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Determination of single and dual crop coefficients and ratio of transpiration to evapotranspiration for canola

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ABSTRACT

Determination of crop coefficient has potential advantage for proper irrigation scheduling. This research was carried out to determine the single crop coefficient (Kc), basal crop coefficient (Kcb) and the ratio of transpiration to evapotranspiration of canola ((Brassica napus L.) based on lysimetric data in Research Farms of the Tabriz University, Iran. Relationships of the crop coefficients Kc or Kcb, and the parameters of days after planting (DAP), degree-growing days (GDD), leaf area index (LAI), ground cover percentage (GC %) and the ratio of transpiration to evapotranspiration (T/ET) with LAI and GC% were analyzed. The values of seasonal crop ET were 582 and 550 mm in the years of 2010 and 2011, respectively. The seasonal transpiration was calculated 467 and 410 for canola in the first and second years, respectively. The average, maximum, and minimum values of Kc were 1.03, 1.47 and 0.57 and of Kcb were 0.76, 1.37 and 0.0 in 2010; also these values in 2011 were 0.90, 1.24 and 0.41 for Kc and 0.64, 1.06 and 0.0 for Kcb, respectively. The value of T/ET ratio was 0.0 at the planting date and increased to 0.80 and 0.87 during the growth season in 2010 and 2011, respectively. The value of T/ET increased rapidly when LAI values were smaller than 3.0 and 2.5 in both experimental years. Finally, results obtained from the study can be used as reference data for irrigation scheduling and soil water modeling of canola.

Keywords: Canola, Crop coefficient, Evapotranspiration, Ground cover, Leaf area index.

INTRODUCTION

Determination of crop evapotranspiration by direct methods are expensive and difficult, and almost all direct methods are impractical for permanent use on a large scale, so evapotranspiration is commonly estimated by developed empirical methods.

FAO proposed Penman–Monteith reference evapotranspiration (ET_o) for irrigation scheduling in FAO-56 technical periodicals [1]. Compared with other common methods, Penman–Monteith method has been widely used because it gives satisfactory results under many climate conditions across the world [2-7].

Actual crop evapotranspiration (*ET*) is calculated by multiplying the reference evapotranspiration by a crop coefficient. Single and/or dual crop coefficient approaches are used to estimate crop evapotranspiration. Single crop coefficient is used for irrigation planning and design, irrigation management, basic and real-time irrigation scheduling of less frequent water applications whereas dual crop coefficient is mainly used in research and for real-time irrigation scheduling, irrigation scheduling of high frequent water application such as daily irrigation, supplementary irrigation and detailed soil and hydrologic water balance studies [1]. Several reports on the estimation of *Kc* are available [8-10]. Doorenbos and Kassam [11] and Jensen et al. [12] have reported crop coefficients for many crops. These values are commonly used in places where the local data are not available. Allen et al. [1] have suggested that the crop coefficient values should be derived empirically for each crop based on lysimeteric data and local climatic conditions because the crop coefficients depend on climate conditions, soil properties, the particular crop and its varieties, irrigation methods and so on.

The ratio of transpiration to evapotranspiration is also required by many water management schemes. Denmead [13] reports that soil evaporation and plant transpiration are essentially independent under conditions where plant transpiration is not limited by water supply and the soil surface is wet. However, Stanhill [14] found evidence of considerable interaction between *E* and *T*. This interaction is expected to be the most prominent under partial ground cover in early growth stages of row crops. Several models have been developed to calculate *E* and *T* independently. Ritchie [15] proposes a model to predict soil evaporation beneath a developing row under line crops canopy. Tanner and Jury [16], Kanemasu et al. [17] and Rosenthal et al. [18] develop similar methods to evaluate *E*, *T* and *ET* for a growing crop with a changing plant cover. Experimentally, several researchers [19-22] have used mini- or micro-lysimeters located between crop rows to calculate transpiration and evaporation independently. Martin et al. [23] also use mini-lysimeter for measuring evaporation. They find that a routine adjustment in soil moisture in the lysimeters is necessary to reduce measurement errors.

Canola is one of the main plants of common stock brassica with seeds containing over 40 percent of oil and full of protein [24]. It has also a great potential in developing biodiesel market. In addition to oil production, the leaves and stems of oilseed rape provide high quality forage suitable for animal feeding because of their low fiber and high protein contents [25]. Because of mentioned advantages during the past 20 years, canola has passed peanut, sunflower and most recently, cottonseed in worldwide production [26].

In Iran, because of its growing population and increasing food requirements, oilseed rape subsidized by the government has become an increasingly popular part of the crop rotation. Results about the crop coefficients for canola in Iran are not available currently. Based on these considerations, in this study single and dual crop (basal) coefficients of canola were obtained by measuring the *ET* and *E* using lysimeter and micro-lysimeter, respectively.

The aim of the study is to determine some relationships, between K_c (or K_{cb}), and days after planting (*DAP*), degree-growing days (*GDD*), leaf area index (*LAI*) and percentage of ground cover (*GC* %). Additionally, relationships between *T/ET* and *LAI*, and also *T/ET* and *GC*% are developed for canola.

MATERIALS AND METHODS

This experiment was carried out during the growing season of 2010 and 2011 on the experimental farms of the Agriculture Faculty of the University of Tabriz, Iran (latitude, longitude and elevation of station are 37º 03´ north, 46º 37´east and 1567.3 m above sea level, respectively). The climate in the experimental area is terrestrial, summers are mild and dry, and winters are cold and snowy. The soil of the research area has a sandy-loam texture. The average values of field capacity, permanent wilting point and bulk density of soil in effective root depth are 0.28 (m^3m^{-3}), 0.125 (m^3m^{-3}) and 1.58 g cm^{-3}, respectively. The water holding capacity of the experimental site was observed as 140 mm in 0-90 cm profile.

The planted cultivar was RGS003, spring type of canola and the crops were sown on 20 April 2010 and 23 April 2011 in a drainable lysimeter located in the middle of the experimental field and surrounded by the same crops. The crop was harvested on early days of August in both experimental years. The surface area of the lysimeter was 7.065 m^2 and its depth was 2 m. Agricultural practices inside the lysimeter and in the surrounding field were the same. Seeding density was 80 plants per m^2. Volumetric soil water contents were measured by PR2 (Profile Probe, Delta-T) at the depths of 0.1, 0.2, 0.3, 0.4, 0.6 and 1 m in seven-day intervals before irrigation events. The required irrigation water was measured based on soil water depletion replenishment of canola in the period of 7 days.

Irrigation water was controlled by a flow meter and crop evapotranspiration was calculated by the following equation [12]:

$$ET = \left[\frac{(I + P - D + \sum_1^n(\theta_1 - \theta_2)\Delta S_i)}{\Delta t}\right]$$

where *I*, *P* and are irrigation, precipitation and deep percolation (mm), respectively, n is the number of layers, ΔS is the thickness of each soil layer in mm, θ_1 and θ_2 are the soil water content at times one and two and Δt is the time interval. Deep percolation depth (*D*) was determined on the basis of the measured drained water volume in the underground room of the lysimeter.

Evaporation (*E*) from the soil top layer was measured with micro-lysimeter. One small cylinder, creating isolated volume of bare soil, was buried in the surface soil. The micro-lysimeter was dug up and weighted every week.

Leaf area was measured with a leaf area meter (model AM300, ADC, Bio Scientific Ltd) and then the leaf area index (*LAI*) was calculated based on plant density. The percentage of *GC* was measured from the real horizontal projection of the canopy, calculated from photographs taken at the distance of 1.5 m above the soil surface.

Crop coefficient is defined as the ratio of the crop *ET* to the reference crop evapotranspiration and calculated by single crop and dual crop coefficient methods [1; 12]. In the present study, single crop coefficient was calculated from the lysimetric-estimated evapotranspiration (*ET*) and reference crop evapotranspiration ($ET_{o)}$ as follow:

$$K_c = \frac{ET}{ET_o}$$

Single crop coefficient includes the effects of evaporation from both plant and soil surfaces. But dual crop coefficient includes the effects of evaporation from soil surface and transpiration from plant, separately. Basal crop coefficients were derived from estimated *ET* from lysimeter, *E* from micro-lysimeter and ET_o as follow:

$$K_{cb} = \frac{(ET - E)}{ET_o}$$

The reference crop evapotranspiration, (ET_o), was calculated according to the FAO Penman-Monteith equation [1]. Also the degree-growing days (*GDD*) was estimated based on recommended method [27]. All optimized equations, so called saturation equations were developed by solver tool in EXCEL software.

RESULTS AND DISCUSSION

Ground cover and growth stages

Variation of ground cover percentage (*GC* %) in experimental years are shown in figure 1. Ground cover percentage as a function of *DAP* were obtained by a multiple regression procedure from one week after emergence as follows:

$GC\% = -0.000300DAP^3 + 0.037727DAP^2 + 0.310335DAP - 14.464332$

$R^2 = 0.98$ (in 2010)

$GC\% = -0.000346DAP^3 + 0.044609DAP^2 - 0.019921DAP - 07.254385$

$R^2 = 0.99$ (in 2011)

Effective cover (80%) was attained approximately on 60 *DAP*, with *LAI* more than 3, and ground cover reached to its maximum value on 80 *DAP*.

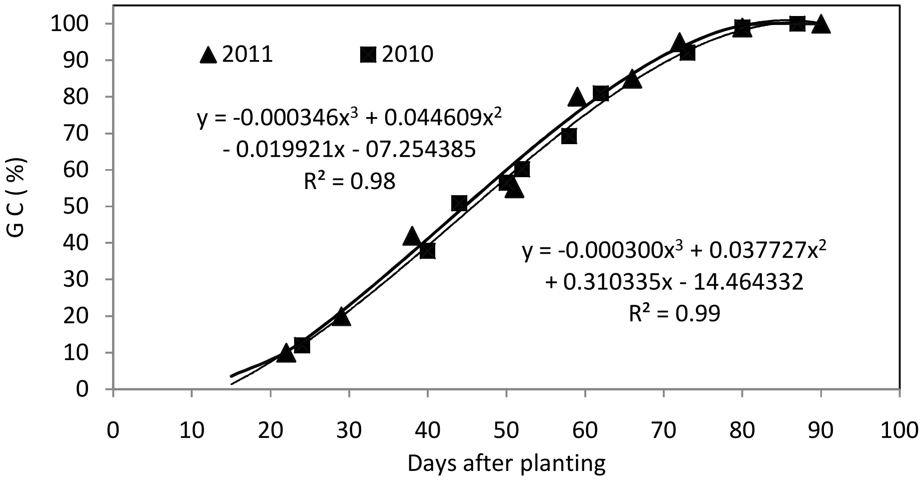

Figure 1. Variations of ground cover percentage (*GC* %) for canola in 2010 and 2011 growing season.

Based on the recommendation by Doorenbos and Kassam [11], the length of the growing stages can be determined by ground cover percentage. The duration of initial stage (germination to 10 percent ground cover) was at 22 and 24 days after planting in the first and second experimental year, respectively. Also 80 percent ground cover obtained in 64 and 62 days after planting in 2010 and 2011, respectively. With considering of plant phenological condition ripening stages aproximately started after 84 and 88 days in the first and second experimental year, respectively.

Variation of reference crop and crop evapotranspiration, transpiration and evaporation

The variations of ET_o, *ET*, *T* and *E* are shown for the canola growing season in Figures 2 and 3 for 2010 and 2011, respectively. The maximum daily values of *ET* and *T* occurred both on 80 *DAP* in 2010 and on 72 and 87 *DAP* in 2011. The maximum *ET* was about 10.5 and 9.2 mm d^{-1} and maximum *T* was 9.3 and 8.0 mm d^{-1}, in 2010 and 2011, respectively. The high evapotranspiration rate could be caused by some local climatic condition in our experimental site. In the semiarid zone, the rate of evapotranspiration is high [28; 29] and may be associated with advection phenomena in arid and semiarid regions such as Iran [30]. The variation of *ET* was controlled by *T*, because evaporation from the soil only included a small part of evapotranspiration and decreased with increasing *DAP*, *LAI* and *GC*%.

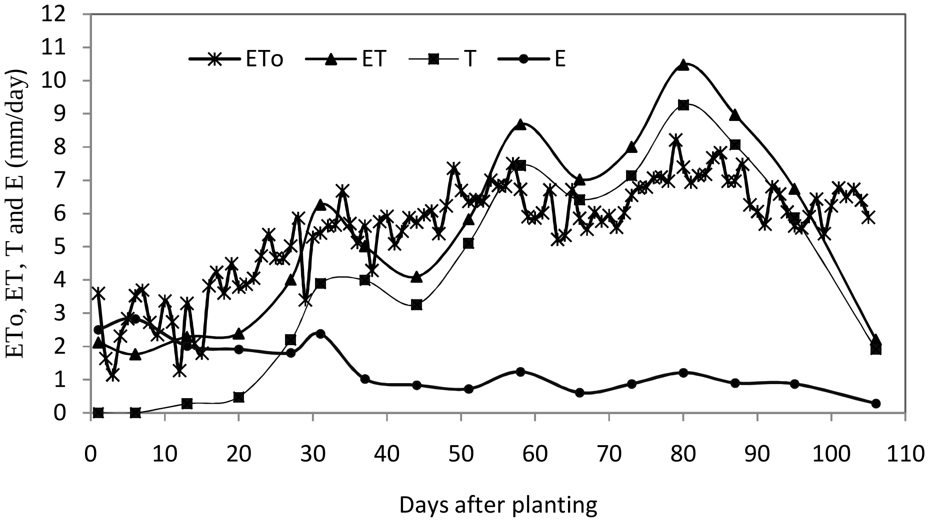

Figure 2. Trends of reference crop evapotranspiration, crop evapotranspiration, transpiration and evaporation from the soil in the field of canola at growing season in 2010.

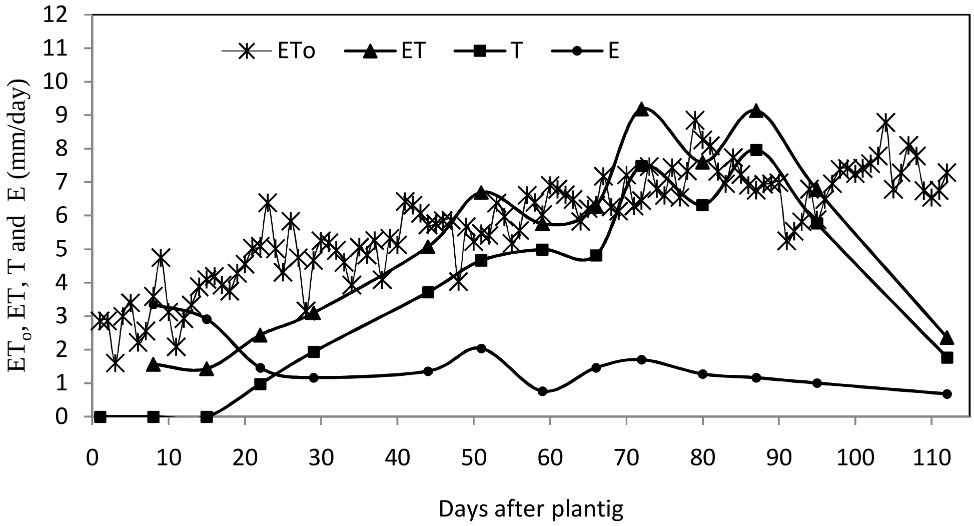

Figure 3. Trends of reference crop evapotranspiration, crop evapotranspiration, transpiration and evaporation from the soil in the field of canola at the growing season in 2011.

The highest daily water consumption was in July at the ripening stage in the both experimental years. The average daily *ET* in this month was 7.3 and 7.0 mm in the first and second experimental year, respectively. Furthermore, the mean daily *ET* values in June were 6.4 and 5.9 mm in the two successive years, which were in agreement with the results obtained by several researchers [25; 31-34].

The average seasonal *ET* for canola was 582 and 550 mm in 2010 and 2011 growing seasons, respectively. Niyazi and Fooladvand [35] reported canola evapotranspiration as 740, 709 and 700 mm in three years experiments in south west region of Iran. Zarei et al. [36] obtained the highest seed yield under 675 mm irrigation water in the experimental farm of Karaj in Iran. Istanbulluoglu et al. [34] found *ET* of oilseed rape as 715 mm at the controlled irrigation regimes in Turkey. They reported that the seasonal *ET* of different oilseed rape varieties under different climatic and soil conditions varied from 300 to 1150 mm.

In this research the calculated seasonal transpirations in two different years were 467 and 410 mm and seasonal evaporations were 115 and 140 mm. The seasonal transpiration was accounted for 80% and 75% of evapotranspiration in 2010 and 2011, respectively. Therefore the soil evaporation in these two years was 20% and 25% of evapotranspiration, respectively. These values were in agreement with the data reported by Ashktorab et al. [37] for tomato in Davies California and Kang et al. [22] for maize and wheat crop in northwest of China.

Single and basal crop coefficients

The variations of *Kc*, *Kcb* and *LAI* based on days after planting are presented in figure 4 for the years of 2010 and 2011. The values of *Kc* and *Kcb* for the canola increased from 0.57 and 0 after sowing to their maximum values in early July of 2010 and then decreased when the canola ripened during late July and early August. Also, in 2011 the values of *Kc* and *Kcb* increased from 0.44 and 0 after sowing and reached their maximum values during July and then declined. The average, maximum and minimum values of *Kc* were 1.03, 1.47 and 0.57, and of *Kcb* were 0.76, 1.37 and 0.0 in 2010 and those for *Kc* were 0.90, 1.24 and 0.41, and for *Kcb* were 0.64, 1.06 and 0.0 in 2011, respectively.

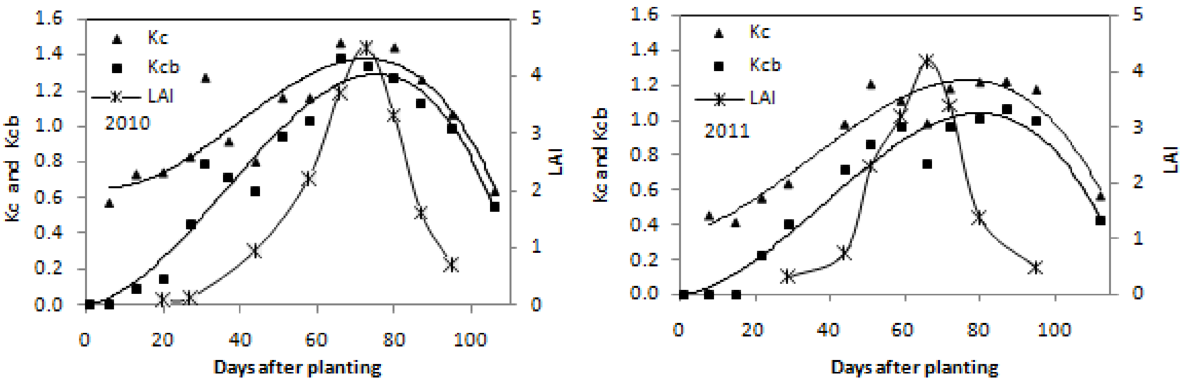

Figure 4. Variations of crop coefficient (*Kc*), basal crop coefficient (*Kcb*) and *LAI* with days after planting for canola

During the experimental years, occurrence of frequent rainfall resulted in continuous soil evaporation, so the values of *Kc* and *Kcb* were high in early weeks of the growing season. The calculated crop coefficients were different and higher than the recommended values by Allen et al. [1] for oil crops. The reason of the higher *Kc* in the mid-season is that the reference evapotranspiration estimated by Penman-Monteith equation is smaller in some semi-arid region. Many earlier results [22; 30; 38-39] showed that reference evapotranspiration estimated by Penman-Monteith equation was small in semiarid regions, and crop coefficients were larger than the relevant literature [1]. Possibly these differences were caused by higher soil bulk density, higher plant density, different crop varieties and local and regional advection.

Correlation of crop coefficients to accumulated degree-growing days or heat units have been used by some researchers to reduce the effects of year-to-year climate variations on crop development and water consumption [40-43]. The variation of *Kc* and *Kcb* based on degree-growing days during the growing period in 2010 and 2011 are presented in figure 5.

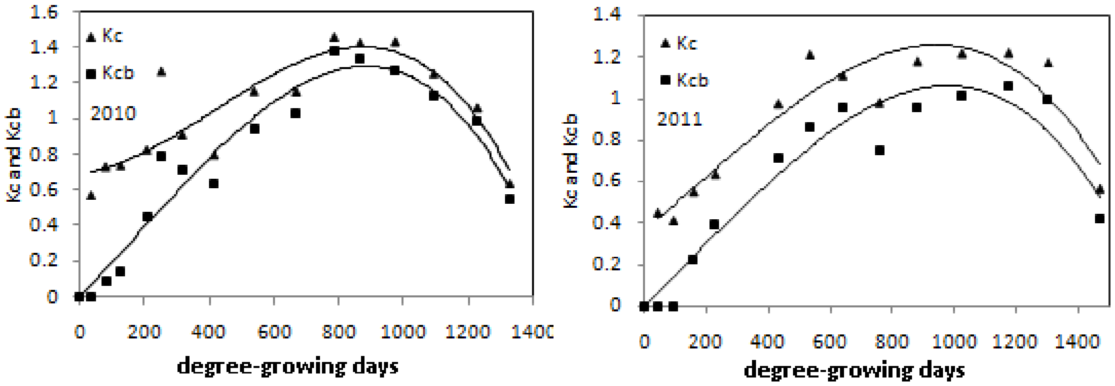

Figure 5. Variations of crop coefficient (*Kc*) and basal crop coefficient (*Kcb*) with degree-growing days for canola

Values of *Kc* and *Kcb* for canola increased after sowing to their maximum values at 868 and 950 *GDD* days and then decreased to their minimum values when canola ripened at 1472 and 1330 *GDD* in 2010 and 2011, respectively.

Variations of *Kc* and *Kcb* can also be estimated as functions of *DAP* [44]. Single and basal crop coefficients as functions of *DAP* and degree-growing days (*GDD*) were obtained by a multiple regression procedure as follows:

For the 2010 experimental year:
$Kc = -5\times10^{-6} DAP^3 + 6\times10^{-4} DAP^2 - 6.2\times10^{-3} DAP + 0.6789$ $R^2 = 0.78$
$Kcb = -5\times10^{-6} DAP^3 + 6\times10^{-4} DAP^2 + 3.6\times10^{-3} DAP$ $R^2 = 0.95$
$Kc = -2\times10^{-9} GDD^3 + 2\times10^{-6} GDD^2 + 5\times10^{-4} GDD + 0.6513$ $R^2 = 0.77$
$Kcb = -1\times10^{-9} GDD^3 + 8\times10^{-7} GDD^2 + 1.9\times10^{-3} GDD$ $R^2 = 0.94$

For the 2011 experimental year:
$Kc = -4\times10^{-6} DAP^3 + 6\times10^{-4} DAP^2 - 1.4\times10^{-2} DAP + 0.6977$ $R^2 = 0.86$
$Kcb = -3\times10^{-6} DAP^3 + 6\times10^{-4} DAP^2 + 3.2\times10^{-3} DAP$ $R^2 = 0.95$
$Kc = -7\times10^{-10} GDD^3 + 3\times10^{-7} GDD^2 + 1.3\times10^{-3} GDD + 0.3592$ $R^2 = 0.87$
$Kcb = -6\times10^{-10} GDD^3 + 3\times10^{-7} GDD^2 + 1.5\times10^{-3} GDD$ $R^2 = 0.93$

In this study the third-order polynomial equations were obtained with high coefficients of determination and fitted well with the calculated data. Sepaskhah and Andam [45] for sesame and Ko et al. [46] for wheat and cotton proposed a third-order polynomial equation for such modeling. Also, De Medeiros et al. [47] proposed a third-order polynomial equation for modeling of *Kcb* as function of day after emergence and ground cover for bean.

Relationship between single and basal crop coefficient with *LAI* and *GC*

The relationships between single and dual crop coefficients and *LAI* are presented in figures 6 and 7 for the two experimental years. Kang et al. [22] proposed similar shape equations between single crop coefficient and *LAI* of winter wheat and maize. De Medeiros et al. [47] found a third-order polynomial equation between *Kcb* and *LAI* for bean in Sao Paulo, Brazil.

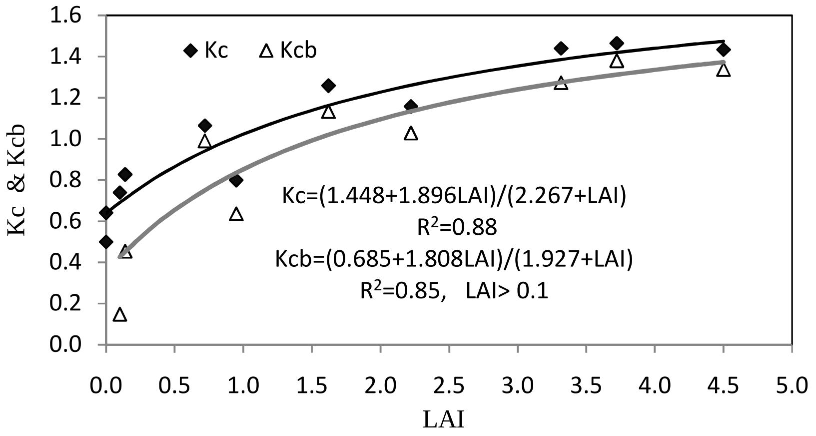

Figure 6. Relations between the single and basal crop coefficients and leaf area index for canola in the 2010 growing season

Variation of ground cover is important for determination of plant growth stages and crop coefficients. Relationships between single and basal crop coefficients, and ground cover percentage (*GC* %) has been interpreted as linear functions, when *GC* percentage is less than 100 as follows:
$Kc = 0.008\ GC\% + 0.5877$ $R^2 = 0.73$ (in 2010)
$Kcb = 0.0142\ GC\%$ $R^2 = 0.82$ (in 2010)
$Kc = 0.0063\ GC\% + 0.6044$ $R^2 = 0.71$ (in 2011)
$Kcb = 0.0111\ GC\%$ $R^2 = 0.76$ (in 2011)

These results were in agreement with the result obtained by Lopez-Urrea et al. [48]. They found linear relationships between *Kc* and *Kcb* with ground cover for onion by lysimeteric data.

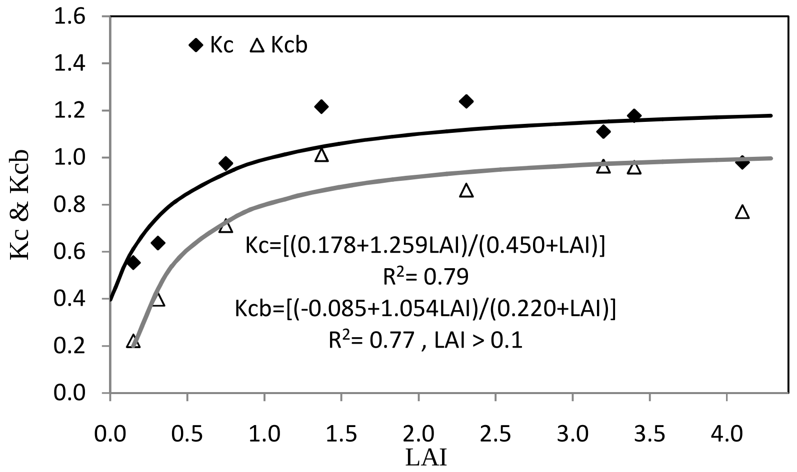

Figure 7. Relations between the single and basal crop coefficients and leaf area index for canola in the 2011 growing season.

Ratio of transpiration to evapotranspiration as a function of *LAI* and *GC*

Measured data showed that the *T/ET* ratio was controlled by ground cover and *LAI*. The value of the mentioned ratio varied from 0 at crop planting date to 0.80 in 2010 and from 0 to 0.87 in 2011. The value of *T/ET* increased rapidly when *LAI* was smaller than 3.0 in 2010 and smaller than 2.5 in 2011, then increased at a very small rate when *LAI* was larger than mentioned value. However, some studies show that transpiration varies smoothly with increasing *LAI* when *LAI* exceeds 3 [49-50].

In this study, *T/ET* as a function of *LAI* was calculated by a multiple regression procedure for both experimental years as follows:

$$\frac{T}{ET} = \frac{0.8878LAI}{0.1410+LAI} \qquad R^2 = 0.90 \qquad \text{(In 2010)}$$

$$\frac{T}{ET} = \frac{0.8423LAI}{0.1375+LAI} \qquad R^2 = 0.82 \qquad \text{(In 2011)}$$

Kang et al. [22] found similar saturated equation between *T/ET* and *LAI* for maize and wheat. Relationship between *T/ET* and *GC*% based on the experimental data was calculated as follows:

$$\frac{T}{ET} = 1 - \exp\left(-0.0238GC\%\right) \qquad GC < 100 \qquad R^2=0.89 \qquad \text{(In 2010)}$$

$$\frac{T}{ET} = 1 - \exp\left(-0.0227GC\%\right) \qquad GC < 100 \qquad R^2=0.87 \qquad \text{(In 2011)}$$

Childs et al. [51] and Belmans et al. [52] proposed this type of equation as a function of *LAI*. Childs et al. [51] also proposed this method to separate potential evaporation and transpiration using the calculated *LAI*. In this study, saturation equation based on *LAI* and exponential equation using ground cover percentage have been introduced for determination of *T/ET* ratio.

CONCLUSION

In study region, the seasonal *ET* values were 582 and 550 mm and the seasonal *T* values were 467 and 410 mm, for canola in the experimental years of 2010 and 2011, respectively. The average, maximum and minimum values were 1.03, 1.47 and 0.57 for *Kc* and 0.76, 1.37 and 0.0 for *Kcb* in 2010 and also those values were 0.90, 1.24 and 0.41 for *Kc* and 0.64, 1.06 and 0.0 for *Kcb* in 2011, respectively. The value of *T/ET* ratio varied from 0 at crop planting date to 0.80 in 2010 and from 0 to 0.87 in 2011. The value of *T/ET* increased rapidly when *LAI* was smaller than 3.0 in 2010 and smaller than 2.5 in 2011. Based on the multiple regression analysis, third-order polynomial equations were obtained to estimate *Kc* and *Kcb* as functions of *DAP* and *GDD*, which were acceptable due to the resulted high determination coefficients. A saturation equation fitted the relationships between *Kc*, *Kcb* and *T/ET*, with *LAI*. Also relationships between *Kc* and *Kcb* with *GC*% were interpreted as linear equations. These results can be reference data for irrigation planning and efficient management of irrigation for canola in this region and similar condition.

REFERENCES

[1] RG Allen, LS Pereria, D Raes, M Smith, Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements, Rome, Italy, *FAO, Irrigation and Drainage Paper*, **1998**, 56.
[2] M Smith, RG Allen, JL Monteith, Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements, Rome, Italy, *FAO, Land and Water Development Division*, **1992**, p60.
[3] PS Kashyap, RK Panda, *Agric Water Manage*, **2001**, 50, 1, 9–25.
[4] RG Allen, *J of Hydrol*, **2000**, 229, 1–2, 27–41.
[5] AA Suleiman, SC Tojo, G Hoogenboom, *Agric Water Manage*, **2007**, 91, 1–3, 33–42.
[6] G Bodner, W Loiskandl, H Kaulm, *Agric Water Manage*, **2007**, 93, 3, 85–98.
[7] Y Liu, Y Luo, *Agric Water Manage*, **2010**, 97, 31–40.
[8] J Doorenbos, WO Pruitt, Crop water requirements, Rome, Italy, *FAO, Irrigation Drainage Paper*, **1977**, 24.
[9] WO Pruitt, E Fereres, K Kaita, RL Snyder, Reference evapotranspiration (ET_0) for California, *Agriculture and Experiment Station Bulletin, University of California*, **1987**, 16 PP, 12 maps.
[10] RL Snyder, BJ Lanini, DA Shaw, WO Pruitt, University of California, *Division of Agricultural and Natural Resources Leaflet* 21427, **1987**, p12.
[11] J Doorenbos, AH Kassam, Yield response to water, Rome, Italy, *FAO, Irrigation and Drainage Paper*, **1979**, 33.
[12] ME Jensen, RD Burman, RG Allen, Evapotranspiration and irrigation water requirements. *ASCE Manuals and Reports on Engineering Practice*, **1990**, 70.
[13] OT Denmead, Relative significance of soil and plant evaporation in estimating evapotranspiration. In: Plant Response to Climatic Factors. *UNESCO, Paris, France*, **1973**, 505-511.
[14] G Stanhill, Evaporation, transpiration and evapotranspiration: a case for Ockham's razor. In: Hadas et al. (Eds.) Physical Aspects of soil water and salts in Ecosystems. *Springer, New York*, **1973**, 207-220.
[15] JT Ritchie, *Water Res Res*, **1972**, 8, 5, 1204-1213.
[16] CB Tanner, WA Jury, *Agron J*, **1976**, 68, 239-243.
[17] ET Kanemasu, LR Stone, WL Powers, *Agron J*, **1976**, 68, 569-572.
[18] WD Rosenthal, ET Kanemasu, LR Ranez, *Agron J*, **1977**, 69, 461-464.
[19] J Conaway, CHM Van Bavel, *J Appl Meteorol*, **1967**, 6, 650-655.
[20] TA Black, WR Gardner, GW Thurtell, *Soil Sci Am Proc*, **1969**, 33, 655-660.
[21] NL Kocke, DF Heermann, HR Duke, Measurement of evaporation and plant transpiration for irrigated corn. In: Proceedings of the Specialty Conference on advanced Irrigation and Drainage: Surviving External pressures, *ASCE, New York*, **1985**, 55-62.
[22] S Kang, B Gu, T Du, J Zhang, *Agricultural Water Management*, **2003**, 59, 293-254.
[23]DL Martin, NL klocke, DL DeHann, Measuring evaporation using mini-lysimeteres. In: Proceedings of the ASCE National Symposium on Advanced Evapotranspirations, Chicagoo, **1985**, p11.
[24] HR Mobasser, E Rahimi Fard, *Annals of Biolo Res*, **2012**, 3, 2, 1080-1084.
[25] GS Banuelos, DR Bryla, CG Cook, *Indus Crops and Prod*, **2002**, 15, 237–245.
[26] P Fouladi, DN Salamat, R Maheri Sis, N Ahmadzade, A Aghdam shahriar, H Gorbani, A Agajanzade, *Annals of Biolo Res*, **2012**, 3,2, 829-836.
[27] MJ Morrison, PBE Mc Vetty, CF Shaykewich, *Canadian J of Plant Sci*, **1989**, 69:455-464.
[28] A Majnooni-Heris, Sh Zand-Parsa, AS Sepaskhah, MR Neyshaburi, E Asadi, *9th National Seminar on Irrigation and Evapotranspiration, 5-7 Feb*. **2008**, Kerman, Iran, 265.
[29] A Majnooni-Heris, Sh Zand-Parsa, AS Sepaskhah, AA Kamgar-Haghighi, J Yasrebi, *Arch of Agron and Soil Sci*, **2011**, 57, 4, 401-420.
[30] A Majnooni-Heris, Sh Zand-Parsa, AS Sepaskhah, AA Kamgar-Haghighi, *J of Sci and Techn of Agric and Natu Res*, **2007**, 11, 41, 29-42.
[31] DC Nielsen, *J of Prod Agric*, **1997**, 10, 2, 307–313.
[32] AA Rahnema, AM Bakhshandeh, *Asian J of Plant Sci*, **2006**, 5, 3, 543–546.
[33] JM Sinaki, EM Heravan, AHS Rad, G Noormohammadi Gand, G Zarei, *American-Eurasian J of Agric and Environ Sci*, **2007**, 2, 4, 417–422.
[34] A Istanbulluoglu, B Arslan, E Gocmen, E Gezer, C Pasa, *Biosys Eng*, **2010**, 105, 388-394.

[35] J Niyazi, HR Fooladvand, *J of Sci and Techn of Agric and Natu Res*, **2007**, 10, 3, 71-81.
[36] GR Zarei, H Shamsi, SM Dehghani, *J of Res in Agric Sci*, **2010**, 6, 29-37.
[37] H Ashktorab, WO Pruitt, KT Paw, *J Irrig and Drain Eng*, **1994**, 120, 2, 450-464.
[38] SZ Kang, ZZ He, X Zhang, Crop Water Requirement and Irrigation Scheduling in Shaanxi Province. *China water resources and Hydro-power press, Beijing*, **1992**, p 299.
[39] YM Chen, GS Guo, GX Wang, SZ Kang, **1995**. Water Requirenment and Irrigation for Main Crops in China. *China water resources and Hydro-Power press, Beijing*, **1995**, p 359.
[40] TW Sammis, CL Mapel, DG Lugg, RR Lansford, JT Mcguckin, Trans ASAE, **1985**, 28, 773-780.
[41] B Amos, LR Stone, LD Bark, *Agron J*, **1989**, 81, 713-716.
[42] DC Nielsen, SE Hinkle, *Trans ASAE*, **1996**, 39, 97-103.
[43] MS Al-Jamal, TW Sammis, S Ball, D Smeal, *ASAE Appl Eng Agric*, **1999**, 15 (6), 659–668.
[44] J L Wright, *J Irrig and Drain Eng*, **1982**, 108 (1), 57–74.
[45] AR Sepaskhah, M Andam, *Agric Water Manage*, **2001**, 49, 51-63.
[46] J Ko, G Piccinni, T Marek, T Howell, *Agric Water Manage*, **2009**, 96, 1691–1697.
[47] GA De Medeiros, FB Arrunda, E Sakai, M Fujiwara, *Agric Water Manage*, **2001**, 49, 211–224.
[48] R Lopez-Urrea, F Martın de Santa Olalla, A Montoro, P Lopez-Fuster, *Agric Water Manage*, **2009**, 96, 1031–1036.
[49] JT Ritchie, E Burnett, *Agron J*, **1971**, 63, 56-62.
[50] KJ Kristensen, *Nordic Hydrol*, **1974**, 5, 3, 173-182.
[51] SW Childs, JR Gilley, WE Spinter, *Trans ASAE*, **1977**, 20, 858-870.
[52] C Belmans, JG Wesseling, FA Feddes, *J of Hydrol*, **1983**, 63, 271-286.