Journal of Medicinal Plants and By-products (2019) 1: 1-6

Original Article

Study of the Essential Oil, Morphological Parameters, and Growth–stage-Specific Crop Coefficients of Summer Savory (*Satureja hortensis* L.)

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Article History: Received: 05 June 2018 /Accepted in revised form: 12 November 2018

Abstract

This research was conducted to study of the essential oil content, some morphological parameters, crop evapotranspiration (ET_c) and crop coefficient (K_c) of Summer Savory (*Satureja hortensis* L.) in the west of Iran (Khorramabad region) in 2017. Weighing Lysimeters (25 cm diameter and 30 cm height) were used to measure important morphological parameters, the evapotranspiration of grass (ET_0) and Summer Savory (ET_c.) for the first time (Three lysimeters for each plant that was considered as replication). Irrigation was performed by the weighing method. The results showed that the essential oil content was 1.083%(w/w), and the average of plant height, stem diameters, root length, root diameter, number of leaf per plant, leaf and flower dry weight, stem dry weight were 47cm, 3.13mm, 14.5cm, 2.26mm, 630.7, 0.866 g/plant, 0.890 g/plant, respectively. Crop coefficient (K_c) can be used in predicting exact water requirement of crops. The result indicated that seasonal $ET_0$and ETcwere884.26 mm and 776.64mm. The best polynomial curve for K_c values as a function of the days after planting (DAP) was a third polynomial ($K_c = 0.3908 + 15 \times 10^{-4}(DAP) + 3 \times 10^{-4}(DAP^2) - 2 \times 10^{-6}(DAP^3)$). Likewise, the growth-stage-specific crop coefficient, based on FAO approach (FAO-56 K_c) was 0.45, 0.78and 1.3. Development of the regional K_c helps in irrigation management and water resources protection.

Keywords: Crop coefficient, Crop evapotranspiration, Essential oil, Morphological parameters, Weighing Lysimeters

Introduction

Summer Savory (*Satureja hortensis* L.) is one of the most important medicinal plants in Iran. It is an annual herbused in the traditional medicine for treating stomach and intestinal disorders [1-3]. Generally, the aerial parts of the plant, which is usually harvested at flowering stage, is rich in essential oil and used in the food, drinks and perfume industries [4, 5, 6].The study of regional crop parameters like essential oil content, Kc, etc. help to manage regional growth performance and irrigation programming.

Crop evapotranspiration (ET_c) is considered as one of the most important indicators to manage the irrigation programming, especially in arid and semi-arid regions. The effect of the climate on the crop water requirement is given by the reference evapotranspiration (ET_0). ET_0 may be measured directly from green grass [7, 8] or can be calculated from the weather data such as temperature [9], radiation [10,11] and the combination models like FAO penman method [12]. Weighing Lysimeters are used to measure ET_c directly by detecting changes in weight of the soil and crop [13-15]. This method is very expensive and time consuming. Therefore, researchers preferred to use indirect

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method (ET_c= K_c. ET_0)to reduce costs [16-18].Determined ratio of the crop ET_c to the reference ET_0, called crop coefficient (K_c) and it represents an integration of the effects primary characteristics (crop height, albedo, canopy resistance and evaporation from soil) that distinguish the crop from reference grass. The K_c vary over the growing period. In FAO approaches [12],the growing period can be divided into four stages, including different K_c (initial, crop development, mid-season and late season). The initial stage begins from planting date up to approximately 10% ground cover. The second stage begins from 10% ground cover to effective full cover (approximately initiation of flowering), and the mid- season stage begins from effective full cover to the start of maturity. At this stage, the amount of K_c reaches its maximum value and the late season stage begins from the beginning of maturity to harvest time [12]. Marin *et al*. and Daniel *et al*. reported that, it is necessary to consider the great advancement of technologies for crop water supply [19,20]. They indicated that, there was a strong coupling of crop's water requirement to the atmosphere and vapor pressure.

However, up to the best of our knowledge, little documented investigations are reported about determination of the ET_c and K_c from these plants. Therefore, the main objective of this research was to determine the essential oil content, some morphological parameters, and ET_c and K_c of Summer Savory, using mini-weighing Lysimeters, in the Khorramabad region of Iran.

Material and Methods

The experiment was conducted in the research field of Faculty of Agriculture, Lorestan University, Khorramabad, Iran, through June to October 2017. The experimental site was located at $33^0$29'N latitude, $48^0$22'E longitude and 1125 m altitude above mean see level. The average temperature, humidity and rainfall values during the growing season were 28.01 °C, 21.7%, 0mm,respectively.Sixplasticpots(25 cm diameter and 30 cm height)were filled with the soil of the research field and used as mini-Lysimeters. The soil texture was loam. Weighing moisture at the field capacity point (θ_{FC}) and wilting point (θ_{PWP}) were obtained 31% and 16% using pressure plate. Seeds of Summer Savory were planted with a density of 150 plants per square meter.

Plant Growth and Morphological Characteristics

At the end of the experiment, aerial parts of the plants were harvested from each pot at flowering stage and the growth performance of Summer Savory plants was determined based on the plant height, stem diameters, root length, root diameter, number of leaf per plant, number of branch per plant, branch height, leaf and flower dry weight, stem dry weight, and root dry weight. Harvested plants were oven dried at 40 °C for measuring dry weight. Finally, the essential oil of dried samples was isolated by hydro distillation for 3 h, using a Clevenger-type apparatus [21]. The obtained oils were dried over anhydrous sodium sulfate and the essential oil content (w/w) was determined.

Measurement of the Evapotranspiration

ET_0 was determined from direct measurement of the various components of the soil water balance, using the weighing Lysimeter. The method consists of assessing the inlet and outlet water flux into the root zone over a particular time period by using following formula [1].

$$ET_c = I + P - D \pm \Delta S \quad (1)$$

Where I is irrigation (mm); P is rainfall (mm) and ΔS is the change in soil water content (mm). Each of the above formula components was measured during the growth period by weighing method and ultimately, the actual evapotranspiration was calculated.

Irrigation Programming

Irrigation was performed, when the weighing moisture of soil (θ_m) reached to the low level of the readily available water (RAW). These parameters were obtained from the following formulas [12].

$$RAW = MAD(\theta_{FC} - \theta_{PWP}) \quad (2)$$

$$\theta_m = \left|\theta_{fc} - MAD(\theta_{fc} - \theta_{PWP})\right| \quad (3)$$

Where MAD is the maximum allowable depletion that was supposed to be 0.5; θ_{FC} is weighing moisture at the field capacity point;θ_{PWP} is weighing moisture at the wilting point.

Crop Coefficient (K_c)

Crop coefficient (K_c) was calculated using the following formula

$$k_C = \frac{ET_C}{ET_0} \quad (4)$$

ET_0 was determined directly from the grass Lysimeters [22]. K_c curve was fitted to the best polynomial. Likewise, the K_c curve was depicted according to FAO approach.

Result and Discussion

The essential oil content and the measured morphological parameters of Summer Savory are indicated in table (1).As can be seen, plant height and Leaf and flower Dry weights were 47 cm and 0.866 g/plant, respectively. The average of the essential oil content under the condition of using Lysimeters was 1.08%. The average of stem diameters, root length, root diameter, number of leaf per plant, and stem dry weight were 3.13 mm, 14.5 cm, 2.26 mm, 630.7, 0.890 g/plant, respectively. Estaji *et al*. [23] showed the essential oil content of Summer Savory under the condition of greenhouse varied between 2.47-3.65 % in Baft and Rafsanjan accession, respectively. Likewise, their results showed that the maximum plant height and shoot dry weight were35.5 cm and 14.5 g/plant [23]. Mumivand *et al*. [24] reported that the essential oil content and dry weight of summer Savory under the field condition were 4.38% (v/w) and 42.2 g/plant, respectively. These values are more than those obtained in our study under the condition of using Lysimeters. It is well-known that growth and essential oil production of plants are mainly dictated by the combined influences of both genetic factors and cultivation conditions such as climate, plant density, the use of fertilizers [3].

The average of the reference evapotranspiration (ET_0) that measured by Lysimeters ranged between 6 and 14.5 mmd^{-1}, over the growing season (Fig. 1). Piccinni *et al*. [22] and Ko *et al*. [7] indicated that these values (ET_0) ranged between 1 to 10 mmd^{-1} and 1to 12 mm^{-1}. Likewise, seasonal ET_0was884.26mm [11,17]. This value (ET_0) was reported 1123mm in 2014 by Ebrahimipak and ghalebi [25] and 962.7mm in 2015 by Reyhani and Khashei Siuki [26] using Lysimeters.

Table 1 Plant growth, morphological characteristics and essential oil content of Summer Savory (*Satureja hortensis* L.)

Measured traits	Mean	SEM
Plant height (cm)	47	0.50
Root length (cm)	14.5	0.25
Number of leaf per plant	630.7	2.50
Number of branch per plant	36.7	0.50
Branch height (cm)	30.5	0.50
Root diameter (mm)	2.26	0.02
Stem diameter (mm)	3.13	0.025
Stem Dry weight per plant (g)	0.890	0.0005
root Dry weight per plant (g)	0.220	0.0005
Leaf and flower Dry weights per plant (g)	0.866	0.0005
Essential oil (%)	1.083	0.025

During the period of growing season, the crop evapotranspiration (ET_c) of Summer Savory ranged between 3 and 16 mmd^{-1} (Fig. 2). Reaching the peak at 73 days after planting (ET_c=16 mmd^{-1}).The total Amount of real evapotranspiration during the growing season wasobtained776.64mm. Determination of the ET_c and K_c from Summer Savory has not been studied so far.

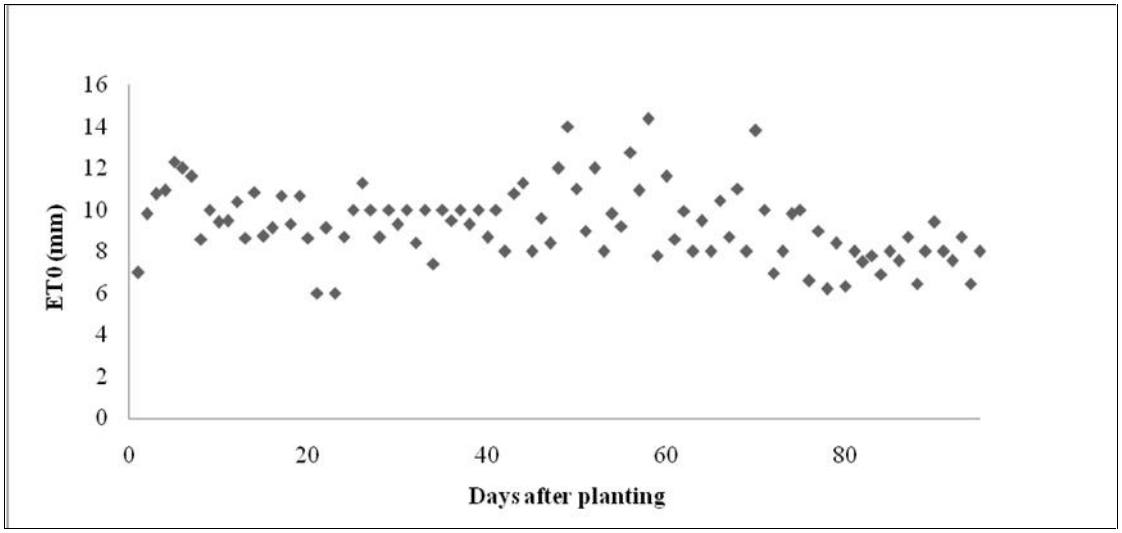

Fig. 1 Reference plant (Grass) evapotranspiration is shown as a function of days after planting during the growing season

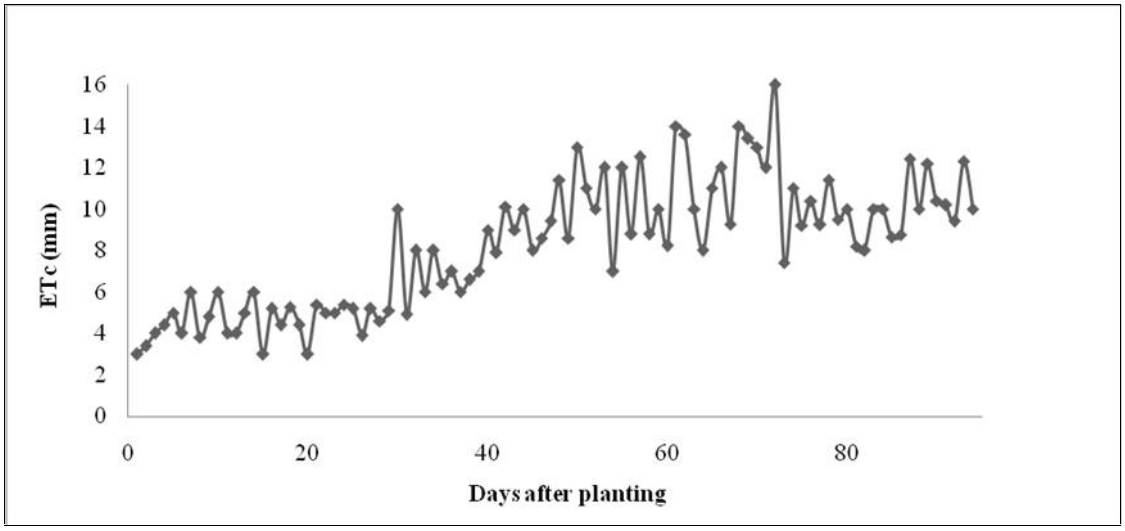

Fig. 2 Crop evapotranspiration of Summer Savory is (*Satureja hortensis* L.) shown as a function of days after planting during the growing season

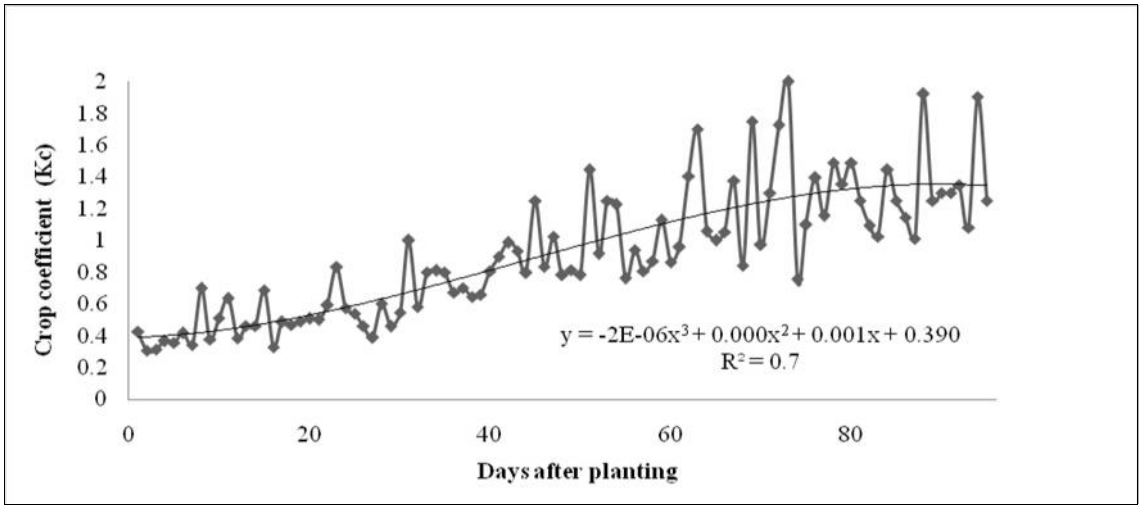

Fig. 3 Summer Savory (*Satureja hortensis* L.) Crop coefficient is shown as a function of days after planting during the growing season

The daily Kc of Summer Savory during the growing season is shown in Fig. 3. At this research, growth-stage-specific K_c values were obtained based on a third-order polynomial curve (Fig. 3). As shown in Fig. 3, there was a great daily variation within the growth period [22, 27].Based on FAO-56approach [12], the K_c values of three stages of growing season were plotted for Summer Savory (Fig. 4).The last stage of growth period was omitted, because the aerial parts of the Summer Savory were harvested at flowering stage, evapotranspiration is generally low [12]. At the crop development stage, the K_c value becomes larger. Because this value corresponds to the canopy cover and plant development [12]. The K_c reaches its maximum value at the mid-season stage, because of the differences in crop height and resistance between the reference crop (grass) and medicinal plants and weather conditions [12].The amount of growth-stage specific $K_c$is indicated at table 1.

This curve shows the distribution of K_c over time throughout the growing season [28, 22, and 27]. A third polynomial equation is as follows:

$$K_c = 0.3908 - 15 \times 10^{-4}(DAP) + 3 \times 10^{-4}(DAP^2) - 2 \times 10^{-6}(DAP^3)$$

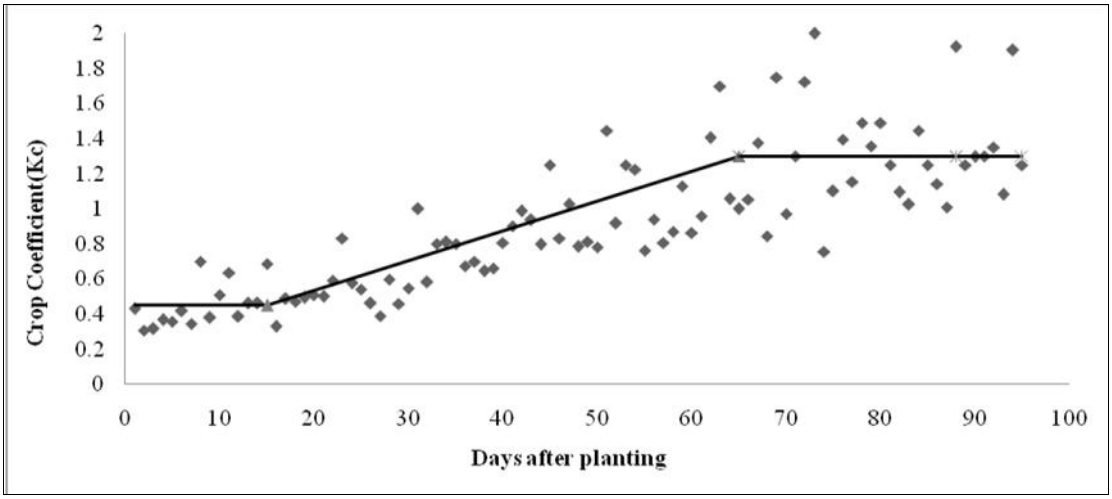

Fig. 4 Summer Savory (*Satureja hortensis* L.) Crop coefficient curve based on FAO-56 approach

Table 2 Crop coefficient determined using Lysimeters

plant	S. hortensis	
	DAP*	K_c
Growth stage		
initial	1-14	0.45
crop development	15-64	0.78
mid-season	65-95	1.3

Conclusion

This research was conducted to investigate the plant growth, morphological characteristics and essential oil content of Summer Savory under the Lysimetric condition in the Khorramabad region for the first time. Some parameters like crop evapotranspiration (ET_c) and crop coefficient (K_c) were also studied. Result showed that the essential oil content was 1.083%.The average of plant height, stem diameters, root length, root diameter, number of leaf per plant, leaf and flower dry weights, and stem dry weight were 47cm, 3.13mm, 14.5cm, 2.26mm, 630.7, 0.866 g/plant, 0.890 g/plant, respectively. Accumulated ET_c of Summer Savory was776.64mm. K_c values as a function of the number of days after planting, were determined based on the best polynomial curve. The best polynomial curve was a third polynomial ($K_c = 0.3908 - 15 \times 10^{-4}(DAP) + 3 \times 10^{-4}(DAP^2) - 2 \times 10^{-6}(DAP^3)$) . K_c values based on the FAO approach, were 0.45, 0.78and 1.3 for initial, development and mid-season stages of the growing period, respectively. These values are necessary to develop irrigation management, to avoid water over use and to enhance water use efficiency.

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