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Evapotranspiration, crop coefficient and water use efficiency of coriander grown in tropical environment

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ABSTRACT

The water scarcity is expected to intensify in the future and irrigation becomes an essential component of crop production, especially in arid and semiarid regions, where the available water resources are limited. Four field experiments were carried out at tropical environment in Brazil in 2013 and 2014, in order to evaluate the effect of planting date on crop evapotranspiration (ET_c), crop coefficient (K_c), growth parameters and water use efficiency (WUE) of coriander (*Coriandrum sativum*) plants. The planting dates occurred during winter, spring, summer and autumn growing seasons. ET_c was obtained through the soil water balance method and the reference evapotranspiration (ET_o) through the Penman-Monteith method, using data collected from an automatic weather station located close to the experimental area. The results of the research showed that the mean values of coriander ET_c and K_c were 139.8 mm and 0.87, respectively. Coriander water demand is higher in the summer growing season and lower in the winter; however, its yield is higher in the autumn and lower in the winter. Coriander has higher yield and development of its growth variables in the autumn growing season. The results also indicated that the interannual climate variations had significant effects on most growth variables, as yield, ET_c and K_c of coriander grown in tropical environment.

Keywords: *Coriandrum sativum*, soil water balance, irrigation, Penman-Monteith approach.

RESUMO

Evapotranspiração, coeficiente de colheita e eficiência de uso de água do coentro cultivado em ambiente tropical

A escassez de água deve intensificar-se no futuro e a irrigação se tornar alternativa essencial da produção agrícola, especialmente nas regiões áridas e semi-áridas, onde os recursos hídricos disponíveis são limitados. Foram realizados quatro experimentos de campo em ambiente tropical (2013 e 2014) com o objetivo de avaliar o efeito da data de plantio sobre a evapotranspiração da cultura (ET_c), o coeficiente de cultura (K_c), as variáveis de crescimento e a eficiência de uso de água de coentro (*Coriandrum sativum*). Os plantios foram realizadas durante as estações de cultivo de inverno, primavera, verão e outono. A ET_c foi obtida através do método do balanço hídrico do solo e da evapotranspiração de referência (ET_o) pelo método de Penman-Monteith, utilizando dados coletados de uma estação meteorológica automática localizada próxima à área experimental. Os resultados da pesquisa mostraram que os valores médios de ET_c e K_c do coentro foram 139,8 mm e 0,87, respectivamente. A demanda hídrica da cultura foi maior durante o verão e menor no inverno; e no entanto, a sua produtividade é maior no outono e menor no inverno. Os resultados também indicaram que o coentro tem maior produtividade e desenvolvimento de suas variáveis de crescimento durante o período de outono. As variações climáticas exerceram efeitos significativos sobre a maioria das variáveis de crescimento, produtividade, ET_c e K_c de coentro cultivadas em ambiente tropical no Brasil.

Palavras-chave: *Coriandrum sativum*, balanço hídrico do solo, irrigação, método de Penman-Monteith.

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Coriander (*Coriandrum sativum*) is an herbaceous vegetable with high economic value and socioeconomic importance in the world. The green leaves and crushed seeds provide the spicy flavor, while the seed oil is used in perfumes, cosmetics and soaps. This crop stands out in Asia, where the leading countries in production and consumption are located; however, it has been also cultivated in South America, North Africa and India (Zekovíc *et al*., 2016). Coriander is a hot-climate crop and does not tolerate low temperatures. In regions of hot climate and low altitude, it can be sown during the entire year and its harvest can be performed 3 to 5 weeks after sowing.

Coriander is one of the oleaginous seasonings with the most diverse purposes, whose seeds contain essential oil rich in linalool and are used mainly as a component of foods, medicinal drugs, flavoring agents and perfumes. Seeds and leaves of coriander are used as condiment in food industry, and recent studies have addressed the use of coriander leaf extracts in applications of biomedicine, pharmaceutical industry and biotechnologies (Narayanan & Sakthivel, 2008). In addition, the vegetable oil extracted from coriander fruits has high concentration of monounsaturated fatty acids, especially petroselinic acid, a compound useful for the production of detergents, which can be used in the synthesis of nylon polymers (Msaada *et al*., 2009).

Coriander cultivation mainly aims at the production of fresh leaf matter, while its dried fruits (seeds) are widely used in the industry of condiments. Some varieties are used for the extraction of essential oils with high added value, employed in the industries of flavoring agents, cosmetics and medicinal drugs. Coriander's popularity comes not only from its use for oil, such as soap, creams, lotions and perfumes, but also from its use as a domestic spice (Burdock & Carabin, 2009). Coriander essential oil is used as a flavor ingredient, but it has also been used as a traditional medicine (Burdock & Carabin, 2009). On the other hand, coriander seeds are mainly responsible for its medical use and have been used as a drug for indigestion, against worms, rheumatism and pain in the articulation (Wangensteen *et al*., 2004). The properties of coriander vegetable oil have great commercial importance, because the profile of this oil comprises the five types of fatty acids (palmitic, stearic, oleic, linoleic and linolenic), characteristic for the production of biodiesel.

Coriander fruits are potentially an important source of petroselinic acid, which has numerous industrial applications (Msaada *et al*., 2009). However, no water requirements and crop coefficients have been reported so far in researches about coriander, particularly in semiarid regions (Ghamarnia *et al*., 2013). Thus, despite the importance of coriander in various sectors of economy, cookery and medicine, among other activities, studies on the adequate management of coriander cultivation in tropical regions are still scarce in the literature. Therefore, conducting regional experiments with the coriander crop in order to search for improvements in its large-scale production, adapted to the edaphoclimatic conditions of the region, comes to fill a large gap for production optimization. To address this issue, the present study aims to determine evapotranspiration, crop coefficients and water use efficiency of coriander grown in a tropical environment. Another objective was to study the effects of growing seasons on yield and growth variables of coriander.

MATERIAL AND METHODS

Four field experiments were carried out over four successive seasons in 2013 and 2014 at the Vegetable Production Unit, belonging to the company Hortaliças Vida Verde (Itabaiana, Sergipe State), in partnership with the Federal University of Sergipe (UFS), Brazil (10°41'06"S; 37°25'31"W; 188 m altitude). The vegetable cultivation area belonging to this business enterprise comprehends approximately 6.5 hectares. The climate is characterized as tropical, with 24.5ºC mean annual temperature, 1,850 mm annual evaporation, 60% mean relative humidity and 839 mm mean rainfall. The rainy period occurs between May and July (Silva, 2004). The rainfall regime in the region has an irregular spatial and temporal distribution, which is a characteristic of the Brazilian northeast region. Because of that, its rainfall seasonality concentrates almost all its volume during the five months in the winter period (Silva *et al*., 2009).

The soil in the experimental area is classified as Red Yellow Argisol, with sandy loam texture, as sand at 0-15 cm depth and as loam at 15-30 cm. The soil chemical composition indicated mean contents of potassium, calcium and magnesium of 87.3 mg/dm^3, 50 mg/dm^3 and 2.9 cmol/dm^3, respectively. The daily meteorological data were obtained from the regional automatic weather stations located 600 m away from the experimental area. The study analyzed the coriander crop, cultivar 'Tabocas', planted on the density of 550,000 plants/ha. This cultivar is considered being early, 35 to 46 days cycle, uniform, excellent rusticity and good tolerance to early bolting. The leaves are large, slightly jagged, with an intense, shiny green color and good adaptation to tropical regions (Silva *et al*., 2013). A micro-sprinkler irrigation system was used and the flow rate of the irrigation pipe was 60 L h^{-1}. Irrigations were performed twice a day, according to the reference evapotranspiration (ET_o). Plant spacings were 0.25 m between rows and 0.10 m between plants.

Plants were fertilized using a compound of urea (0.9 kg/ha), dicalcium phosphate (0.9 kg/ha), cow manure (30 kg/ha) and sheep manure (30 kg/ha) twice a week until the end of the crop cycle. In the case of intense rainfalls, another type of fertigation was used, containing calcium nitrate, applied after a short dry period in order to not compromise the plant with excessive water. Every week, five coriander plants were harvested for the determination of leaf area, using a leaf area meter (LI-COR, LI-3000c Series). Root and stem lengths were measured with a ruler, graduated in mm, and leaves were weighed (fresh matter) at the laboratory.

The smallest number of days from transplanting to harvest occurred in the spring growing season, followed by the summer growing season. Each growing season was characterized with different climatic conditions. Soil water content was measured using a portable soil moisture monitoring system (Diviner 2000, Sentek Pty. Ltd., Australia) previously calibrated for the soil of the experimental area with the gravimetric sampling technique, according to Morgan *et al*. (1999). The Diviner 2000 is a portable soil moisture monitoring instrument that consists of a probe and hand-held data logger (Zhou *et al*., 2008). The measurements of mean volumetric soil water content were performed at daily intervals after each irrigation or rainfall at every 10 cm depth from the surface to 50 cm. For each experimental plot of 15.0 x 0.7 m, 5 access tubes were installed for measurements of soil water content, in three replicates. Irrigation management was performed using the crop coefficient established in the FAO-56 Bulletin (Allen *et al*., 1998).

Crop evapotranspiration (ET_c) was determined through the soil water balance method, as follows:

$$ET_c = P + I + A - D - \Delta W \pm R$$

where P= rainfall; I= irrigation depth; A= capillary rise; D= deep drainage; ΔW= variation of water depth available in the soil and R= surface runoff. All the components of the equation are expressed in mm. Rainfall was monitored using a pluviometer, installed in the experimental area, and ΔW was determined based on the soil moisture profile. The control volume considered for water balance corresponds to the soil layer between surface and effective root system depth (0.4 m). Since the water level in the studied area is more than 1 m deep, the term capillary rise was considered as null. Soil water drainage was obtained based on the procedures established by Azevedo *et al*. (2006). Surface runoff (R) was not considered because of the flat terrain topography. The ET_o values were determined using the air temperature, net radiation, wind speed and relative humidity data and the FAO Penman-Monteith equation (Allen *et al*., 1998). The meteorological data of the experimental site for determining ET_o were obtained from an automatic weather station near the experimental site. The crop coefficient was determined through the ratio between ET_c and ET_o defined by meteorological data. On the other hand, water use efficiency (WUE) was obtained as the ratio between grain weight or biomass yield and crop evapotranspiration expressed in kilogram units per hectare per millimeter of water.

A multivariate analysis of variance (MANOVA) was performed to compare the effect of different growing seasons (winter, summer, spring and autumn) on coriander growth variables (leaf area, root length, stem diameter, fresh leaf weight, yield and daily evapotranspiration). Differences between means were tested using Tukey and Scott-Knott tests at $p<0.05$. Statistical analyses were performed using the program ASISSTAT (Silva, 1996). The experimental design was of randomized complete blocks in factorial scheme 4x3, factor 1 (treatments) corresponding to 4 growing seasons and factor 3 to three replications. Spacing between plants and rows was 10 and 25 cm respectively. Each experimental plot's useful area measured 9.8 m^2 (0.7 m width x 14 m length) with 65 plants.

RESULTS AND DISCUSSION

Climatic data

The values of meteorological variables during the four experimental campaigns with the coriander crop in the studied region are presented in Table 1. Seasonal rainfall during the winter growing season was highest in comparison to the other periods, with 197.2±5.68 mm; however, the summer showed the lowest total rainfall, representing only 24% of the total of the winter. The highest insolation and Class A pan evaporation values were recorded for the summer growing season, while the insolation in the winter represented 74% of that of the summer and 90% of that of the autumn. Temperatures showed little variation between growing seasons, and the mean values of summer and autumn were virtually equal, around 27ºC, representing only 10% of the mean temperature of the first experimental campaign during the winter. Mean annual relative humidity varied significantly among growing seasons, from 39±5.4% in spring to 56±12.5% in autumn. Summer transplanting date was the warmest, followed by the autumn and winter growing seasons and insolation was quite high during all seasons.

Growth parameters

The growth variables of the coriander crop were measured starting 14 days after planting date (DAP), when the plants presented favorable size for measurements. From this date on, the following growth variables were measured: leaf area, root length, stem length and fresh leaf weight. The values of coriander growth variables in the four experimental periods are shown in Table 2. The crop showed the highest values of leaf area during the autumn growing season, varying from 27.5 cm^2 to 350.4 cm^2 at the end of the crop cycle. The value of leaf area at 38 DAP in the autumn season is statistically significant at the 0.05 level of confidence. The lowest leaf area of coriander was observed in the summer, represented only 9% of that in the autumn cultivation. Such performance is not only associated with the absence of rains in the summer, because in the winter the leaf area showed its second lowest value, only 91.63 cm^2, which represents more than 26% of that in the winter growing season. Hence, it is observed that the autumn growing season is the most adequate period for coriander cultivation in the studied region.

Root length values are the highest ones and strictly equal during the spring and autumn growing seasons (14 cm), which are statistically significant at the 0.05 level from those found in winter and summer growing seasons. In the winter period, in which the rainfall

Table 1. Mean ± standard deviation of climate data during four growing seasons of coriander grown in tropical environment. Mean air temperature (Temp), Wind speed (WS), Relative humidity (RH), Class A pan evaporation (Class A), Insolation (Ins) and Rainfall (Rain). Itabaiana, UFS, 2013-2014.

Growing seasons	Temp (ºC)	WS (m/s)	RH (%)	Class A	Ins (h)	Rain (mm)
Summer	27.5±0.75	1.8±0.59	57±11.9	364.0±1,9	320.8±3.2	48.0±1.99
Autumn	27.1±1.16	0.7±0.32	56±12.5	259.7±1,9	265.1±2.7	121.2±5.70
Winter	24.5±1.14	1.4±0.44	47±10.6	217.8±3,6	239.0±3.2	197.2±5.68
Spring	27.2±1.19	2.3±0.64	39±5.4	309.1±1,51	328.1±2.94	15.2±1.64

indices are higher, root growth is lower, because the search for water and nutrients is facilitated by the interaction with the environment. In this period of the year, total rainfall was equal to 197.2 mm and mean air temperature was 24.5ºC (Table 1). At the beginning of vegetative growth (14 DAP), stem length showed lowest value in the winter season, representing less than 50% of that of the spring season. On the other hand, at the end of the crop cycle, stem length was higher in summer and lower in spring growing season. At the end of the coriander development cycle, the difference between stem length values in the winter and summer periods is not statistically significant at the 0.05 level, but is statistically different from those found in the summer and autumn growing seasons. Only the stem length referring to the spring growing season did not show statistically significant difference between the values of 21 and 38 DAP. Coriander showed higher vegetative development in the autumn growing season. Coriander plants have high values of leaf area, root length, yield and water use efficiency in the autumn growing season. However, stem length and fresh leaf weight are highest during summer and spring growing seasons. There were significant differences in growth variables between growing seasons at the end of crop cycle (38 DAP).

Table 2. Growth variables throughout the development cycle of coriander plants grown in tropical environment. Itabaiana, UFS, 2013-2014.

Growing seasons	Day after planting (DAP)		
	14º	21º	38º
		Leaf area (cm^2)	
Winter	1.30 aB	9.17 bB	91.63 bA
Spring	2.40 aB	47.60 bB	100.77 bA
Summer	3.43 aA	10.60 bA	31.63 cA
Autumn	27.53 aC	119.13 aB	350.40 aA
		Root length (cm)	
Winter	4.67 bB	11.17 aA	10.17 bA
Spring	6.67 bB	12.67 aA	14.00 aA
Summer	8.67 aB	9.50 aB	11.83 bA
Autumn	5.67 bC	9.67 aB	14.00 aA
		Stem lenght (cm)	
Winter	0.67 bB	1.83 aA	1.50 bA
Spring	1.33 aB	1.83 aA	1.17 bB
Summer	0.60 bB	1.83 aA	2.00 aA
Autumn	0.50 bB	1.50 aA	1.83 aA
		Fresh leaf weight (cm)	
Winter	0.23 aB	1.20 bB	6.53 cA
Spring	0.10 aB	3.23 bB	10.00 bA
Summer	0.43 aB	1.70 bB	4.93 cA
Autumn	1.40 aC	6.37 aB	4.73 aA

Means followed by the same letter(s), uppercase in rows and lowercase in columns, do not differ by the Scott-Knott test ($p<0.05$).

Table 3. Cumulative crop evapotranspiration [Cumulated ET_c (mm)], reference evapotranspiration [ET_o (mm/day)], daily evapotranspiration [Daily ET_c (mm/day)], Yield [Y (kg/ha/mm water)] and water use efficiency [WUE (kg/ha/mm water)] of coriander grown in tropical environment. Itabaiana, UFS, 2013-2014.

Growing seasons	Cumulated ET_c	ET_o	Daily ET_c	Y	WUE
Winter	103.4	2.70	2.3 b	3597 ab	34.9
Spring	187.7	3.46	4.9 a	5500 ab	29.9
Summer	223.1	4.62	5.2 a	2715 b	12.2
Autumn	180.8	3.07	3.9 ab	8103 a	44.8

Means with the same letter within columns are not significantly different at $p<0.05$ by Tukey test.

The differences between means of fresh leaf weight for autumn and the other growing seasons were deemed to be significant at $p<0.05$. The fresh leaf weight of coriander showed slight development in the summer season, as well as the other growth variables, because the plant has high sensitivity to high temperatures and low rainfalls that normally occur in this period of the year. The variation in coriander fresh leaf weight only occur between 21 and 38 DAP, precisely at the end of the crop cycle. On the other hand, between 14 and 21 DAP, there was no statistically significant change in fresh leaf weight, according to the Scott-Knott test. Unfavorable environmental conditions were responsible for changes in coriander growth variables.

Evapotranspiration and water use efficiency

Fresh leaf weight yields of coriander during the four experimental campaigns are shown in Table 3. The lowest crop yield occurred in the summer, representing only 33.5% of that obtained in the autumn growing season. The highest crop yield in the autumn is statistically significant at the 0.05 level from those of the other growing seasons. Otherwise, there were no significant differences between yields of winter and spring growing seasons. Yields of coriander grown in tropical environment in Brazil were significantly high, specially throughout the autumn growing season. Coriander yield varied from 2,715 kg ha^{-1} in the summer to 8,103 kg ha^{-1} in the autumn. Similar results were obtained by Tavella *et al.* (2010), who observed yields ranging from 7,218 kg ha^{-1}, with conventional soil tillage, to 8,004 kg ha^{-1}, with no tillage. Low values in coriander yield varying from 800 kg ha^{-1} to 2,297 kg ha^{-1} have been previously reported (Ayanoglue *et al*., 2002). Zheljazkov *et al*. (2008) reported coriander yield during both summers of 429 kg ha^{-1} when analyzing the effects of sowing date on seed yield and oil composition in Atlantic Canada. Our results indicated that the interannual climate variations showed significant effects on growth variables, yield, ET_c and K_c of coriander grown in tropical environment. These significant effects were due to the changes in air temperature, rainfall and relative humidity throughout the year (Table 2). Similar results were obtained by Msaada *et al*. (2009), who found changes in essential oil yield for the eight samples of coriander growing in two different Tunisian regions. They also reported that changes during fruit maturation and the physiological maturation process promote changes in yield. In addition, coriander plants produce high biomass, grain yield and essential oil in favorable environments (Lenardis *et al*., 2007).

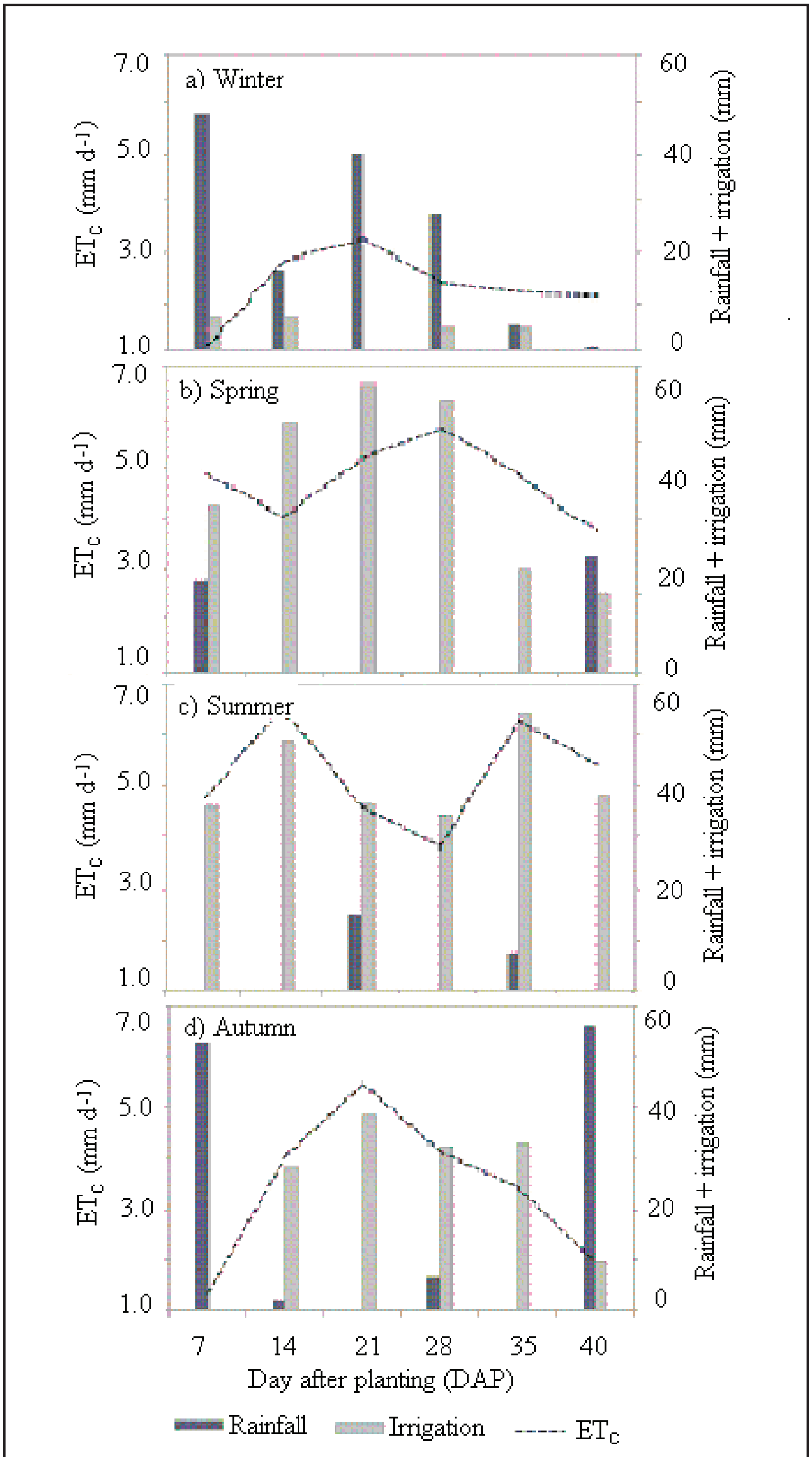

Figure 1. Seasonal course of evapotranspiration, rainfall and irrigation during winter, spring, summer and autumn growing seasons in tropical environment. Itabaiana, UFS, 2013-2014.

Coriander water consumption is higher in the summer (5.19 mm/day), in the period in which temperatures are higher and rainfalls are lower, followed by spring, reaching a mean value of 4.9 mm day^{-1}. The winter is the period in which coriander plants show the lowest water demand, 2.3 mm day^{-1}, probably in response to the milder temperatures and higher values of total rainfall. Coriander ET_c during the winter campaign was statistically different from those observed in the spring, summer and winter campaigns, according to the Tukey test at 0.05 probability level. In addition, ET_c still in the winter campaign was, on average, lower than half of the values found in spring and summer campaigns, and 57% lower than the values of the autumn campaign. This is associated with the fact that the mean values of air temperature, insolation and wind speed were lower in the autumn compared with spring and summer campaigns. Thus, crop evapotranspiration is strongly influenced not only by soil water content, but also by air temperature and the number of hours in which the plant is subjected to it.

The smallest Y and WUE values occurred on the summer growing season because of the inherent highest values in crop evapotranspiration. There were no significant differences of Y values between the winter, spring and autumn growing seasons. Otherwise, there were significant differences for Y values between autumn and the other growing seasons. The results of the current study also indicate that the autumn cultivation

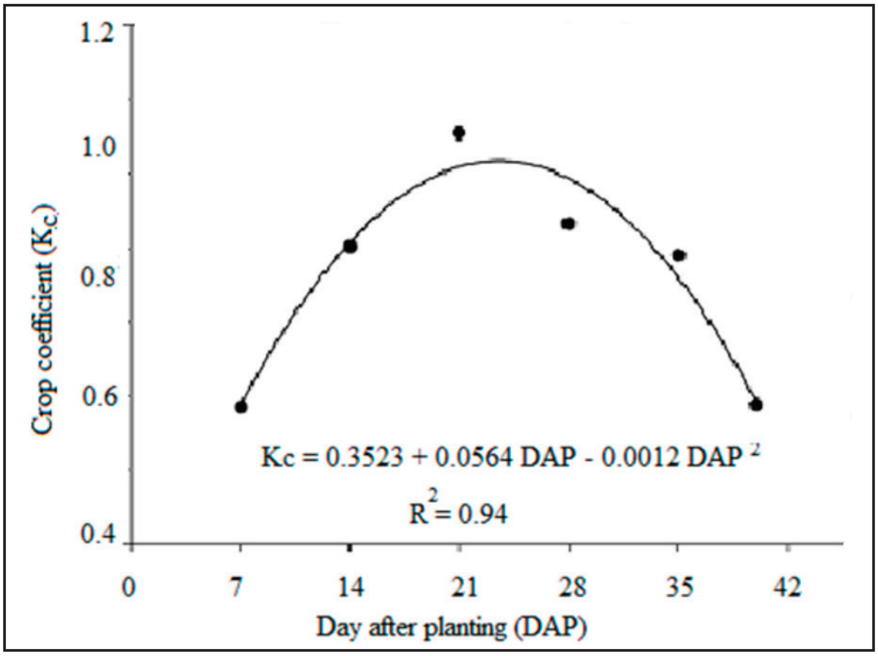

Figure 2. Coriander crop coefficient curve (solid line) and mean weekly values (filled circles) along its growth development for tropical environment. Itabaiana, UFS, 2013-2014.

provides significant increases in both Y and WUE of coriander grown in tropical environment. The lowest values of water use efficiency were achieved in the summer, when rainfall is low and air temperature, Class A pan evaporation and insolation are high. These results are in agreement with Farahani *et al*. (2008), who pointed out that drought stress significantly affects WUE, studying the effects of drought stress on some characteristics of coriander in Iran.

The values in ET_o follow the same behavior pattern of ET_c, with maximum values in the summer and minimum values in the winter. Cumulative crop evapotranspiration varied from 103.4 mm in the winter to 223.1 mm in the summer. These results are in contrast with previous findings reported by Ghamarnia *et al*. (2013), who found ET_c values of coriander grown in semiarid climate in Iran to be 647 mm. This abrupt difference between results can be attributed to climate conditions, crop variety, soil and crop management practices, growing conditions and planting arrangement. Increasing water amounts in the winter growing season decreased crop evapotranspiration and did not increase yield as expected. Leaf area and yield are lowest during summer and highest during the autumn growing season. These results suggest that the climatic variables during the summer growing season produce changes in the metabolism of coriander, which resulted in decrease of its yield variables.

Seasonal course of evapotranspiration

During the winter growing season, there was the highest total rainfall (47.7 mm) at 7 DAP (Figure 1a). In addition, due to the higher amount of rains in this period, there were not many irrigations in the coriander plantation area and the highest irrigation depth applied was equal to 7.1 mm, at 14 DAP. This indicates that ET_c responded to the reduction in evapotranspiration with the excess of moisture in the soil and the low evaporative demand. During the spring growing season, coriander ET_c reached 5.8 mm at 38 DAP (Figure 1b), when there were less rainfalls and consequently more irrigations, which varied from 38.0 to 35.5 mm between 21 and 38 DAP, respectively.

The same occurred during the summer growing season (Figure 1c), a period in which the crop showed the highest values of ET_c, due to the small number of rainfall events and high number of irrigations. In this case, coriander ET_c reached highest values, which varied from 6.53 mm at 14 DAP to 6.28 mm at 35 DAP. During the autumn experimental period (Figure 1d), there were the highest rainfall values at the beginning and at the end, which were equal to 53.1 and 56.2 mm at 7 and 40 DAP, respectively. The highest irrigation depths applied in the area were 38.5 mm at 21 DAP and 32.9 mm at 35 DAP.

Crop coefficient

The values in K_c of coriander obtained through the soil water balance method as a function of the days after planting (DAP) are presented in Figure 2. In this case, coriander K_c can be obtained through the equation: K_c= 0.3523 + 0.0564 DAP - 0.0012 DAP^2 with R^2= 0.94. The mean K_c is 0.86, with values of 0.80, 1.00 and 0.80 in the initial, middle and final stages, respectively. Therefore, the observed temporal variation in K_c is assumed to be a function of the DAP, with highly significant correlation coefficient. These results suggest that the equation reasonably describes the relationship between the crop coefficient and DAP.

Similar results were obtained by Silva *et al*. (2013), using the methodology of dual crop coefficient. These authors found K_c values for coriander phenological stages of 0.82 (initial); 1.03 (developing); 1.07 (middle) and 0.93 (final). However, Ghamarnia *et al*. (2013) reported different K_c values in the calculation of crop water requirements and crop coefficients of coriander grown in semiarid climate in Iran. They found single crop coefficient values of 0.66, 1.19, 1.36, 0.98 for the initial, developing, middle and final stages, respectively. The interannual climate variations have effects on most growth parameters, yield, ETc and Kc of coriander plants. Similar results were obtained by Rashed & Darwesh (2015), who analyzed the effect of microclimate on coriander planting date and water requirements under different nitrogen sources in Egypt. During the phenological stages of coriander, its growth variables varied significantly between the growing seasons.

According to the result of the interaction between the coriander crop and the atmosphere, there is higher development in the growth variables and higher yield values for the autumn growing season. The coriander crop shows higher water demand in the summer period, due to the high temperatures and low total rainfall in the region. Evapotranspiration, yield and water use efficiency of coriander are highly affected by the climatic conditions of the growing seasons. Leaf area, root length, stem length and fresh leaf weight changed significantly ($p<0.05$) between the growing seasons. Our results showed that vegetative growth characteristics during the summer growing season had significant effect on yield variables of coriander grown in tropical environment. The results from the present study clearly demonstrate the decrease in coriander yield and WUE during the summer growing season are due to unfavorable environmental conditions.

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