil moisture content (equivalent depth mm) for depth 1220mm
23-Jul.	2.18	2.92
24-Jul.	3.48	4.65
25-Jul.	5.49	7.32
26-Jul.	6.05	8.05
27-Jul.	5.03	6.71
9-Aug.	4.12	5.49
10-Aug.	4.48	5.97
11-Aug.	2.18	2.92
12-Aug.	3.66	4.88
13-Aug.	3.56	4.75
15-Aug.	3.66	4.88
16-Aug.	3.94	5.26
17-Aug.	3.38	4.5

Table 2. Soil moisture content as in equivalent depth for year 2011.

Date	Soil moisture content (equivalent depth mm) for depth 915mm	Soil moisture content (equivalent depth mm) for depth 1220mm
24-June	2.85	3.79
25-June	4.93	6.58
26-June	4.47	5.97
27-June	6.86	9.14

Table 3. Summary of absolute error for year 2010 and 2011.

Year	Month	Crop coefficient (Kc)	Absolute error $\lvert ET4 - ET2 \rvert$	Absolute error $\lvert ET4 - ET3 \rvert$
2010	July	1.02*	6.98	6.67
	July	1.2**	5.98	7.4
	August	1.02*	8.12	13.67
	August	1.2**	6.83	17.0
2011	June	1.0*	11.42	7.23
	June	1.2**	9.59	5.01

* Developed by MSU.

** Developed by FAO.

Table 4. Crop coefficients developed by MSU and the modified values.

Month	June	July	August
Kc (MSU)	1.0	1.02	1.02
Modified Kc	1.20	1.20	1.20

Figure1. Cherries field in research area- Travers City / Michigan State.

Figure 2. Location and depth of the time domain reflectometer (TDR) beside the irrigation system in the research area.

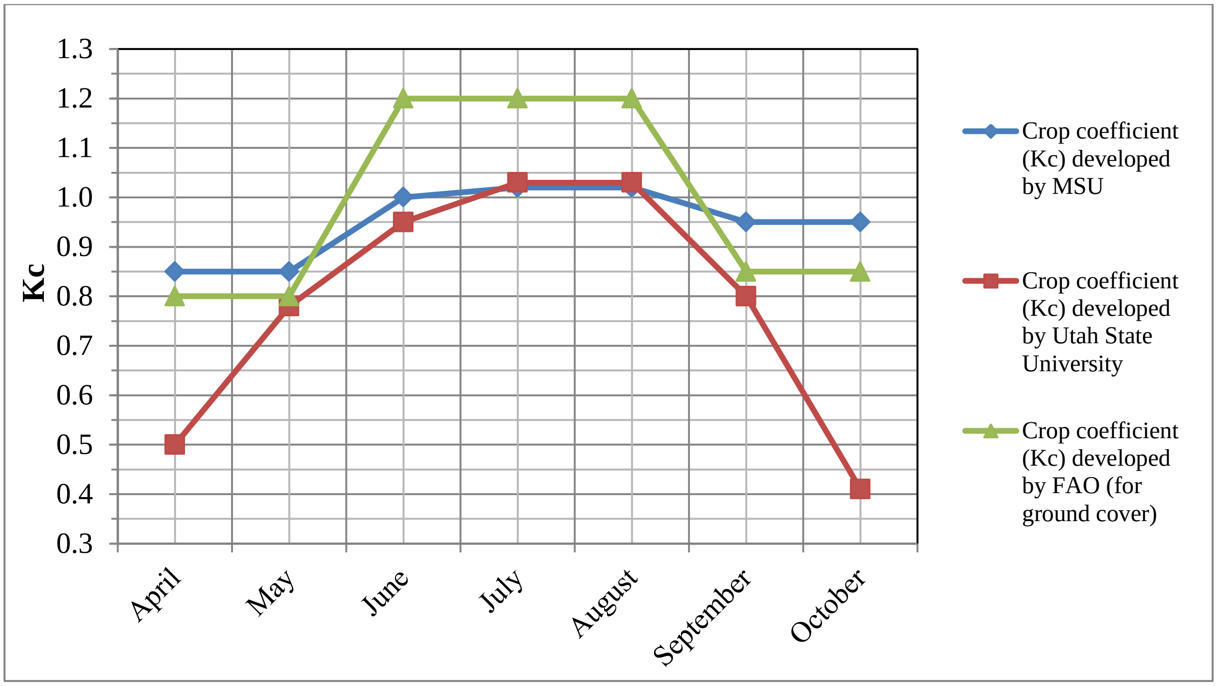

Figure3. Comparison between values of crop coefficients for Cherries.

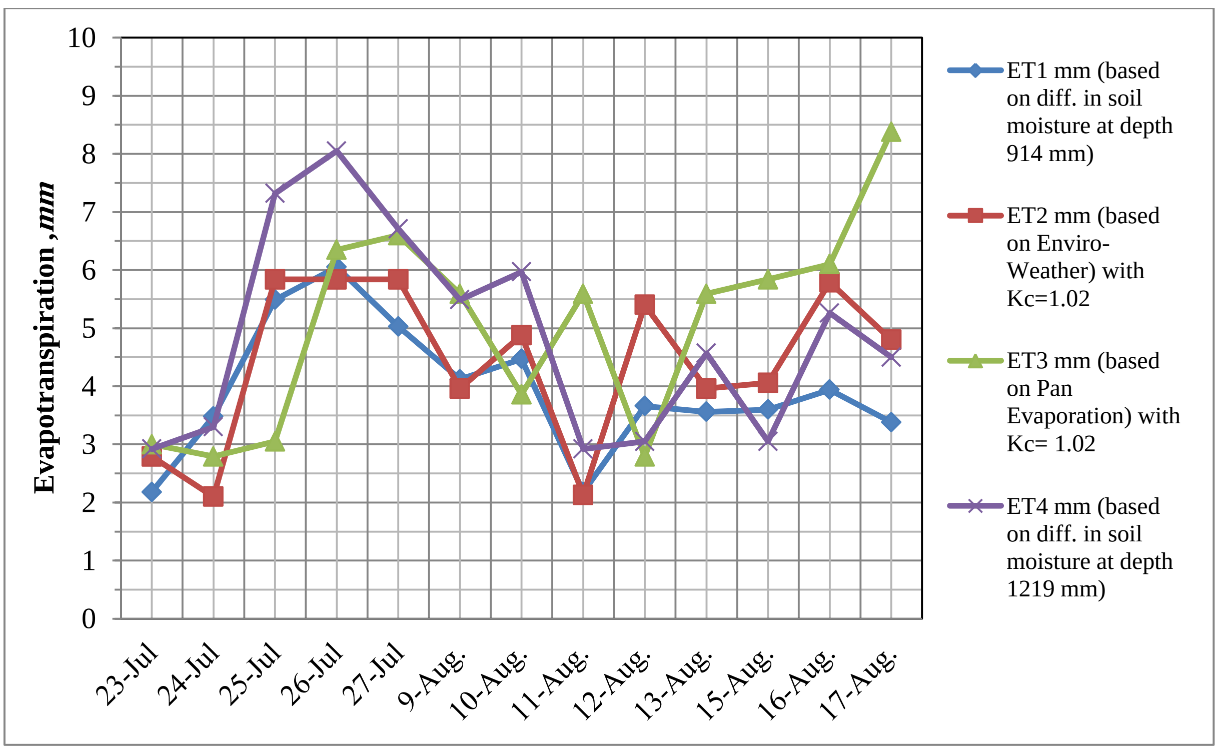

Figure 4. Calculated evapotranspiration for different approaches and methods using Kc=1.02 for Cherries in 2010.

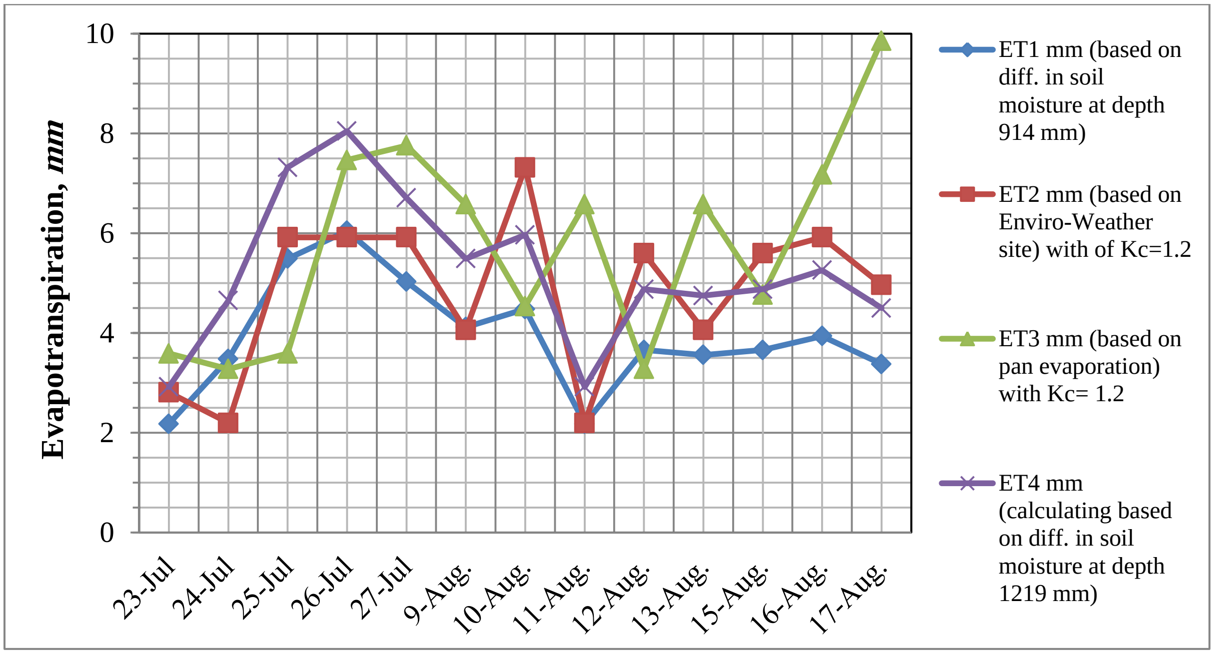

Figure 5. Calculated evapotranspiration for different approaches and methods using Kc=1.2 for Cherries in 2010.

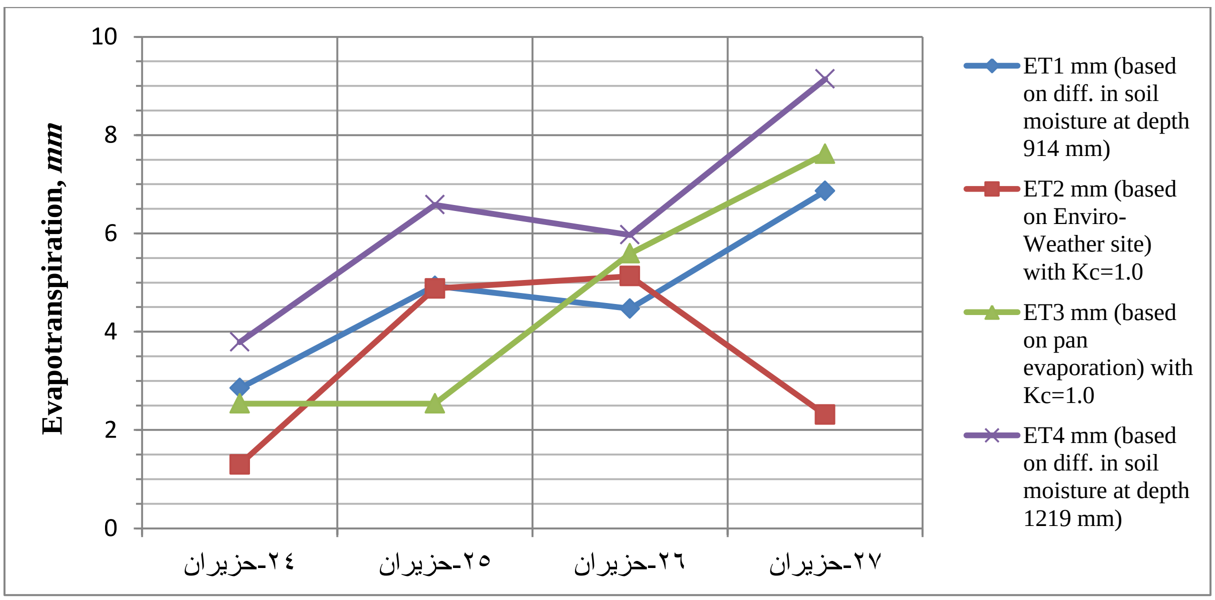

Figure 6. Calculated evapotranspiration for different approaches and methods using Kc=1.0 for Cherries in 2010.

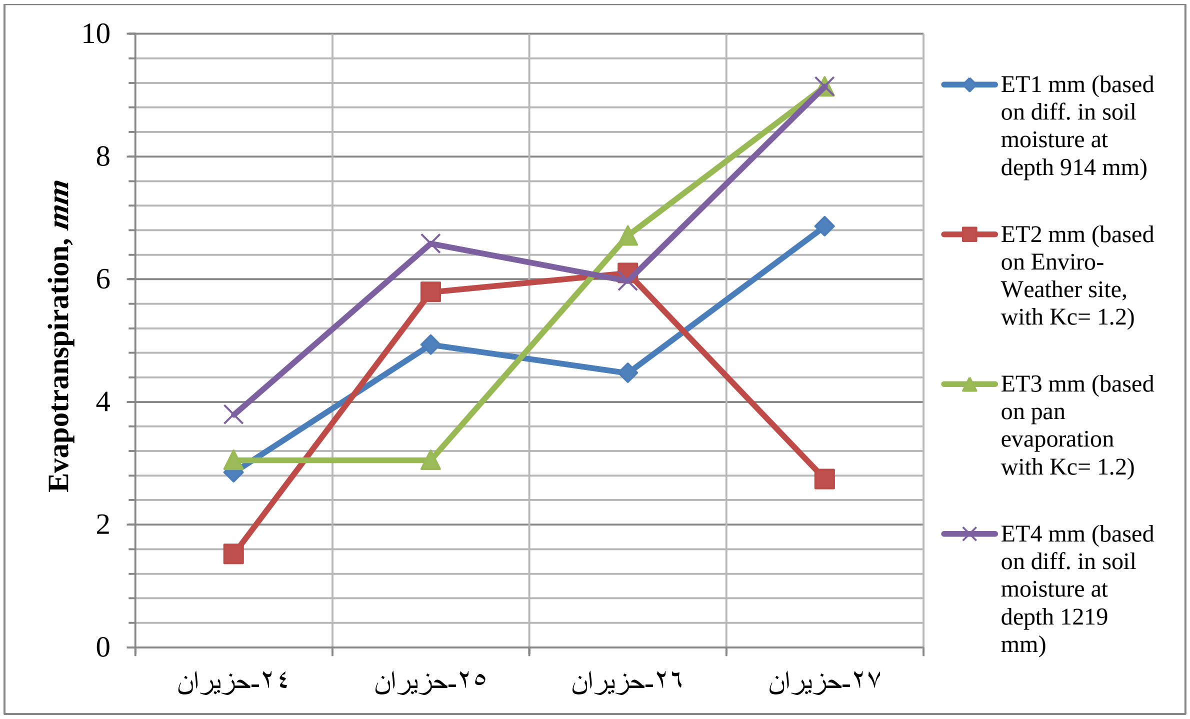

Figure 7. Comparison between different approaches and methods for calculating actual evapotranspiration using Kc=1.20 for Cherries 2011.

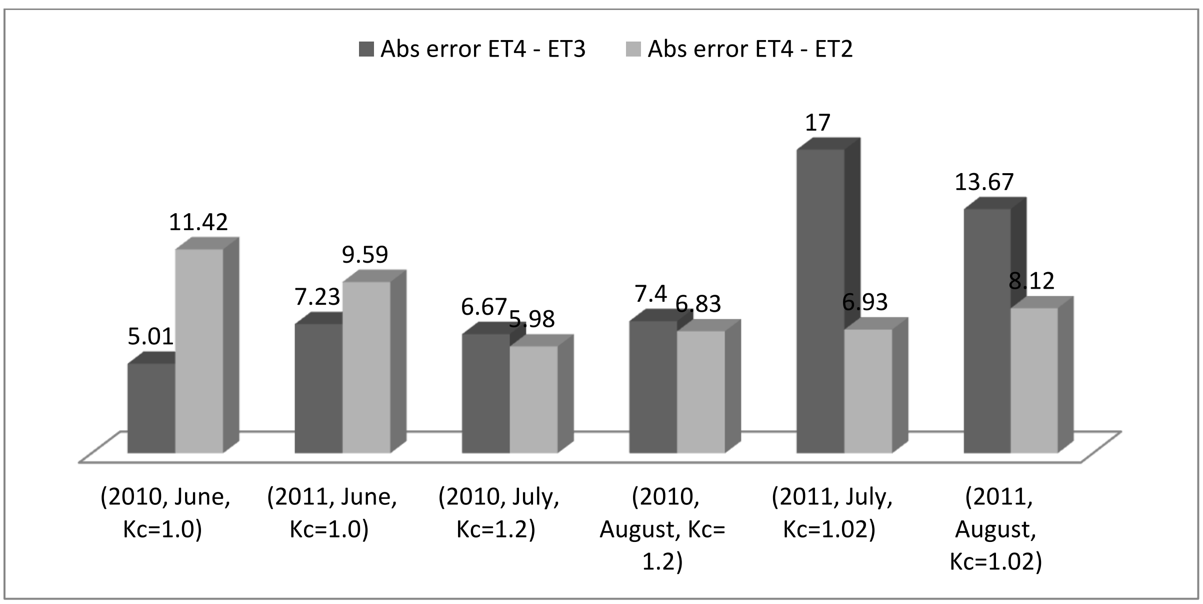

Figure 8. Absolute error for actual evapotranspiration using TDR, Enviro –Weather (modified Penman-Monteith equation) and Pan evaporation for years 2010 and 2011.