Turkish Journal of Agriculture - Food Science and Technology, 11(4): 838-845, 2023
DOI: https://doi.org/10.24925/turjaf.v11i4.838-845.5822

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effect of Irrigation Intervals on Some Morphological Traits, Seed Properties and Essence Yield of Savory (*Satureja spicigera* L.) Under Field Conditions

Seyyed Fazel Fazeli Kakhki[1,a], Mohammad Joleini[1,b], Nasser Beikzadeh[1,c,*]

[1]*Khorasan Razavi Agricultural and Natural Resources Research and Education Center, AREEO, Mashhad, Iran*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 05-12-2022
Accepted : 07-02-2023

Keywords:
Plant canopy area
Essence yield
Survival percentage
Width of seed
Irrigation interval

ABSTRACT

Agricultural management is one of the main factors to ameliorate environment adverse effects. Climate change has adverse effects on water availability in drought and semi-drought regions that constrain crop survival. In order to investigate the effect of irrigation intervals on morphological characteristics and yield components of savory plant (*Satureja spicigera* L.), an experiment was carried out based on randomized complete block design in three levels irrigation interval treatments (7 days (I7), 14 days (I14) and 21 days (I21)) with three replications in Khorasan Razavi Agricultural and Natural Resources Research and Education Center during of 2019. Results showed that with increase in irrigation intervals, all morphological characteristics and yield components were decreased. However there was no significant differences in seed and essence yield, plant canopy area, number of main stems, number of branches and stem diameter due to I7 and I14 treatments. In drought stress (I21), seed width was more affected than seed length. The lowest percentage of survival was observed in I21 treatment which was reduced by 26% and 35% respectively, compared to treatments I14 and I7. By increasing the irrigation interval to 21 days, the highest reduction in savory characteristics occurred, so that the highest and lowest biomass and seed yield were recorded from I7 and I21 treatments, respectively. There was a significant positive correlation between biomass and plant height ($r = 0.998^*$), total plant leaf area ($r = 0.770^*$), number of main stems ($r = 0.796^*$) and number of branches ($r = 0.998^*$). It seems that savory production can be improved in acceptable amount with 14-day irrigation interval.

[a] *a.sf_fazeli@yahoo.com* *https://orcid.org/0000-0003-1410-5228*
[c] *beiczadeh@gmail.com* *https://orcid.org/0000-0003-4789-5641*
[b] *b.mjolaini_re@yahoo.com* *https://orcid.org/0000-0003-0496-1629*

Introduction

Undoubtedly, water is the most valuable natural resources that can limit social and economic development in many areas (Chenoweth, 2008). This factor has more deficient due to more extraction, pollution and over increasing population and entrance pressure in sweet water resources (Anonymous, 2007). The distribution of water in many areas is uninformed, on the other hand, the presence of industries and technology has increased world temperature due to greenhouse effect of CO_2 and soil water losses that lead to restriction in production in arable lands as a result of low precipitation and more evaporation (Masoumi, 2010). Water scarcity has led to climate changes. This is more severe in arid and semi-arid regions which have about 40% of the effective land in the world (Gamo et al., 2013). With respect to agroecological, Iran found herself in arid and semi-arid region (Masoumi, 2010). In this area, water scarcity is the most limiting factor in crop production. Ecological fluctuations are entrance pressure to plant species so that some of plants may removal or migrate and some plant species must decrease some morphological and yield properties in this areas for survival (Grimm et al., 2008). Inadequate access to water has led to the application of appropriate irrigation management to achieve greater efficiency in water consumption at each growth stage based on environmental Therefore, in the time planning of growth, there is a period of time when the potential of the plant can be used to increase the efficiency of water in irrigation (Donk et al., 2012). In irrigation program, we need to expect crop yield and net investment return during agronomic year. The best decisions in the front of inadequate irrigation water are: A) Is irrigation required before planting?? (Stone et al., 2006), B) when should the first irrigation lunched? And C) when should the last irrigation finished? It is arrangement between the first and final irrigation based on water resources accessible and must be regulated irrigation interval in farm (Klocke et al., 2010). In this regard, it is necessary to know the phonological stages sensitive to water limitation, and in this situation, irrigation is applied within the limits of the plant's tolerance to water deficit.

This strategy, known as “less watering with less time” requires constant assessment of the plant’s condition (Therios, 2008). In this "less water, less time" process, the plant adjusts evapotranspiration with the available water, resulting in less plant growth reduction so that the plant does not experience drought symptoms (Santos et al., 2003). The results of Masoumi (2010) showed that applying drought stress in some growth stages in koshia (*Kochia scoparia*) had not significant difference in dry and fresh biomass. In another study in Fenugreek plant (*Trigonella foenum-graecum*), the highest yield was obtained from irrigation period with 4 days interval and hadn’t significant difference with 8 days irrigation interval (Baradaran et al., 2013).The results of Abbaszadeh et al. (2017) showed that some morphological traits (leaf yield, petiol yield and shoot yield) in Clary Sage (*Salvia sclarea* L.) was reduction with increased the interval irrigation time from 3, 6 to 9 days. In fennel plant (Foeniculum vulgare), increasing the irrigation interval caused a decrease in morphological traits and yield. However, the maximum yield of the plant was obtained at an irrigation interval of 10 days. (Koocheki et al., 2006).

Savory (*Satureja spicigera* L.) belongs to the tribe Mentheae of the subfamily Nepetoideae within the family Lamiaceae (Omidbaigi, 2018). The origin of this plant is the third era geological period and from this period it has spread in arid habitats and especially established in eastern parts of the Mediterranean area. Savory is annual herbaceous plant with a woody base. This plant is aromatic and with numerous upright or curved or arched stems up to 60 cm in height. Stems and shoots covered with hairs and glandular hairs can be found in various organs (Jamzad, 2009). The major chemical constituents of savory are carvacrol, γ-terpinene, p-cymene, trans-alpha-bergamotene and thyme that their value varies between species. Savory is used to treat bloody diarrhea and colonic inflammation and has analgesic, antioxidant, anti-diabetic, anticoagulant and antibacterial properties. Faker Baher et al. (2002) suggested with increasing drought stress levels, the amount of essence increases in *Satureja horensis* L. In another study, Jalilvand et al. (2011) suggested that water stress induces reduction in morphological traits in savory plant. Climate change, that is, temperature rise and irregular rainfall patterns lead to spreading drought stress in higher latitudes that these conditions have reduced crop productivity (Sodaeizadeh et al., 2016). High range of morphological, physiological, and molecular programs are applied by plant to counteract the effect of drought for the completion of the life cycle and survival of its generation (Karlberg et al., 2007). Thus, this study was designed to evaluate the effect of irrigation intervals on growth and development of savory plant in the field conditions.

Materials and Methods

This experiment was conducted at Khorasan Razavi Agricultural Research and Education Station, Mashhad, Iran. The specified location of the station is 36°, 13′ north latitude, longitude is 59°, 40′, and its height is 985 meters above sea level. Based on 30 years of data, the average annual temperature is 15.6°C and the average annual rainfall is 210 mm. In order to evaluate the effect of irrigation intervals on morphological characteristics and yield components of savory, an experiment was conducted in a randomized complete block design (RCBD) with three in 2019. The savory seeds were obtained from the center and then were tested for the seed germination. Three Petri dishes were selected for this purpose and 100 seeds were placed in the specified arrangement after disinfection. Seed germination percentage was obtained as 90 percent. Then, trays containing coco coir fiber were used and the seeds were sown in the trays on March 15, 2019. At the stage of four to six leaves, the savory seedlings are transferred to plastic pots. In order to adapt the plants to real conditions, the pots were transferred to the outside of greenhouse for 2 weeks, after that, the plants were transplanted into the field on 30/April/2019. Land preparation was performed according to the area's custom (two plows, a disk, a leveler, a furrower). The results of field soil analysis are shown in Table 1. The dimensions of the plots were 2 m × 2 m, separated by rope. The distance between the rows was 50 cm while the distance between the plants in a row was 30 cm. For complete plant establishment in the field, irrigation was done once a week for three weeks. The Time Domain Reflectometry (TDR) method was used to determine soil moisture. The TDR device used in this experiment was a TRIME type manufactured by IMKO, Germany (IMKO, 1998). During the growth period, soil moisture was measured before each irrigation in the 0-30 cm soil layer. The irrigation interval treatments were 7, 14 and 21 days as I7, I14 and I21, respectively, were done and continued until the end of plant growth in late of September. The water for irrigation was supplied from the well of the station. The results of the water quality are given in Table 2. The amount of irrigation water was done based on moisture depletion. In this way, according to the physical characteristics of the 0 to 30 cm soil profile layer (Table 1), the amount of soil moisture before each irrigation interval (7, 14 and 21 days) was measured using a TDR device. From the following relationship, the depth of irrigation water in each irrigation interval treatment was obtained from equation 1 (Alizadeh, 2009):

$$I_n = \frac{(\theta_{FC} - \theta_i) \times D_z}{100} \qquad (1)$$

Where the I_n is the net depth of irrigation water (mm), θ_{FC}: volumetric soil moisture at the point of field capacity (%), θ_i: Volumetric soil moisture before each irrigation (%) and D_Z: Average depth of plant root development (mm). The average root development depth of the savory plant was considered to be 30 cm. Then the gross depth of irrigation was calculated in the equation 2:

$$I_g = \frac{I_n}{e} \qquad (2)$$

Where I_g: the gross depth of irrigation (mm), I_n: the net depth of irrigation water (mm) and e: Irrigation efficiency was considered equal to 85%.

The volume of irrigation water was calculated and applied by the product of the gross depth of irrigation water in the area of each experimental plot according to equation 3:

$$V = I_g A \qquad (3)$$

Where V: the volume of irrigation water (lit) and A: The area of each experimental plot (m^2).

Table 1. The results of physicochemical analysis of soil

Physicochemical properties of soil	Results
Soil depth (cm)	0 - 30
Silt (%)	58
Sand (%)	14
Clay (%)	28
Field Capacity (%)	28.0
Welting Point (%)	12.2
Available Water (%)	15.8
Bulk Density (g.cm^{-3})	1.41
N (%)	0.07
P mg.kg^{-1}	5.45
K mg.kg^{-1}	247
OM (%)	1.12
CaCO3 (%)	15
EC dS.m^{-1}	2.87
pH	7.35

Table 2. The results of irrigation water

Properties of irrigation water	Results
EC dS.m^{-1}	0.8
pH	7.8
Na^{+}	3
Mg^{2+}	2.4
Ca^{2+} meq.lit^{-1}	2.4
SO$_4^{2-}$	1.8
Carbonate and bicarbonate	2.35
SAR	1.93

The volume of applied water in the entire growing season was equal to 7250 cubic meters per hectare. Irrigation was done based on furrow methods. For weeds control, we used handling methods and no fertilizer was used. At flowering time (late of September and early October), five plants were randomly selected from each plot and used for measuring morphological traits such as plant height, plant canopy area, number of main branches, number of lateral branches, leaf area of plant, stem diameter, seed length, seed width, and 1000 seed weight. At Crop maturity, all plants in each plot were used to determine biomass and grain yield. To determine the essential oil content, the seeds, leaves and branches of each treatment was weighed at 100 g and then the essential oil percentage was measured by water distillation and clevenger apparatus. Data analysis was done with Mstat-C and Minitab V.16. Means comparisons were done using Duncan multiple rage test at 5 percent probability level and charts were drawn with Excel 2016 software.

Results and Discussion

Plant Height

The irrigation interval had significant effect on plant height ($P \leq 0.05$) (Table 3). The highest plant height was obtained from irrigation with 7 days interval and as the distance between irrigation increased, the plant height decreased so that the decline amount was about 16 and 24 % in I14 and I21 compared to I7 treatment (Table 4). Nooshkam et al. (2016) reported that there was no significant difference in plant height of savory plant by irrigation intervals 15 and 30 days but in dry land farming of savory this trait was reduced significantly. The results of Ardakani et al. (2007) revealed that deficiency of water irrigation reduced plant height, number of tiller and internode length in *Melissa officinalis* L. Our findings were consistent with Nouri et al. (2014) who reported that plant height was reduced from 66.07 to 58.67 cm when irrigation intervals were increase from 6 to 9 days in summer savory plant (*Satureja hortensis* L.). It seems that in water deficiency conditions, the total water potential decreases, therefore this phenomenon affects processes such as stomata closure, absorption of nutrients and photosynthesis that reduce cell growth and elongation that leads to reduction of plant height (Harper et al., 2000).

Number of Main Stems and Branches

Increasing the irrigation intervals had a different significant effect ($P \leq 0.05$) on both main stems and branches in savory plant (Table 3). There was numerical difference between two treatments (I7 and I14) but statistically no significant difference was observed between them, both in main stems and branches. As showed in Table 4, the effect of treatment on the number of branches was greater than its effect on the number of main stems. By increasing irrigation intervals from seven to 14 and 21 days, the number of main stems decreased from 4.35 to 3.75 and 2.45, respectively. The highest number of branches (43) was recorded at 7-day irrigation interval and with increasing irrigation intervals, this trait decreased by 19 and 53% in 14 and 21 days irrigation intervals compared to 7-day interval, respectively. Akrami nejad et al. (2016) suggested that in drought stress (50% field capacity), the number of branches of savory plant decreases by about 6% compared to the control treatment. In another study, Arazmjo et al. (2010) reported that with increment of drought stress from 100% fc to 50% field capacity, number of stems decreased by about 21.5%. It seems that in plants, water and food budgeting depends on their availability, when their supply is insufficient; the plant continues to survive by reducing its consumption resources. Therefore, under water deficiency, plants can reduce transpiration rate area by reducing the height, leaf area and number of branches to conserve the absorbed water, and this allows the organisms to survive and produce.

Stem Diameter

The results of Table 3 showed that stem diameter was affected by irrigation intervals treatments. The highest stem diameter was recorded in I7 and the lowest was in I21 treatment. By increasing the irrigation intervals from 14 to 21 days, the stem diameter decreased by about 1.23 mm, but with increasing interval irrigation from I7 to I14, this decrease was 1.07 mm. Our findings indicated that increasing irrigation intervals had greater effect on stem diameter (Table 4). Miranshahi and Sayyari (2016) showed that stem diameter of savory plant decreased with increasing drought stress.

Total Plant Leaf Area (TPLA)

The results of analysis variance revealed that TPLA was affected by water deficiency (Table 3). In complete irrigation (I7), the total plant leaf area (TPLA) was 117 cm^2 and with increasing irrigation intervals, the TPLA dropped very sharp especially in I21 (Table 4). However, with being three-fold irrigation intervals, reduction of TPLA was lesser than 50%, and this showed that with increasing irrigation water deficiency, this plant can adapt to drought stress conditions. The results of Sodaeizadeh et al. (2016) showed that leaf area in savory plant was affected by drought stress so that it was 80, 72 and 58 mm^2 in water stress of 75%, 50% and 25% field capacity, respectively. It seems that cell proliferation and enlargement to be limited by the insufficiency of available water and required metabolites, and the plant's productive potential increases to overcome its effects. As a result, the growth rate of the plant was decrease (Taiz and Zaiger, 2006).

Ratio: A) Flower Branch to Biomass (FB/B) and B) Leaf Dry Weight to Biomass (LDW/B)

The FB/B ratio was affected by treatments ($P \le 0.05$) (Table 3). Although ratio of flower branch to biomass had less value, but this ratio was decreased in irrigation water deficiency treatment, so that in I7, FB/B=0.235 and this ratio was 0.169 and 0.107 in I14 and I21 treatments respectively (Table 4). This indicates that as the available water decreases, the amount of flowering buds and the number of seedlings producing flower bud per branch decreased and this stage of phenology of savory plant is susceptible to drought stress. The LDW/B ratio was also affected by the treatments ($P \le 0.05$) (Table 3). The highest LDW/B ratio (0.845) was recorded from I7 treatment. When the irrigation interval was 14 days, this ratio had no significant difference with 7-day irrigation interval, but with increasing irrigation interval to 21 days, the LDW/B ratio was 0.755. Compared to 7-day treatment, this ratio decreased by 10% and 8% in 14 and 21-day irrigation intervals, respectively (Table 4).

Seed Properties

Irrigation interval had significant difference on 1000 seed weight ($P \le 0.05$) (Table 3). The lowest width of seed was found in I21 which was reduced by about 52% compared to I7 treatment. 1000 seed weight was decreased in I14 by 35% compared to I7 treatment (Table 4). The length of petiole was not affected by irrigation intervals treatments (Table 3). The range of petiole was from 8.87 to 7.79 mm (Table 4). Both seed length and width were affected by experimental treatments (Table 3). The range of seed width and length was 0.897 - 0.423 mm and 1.61 - 0.61 mm, respectively. Seed width was more affected than seed length, so that by increasing irrigation interval from I7 to I14, seed width was reduced by about 33% and had significant differences between them, but 14-day irrigation interval had no significant difference on seed length. With increasing irrigation interval to 21 days, the seed length further decreased and reached 0.61 mm, about 62% less compared to I7 (Table 4).

Seed Yield

The results of means comparison showed that seed yield was affected by experimental treatments ($P \le 0.05$) (Table 3). The highest seed yield (12.8 g.m^{-2}) was in I7 and the lowest (6.78 g.m^{-2}) was in I21 treatment. When the 14-day irrigation interval was used, the decrease in seed yield was about 12% compared to I7 which was not statistically different between them. However, the delay in irrigation from 14 to 21 days compared to 7-day irrigation interval reduced the seed yield by about 46% (Figure 1D.).

Table 3. Analysis of variance (mean-square) of plant properties under irrigation deficiency

S.O.V	Plant height	Number of main stems	Number of branches	Stem diameter	Length of seed	Width of seed	Plant canopy area
Block	178 ns	2.66ns	211ns	10.2ns	1.87ns	0.18ns	2503366ns
Treatment	143.01*	3.10*	398*	0.08*	0.07*	0.12**	1591192*
Error	8.52	0.36	90.3	0.03	0.19	0.001	16032
CV	7.44	14.3	19.1	10.8	19.6	6.04	21.0

S.O.V	1000 seed weight	Survival percentage	Biomass	Flower branch ratio to biomass	Leaf dry weight ratio to biomass	Total plant leaf area	Seed yield	Essence yield
Block	1.11ns	1782*	25325*	201*	156*	2018ns	30.6*	0.25ns
Treatment	0.05ns	1852*	30288*	145*	185*	1918*	42.8*	0.087*
Error	0.002	52.7	90.6	21.3	51.2	140	19.8	0.034
CV	12.4	10.6	16.6	20.8	23.6	15.6	17.1	9.54

Treatments are three irrigation intervals (7, 14 and 21 days); ns, * and ** are non-significant and significant at the 5 and 1% probability level, respectively; df (Block=2; Treatment=2; Error=4)

Table 4. Means comparison of the effects of different irrigation intervals on morphological and yield traits in savory plant

Treatment	Plant height (cm)	Plant canopy area (cm^2)	Number of main stems	Number of branches	Stem diameter (mm)	Survival %	Length of seed (mm)
I 7	55.0 a	1850 a	4.35 a	43 a	7.31 a	89 a	1.61 a
I 14	46.2 b	1650 a	3.75 a	35 a	6.24 a	78 b	1.17 ab
I 21	41.3 b	675 b	2.45 b	20 b	5.01 b	58 c	0.61 b

Treatment	Width of seed (mm)	1000 seed weight (g)	Length of petiole (mm)	Flower branch ratio to biomass	Leaf dry weight ratio to biomass	Total plant leaf area (cm^2)
I 7	0.897 a	0.556 a	8.87 a	0.235 a	0.845 a	117 a
I 14	0.611 b	0.358 b	8.01 a	0.169 ab	0.821 a	85 b
I 21	0..423 c	0.268 c	7.79 a	0.107 b	0.755 b	65 c

I7, I14 and I21 are irrigation intervals in 7, 14 and 21 days respectively; Mean with the same alphabet are not significantly different at α=0.05 by Duncan test.

Table 5. The results of correlation between plant properties under irrigation scarcity in the field conditions.

Traits	1	2	3	4	5	6	7	8	9	10
1	1									
2	0.894ns	1								
3	0.931ns	0.988ns	1							
4	0.946ns	0.982ns	0.999*	1						
5	0.997**	0.879ns	0.942ns	0.953ns	1					
6	0.998**	0.997**	0.956ns	0.997**	0.956ns	1				
7	0.998*	0.969ns	0.796*	0.998*	0.770*	0.597*	1			
8	0.926*	0.838ns	0.912ns	0.936ns	0.997*	0.929ns	0.947ns	1		
9	0.903ns	0.907*	0.917*	0.954*	0.915ns	0.993ns	0.986*	0.880ns	1	
10	0.904ns	0.996*	0.998*	0.994*	0.916ns	0.994ns	0.896*	0.881ns	0.999**	1

1: Plant height; 2: Canopy plant area; 3: Number of main stems; 4: Number of branches; 5: Total plant leaf area; 6: Stem diameter; 7: Biomass; 8: 1000 seed weight; 9: Seed yield; 10: Essence yield; ns, * and ** are non- significant and significant at the 5 and 1% probability level respectively.

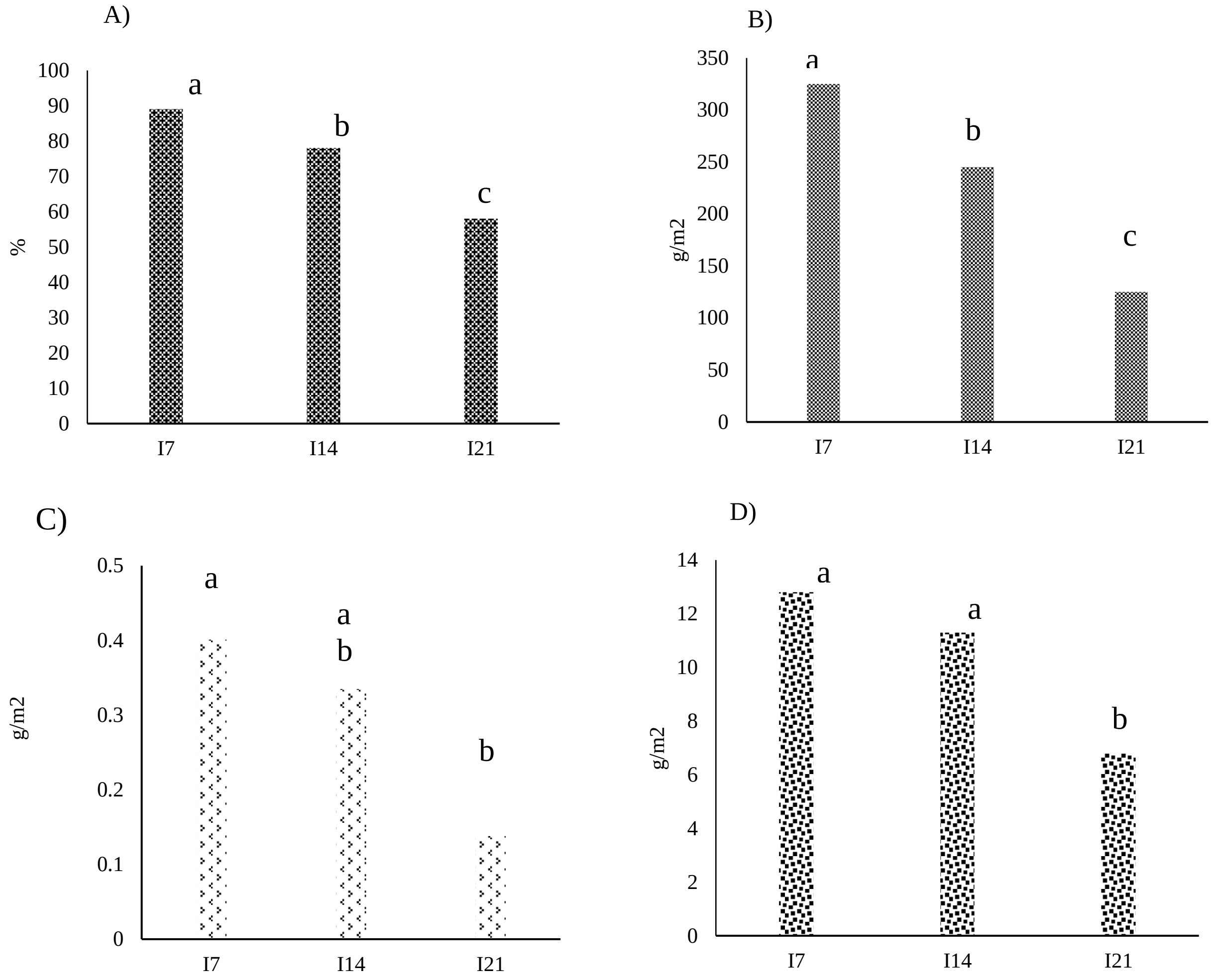

Figure 1. Effect of irrigation intervals (I7, I14 and) on A) survival percentage, B) biomass, C) essence yield, and D) seed yield in savory plant under field conditions (bars with the same alphabet are not significantly different at α=0.05 by Duncan test.).

The results of Akrami nejad et al. (2016) showed that with the increase of drought stress to 50% field capacity, savory seed yield decreased but there was no significant difference with the control. Baher Nic et al. (2004) suggested that yield and essence of savory plant reduced with the application of drought stress. Ucan et al. (2007) reported that there was no difference in sesame yield in irrigation intervals of 7, 14 and 21 days. Lawal and Rahman (2007) found that in different irrigation intervals that changed from 5 to 15 days in 2 years, the yields of pepper (*Capsicum annuum* L.) was different in the first year of experiment but in the second year, pepper yield was not affected by irrigation intervals. There was significant positive correlation between seed yield with biomass (r = 0.986*) and number of branches (r = 0.954*) (Table 5). The results of Nezami et al. (2014) showed that there is a significant positive correlation (r = 0.75**) between seed yield and biological yield in sesame plant. The correlation of seed yield with biological yield indicates that plants with better growth can produce more seeds.

Essence Yield

Irrigation interval had significant effect ($P\leq0.05$) on essence yield of savory plant (Table 3). By increasing irrigation intervals to 14 and 21 days, the amount of essence yield reduction, about 16 and 65 %, respectively, compared to 7-day. The highest essence yield was in I7 treatment (Figure 1C). Essence yield did not differ between I7 and I14 treatments. The results of Table 5 revealed that there was positive correlation (r = 0. 999**) between seed yield and essence yield and this indicates that as seed yield increases, essence yield also increases. Therefore, the amount of essence is indirectly affected by drought conditions. The results of Koocheki and Sabet Teimouri (2011) showed that the percentage of essential oil in rosemary, lavender and hyssop increased with increasing irrigation interval from 10 to 20 days. They also stated that biomass and essence yield decreased with increasing irrigation interval, which is consistent with our findings. The results of another study showed that reducing the frequency of irrigation from 6 times to 3 times during 21-day irrigation interval increased the yield of fennel essential oil (Mohamed and Abdu, 2004). There was significant positive correlation between essence yield and biomass (r = 0.896*) (Table 5). The results of Table 5 also showed that the essence yield had high positive correlation with all vegetative organs such as the number of main stems, number of lateral branches and leaf area. Miranshahi and Sayyari (2016) showed that essential oil yield was correlated with biomass yield, so that essential oil yield in summer savory plant decreased with decreasing biological yield. In aromatic plants, secondary metabolites increase in response to drought stress to increase plant tolerance. The production these metabolites depends not only on genetic factors, but also on environmental factors. Due to the reduction of the leaf area in response to drought stress conditions, the accumulation of essential oil in the leaf gland and subsequently the essence yield decreases. On the other hand, with premature aging of the leaves and reduced photosynthesis, the amount of shared carbon decreases and this may lead to a decrease in essential oil content, which is a balance between growth and defense mechanisms (Andalibi et al., 2011).

Biomass

The results of Table 3 revealed that the irrigation interval had significant effect ($P\leq0.05$) on biomass. The highest (325 $g.m^{-2}$) and lowest (125 $g.m^{-2}$) biomass was recorded from I7 and I21 treatments, respectively (Figure 1B). By increasing irrigation interval from 7 to 14 days, the biomass decreased by about 25%. When the irrigation period reached 21 days, compared to 14 and 7-day, the amount of biomass was about 49 and 62%, respectively. Nadjafi (2006) reported that the highest herbage biomass and essential oil yield were obtained at irrigation intervals of 7 and 14 days compared to 21 days on *Nepeta binaludensis* Jamzad. It seems that under water scarcity conditions, the leaf water potential becomes negative, so the xylem dos not fill with water and as a result, the embolism and cavitation in the xylem are induced, the continuity of the water column is broken, and the transfer of water in the xylem is prevented. If the rupture created in the continuity of water in the xylem is not repaired, the main pathway of water transfer will be blocked and this will be disastrous for the plant. Such embolisms cause the dehydration and death of leaves and decrease plant biomass (Taiz and Zeiger, 2006). The results in Table 5 revealed that the biomass had significant positive correlation with vegetative organs such as plant height (r = 0.998*), total plant leaf (r = 0.770*), number of main stems (r = 0.796*) and number of lateral branches (r = 0.770*). This indicates that with the reduction of vegetative components in savory plant, the biomass decreases. It seems that under drought stress, leaf relative water content dropped and this lead to reduction turgidity (Reddy et al., 2003). On the other hand, low turgor pressure prevents cell expansion and as result, leaf senescence, fresh and dry weight of plant organs decreases.

Survival Percentage (SP)

There was significant differences ($P\leq0.05$) between treatments effect on SP trait (Table 3) and the SP decreased with increasing irrigation interval. The lowest SP observed in I21 which was reduced by about 26 and 35%, respectively (Figure 1A), compared to I14 and I7 treatments. It seems that under little available water, the photosynthesis rate was decreased due to stomata closure. With drought progressing, the CO_2 fixation decreases due to occurring biochemical changes in chloroplast. In this condition, NADPH (nicotinamide adenine dinucleotide phosphate, which serves as a coenzyme in the redox reaction of photosynthesis) and ATP (adenosine triphosphate is the main energy currency of the cell) (both them are produced in the light-dependent reaction of the first stage of photosynthesis) are not consumed. Therefore, the photosynthetic electron transport chain is drastically reduced, as a result, it causes the leakage of electron to the oxygen molecule and the formation of reactive oxygen species (ROS) (Taiz and Zeiger, 2006). At high concentration, ROS is attracted to biological membranes and causes damage to the natural mechanisms of cells through the oxidative degradation of lipid, protein and nucleic acid. Plant cells are equipped with a free radical scavenger system to protect against stress damage. This system is activated by genetic potential, and so in some plants, where the expression of genes is delayed or genes is expressed in low quantities, leading to the destruction of cells and the death of the plant (Shabala, 2012). This genetic potential is varies between species and even within a species (Hadian et al., 2008). In present study, SP reduction can be attributed to this reason.

Conclusion

In recent years, water scarcity has become a main factor limiting crop production, however, it can be ameliorated by agriculture management. The results of the present research showed that an acceptable product can be produced by changing the irrigation intervals, so that in savory plant, there was no significant difference between irrigation intervals 7-day (I7) with 14-day (I14) in seed and essence yield. It was also found that there was no significant difference in traits such as canopy plant area, number of main stems, number of branches and stem diameter in application of I7 and I14 treatments. Therefore, in this plant by increasing the irrigation interval up to 14 days, an acceptable product can be produced.

References

Abbaszadeh B, Safikhani F, Layeghhaghighi M. 2017. Effects of irrigation interval and nitrogen amount on different clary sage (*Salvia sclarea* L.) characters in Karaj. Journal of Medicinal Plants and By-products, 2: 139-144

Akrami nejad O, Saffari M, Abdolshahi R. 2016. Effect of organic and chemical fertilizers on yield and essence oil of two ecotypes of savory (*Satureja hortensis* L.) under normal and drought stress conditions. Iranian Journal of Field Crops Research, 13: 675-686. doi: 10.22067/GSC.V13I4.23866.

Alizadeh A. 2009. The water, soil and plant relationship. Publications of Imam Reza University (AS). 484 pages.

Andalibi B, Zehtab Salmasi S, Ghassemi Gholezani K, Saba J. 2011. Changes in essential oil yield and composition at different parts of dill (*Anethum graveolens* L.) under limited irrigation conditions. Journal of Agricultural Science and Sustainable Production, 21: 11-22. Available from: https://sustainagriculture.tabrizu.ac.ir/article_1107_95a82cb1edc16ba37953b75631ea18ca.pdf?lang=en

Anonymous. 2007. World population will increase by 2.5 billion by 2050; people over 60 to increase by more than 1 billion. United Nations, Press Release POP/952, NY, USA. Available from: https://press.un.org/en/2007/pop952.doc.htm

Arazmjo E, Heidari M, Ghanbari A. 2010. Effect of water stress and type of fertilizer on yield and quality of chamomile (*Matricaria chamomilla* L.). Iranian Journal of Crop Sciences, 12: 100-111. doi: 10.22092/IJMAPR.2010.7131

Ardakani MR, Abbaszadeh B, Sharifi Ashourabadi E, Lebaschi MH, Paknejad F. 2007. The effect of water deficit on quantitative and qualitative characters of balm (*Melissa officinalis* L.). Iranian Journal of Medicinal and Aromatic Plants, 23: 251-261. Available from:https://ijmapr.areeo.ac.ir/article_10865_8a70ab93385f3a34b908c1f1ae4dbf7a.pdf?lang=en

Baghalian K, Abdoshah Sh, Khalighi-Sigaroodi F, Paknejad F. 2011. Physiological and phytochemical response to drought stress of German chamomile (*Matricaria recutita* L.). Plant Physiology and Biochemistry, 49: 201-207. doi: 10.1016/j.plaphy.2010.11.010

Baher Nic Z, Rezaee MB, Ghorbanli M, Asgari F, Araghi MK. 2004. Research on the changes of metabolism in response to water stress in *Stureja hortensis* L. Iranian Journal of Medicinal and Aromatic Plants Research, 20: 263-275. Available from: https://ijmapr.areeo.ac.ir/article_115261_2cdc5b95df02cbc48f460256706894b6.pdf?lang=en

Baradaran R, Shokhmgar M., Mosavi Gh, Arazmjo E. 2013. Evaluating the effects of irrigation interval and nitrogen on yield and yield components of fenugreek (*Trigonella foenum-graecum* L.). Journal of Horticultural Science, 27: 295-300. doi: 10.22067/JHORTS4.V0I0.26386

Chenoweth J. 2008. Minimum water requirement for social and economic development. Desalination, 229: 245–256. doi: 10.1016/j.desal.2007.09.011

Donk SJV, Shaver TM, Petersen JL, Davison DR. 2012. Effects of crop residue removal on soil water content and yield of deficit-irrigated soybean. Transactions of the ASABE, 55: 149-157. doi: 10.13031/2013.41266

Faker Baher Z, Rezaii MB, Mirza M, Abaszadeh B. 2002. Research on quality and quantity of essential oil of *Satureja hortensis* L. under water stress in field. Iranian Journal of Medicinal and Aromatic Plants Research, 11: 37-51. Available from: https://ijmapr.areeo.ac.ir/article_118362_d86e480ba5a97e154f470f5ec4c26e5e.pdf?lang=en

Gamo M, Shinoda M, Maeda T. 2013. Classification of arid lands, including soil degradation and irrigated areas, based on vegetation and aridity indices. International Journal of Remote Sensing, 34:19, 6701-6722. doi: 10.1080/01431161.2013.805281

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM. 2008. Global change and the ecology of cities. Science, 319: 756-760

Hadian J, Tabatabaei SMF, Naghavi MR, Jamzad Z, Ramak-Masoumi R. 2008. Genetic diversity of Iranian accessions of *Satureja hortensis* L. based on horticultural traits and rapid markers. Scientia Horticulturae, 115: 196-202. doi: 10.1016/j.scienta.2007.08.007

Harper SM, Kerven GL, Edwards DG, Ostatek-Boczynski Z. 2000. Characterization of fulvic and humic acids from leaves of *Eucalyptus camaldulensis* and from decomposed hay. Soil Biology and Biochemistry, 32: 1331-1336. doi: 10.1016/S0038-0717(00)00021-3.

IMKO Company. 1998. “User’s manual, moisture measuring systems for soil science’’.

Jalilvand P, Esmailpour B, Hadian J, Rasoulzadeh A. 2011. The effect of drought stress and mycorrhiza fungi on growth and secondary metabolites of savory. The 7th Iranian Conference of Horticultural Sciences, Isfahan, Iran, 5 September 2011, Isfahan Industrial University.

Jamzad Z. 2009. Thymus and Satureja species of Iran. Research Institute of Forests and Rangelands, Tehran, Iran. ISBN 9789644733055.

Karlberg L, Rockstrom J, Annandale JG, Steyn JM. 2007. Low-cost drip irrigation-A suitable technology for southern Africa?: An example with tomatoes using saline irrigation water. Agricultural Water Management, 89: 59-70. doi: 10.1016/j.agwat.2006.12.011

Klocke N, Currie RS, Stone LR, Bolton DA. 2010. Planning for deficit irrigation. Applied Engineering in Agriculture, 26: 405-412. doi: 10.13031/2013.29955

Koocheki A, Nassiri Mahallati M, Azizi G. 2006. The effect of different irrigation intervals and plant densities on yield and yield components of two fennel (*Foenicolum vulgare)* landraces. Iranian Journal of Field Crops Research, 4: 131-141. Doi: 10.22067/GSC.V4I1.1323

Koocheki A, Sabet Teimouri M. 2011. Effect of irrigation intervals, type of fertilizers and harvesting time on essence content and yield of three medicinal plants: lavender (*Lavandula angustifolia*), rosemary (*Rosemarinus officinalis*) and) and hyssop (*Hyssopus officinalis*) in Mashhad conditions. Iranian Journal of Field Crops Research, 9: 78-87. doi: 10.22067/GSC.V9I1.10497

Lawal AB, Rahman SA. 2007. Effect of irrigation, fertiliser and manure on yield and economic return of okra/pepper intercrops. Tropical Science, 47: 45–48. doi: 10.1002/ts.194

Masoumi A. 2010. Effect of drought stress on morphophysiological parameters two mass native kochia (*Kochia Scoparia*) in greenhouse and field conditions. PhD Dissertation. Ferdowsi University of Mashhad, Mashhad, Iran.

Miranshahi B, Sayyari M. 2016. Methyl jasmonate mitigates drought stress injuries and affects essential oil of summer savory. Journal of Agriculture Science and Technology, 18: 1635-1645. Available from: https://jast.modares.ac.ir/article-23-6851-en.pdf

Mohamed MA-H, Abdu M. 2004. Growth and oil production of fennel (*Foeniculum vulgare* Mill): effect of irrigation and organic fertilization. Biological Agriculture and Horticulture, 22: 31-39. Doi: 10.1080/01448765.2004.9754986

Nadjafi F. 2006. Evaluation of ecological criteria of *Nepeta binaludensis* Jamzad for adaptation in low input agricultural systems. PhD Dissertation. Ferdowsi University of Mashhad, Mashhad, Iran.

Nezami A, Fazeli Kakhki SF, Zarghani H, Shabahang J, Gandomzadeh MR. 2014. Preliminary evaluation of yield and yield components of some Khorasanian sesame ecotypes (*Sesamum indicum* L.). Iranian Journal of Field Crops Research, 12: 189-195. doi: 10.22067/GSC.V12I2.39144

Nouri M, Asadi P, Dehghan Rahimabadi A, Golchin A. 2014. The Effect of drought stress and nitrogen fertilizer levels on growth and essential oil of savory (*Satureja hortensis* L.). Bulletin of Environment, Pharmacology and Life Sciences, 3 (10): 71-77. Available from: https://bepls.com/sep_2014/13A.pdf

Nooshkam A, Majnoun Hoseini N, Hadian J, Jahansooz MR, Khavazi K, Salehnia A, Hedayatpour S. 2016. The effect of irrigation intervals on quantitative and qualitative of two savory medicinal species (*Satureja khuzistanica* Jamzad and *S. rechingery* Jamzad) in West Lorestan region. Plant Productions, 39: 11-20. doi: 10.22055/ppd.2016.12039

Omidbaigi R. 2018. Production and processing of the medicinal plants (Vol. 1, 9th edition). Astan Qods Razavi Publications, Mashhad, Iran. ISBN 9789640208274.

Reddy TY, Reddy VR, Anbumozhi V. 2003. Physiological Responses of groundnut (*Arachis hypogea* L.) to drought stress and its amelioration: a critical review. Plant Growth Regulation: 41: 75-88. doi: 10.1023/A:1027353430164

Santos TPD, Lopes CM, Rodrigues ML, Souza CR, Maroco JP, Pereira JS, Siva JR., Chaves MM. 2003. Partial rootzone drying: effects on growth and fruit quality of field-grown grapevines (*Vitis vinifera* L.). Function Plant Biology, 30: 663-671. doi: 10.1071/FP02180

Shabala, S. 2012. Plant stress physiology. Wallingford, CABI. ISBN 9781845939953.

Sodaeizadeh H, Shamsaie M, Tajamoliyan M, Mirmahammadi Meybodi SAM, Hakimzadeh MA. 2016. The Effects of water stress on some morphological and physiological characteristics of *Satureja hortensis.* Journal of Plant Process and Function, 5: 1-11. Available from: https://jispp.iut.ac.ir/article-1-344-en.pdf

Stone LR, Schlegel AJ, Khan AH, Klocke NL, Aiken RM 2006. Water supply: yield relationships developed for study of water management. Journal Natural Resources and Life Sciences Education, 35: 161-173. doi: 10.2134/jnrlse2006.0161

Taiz L, Zeiger E. 2006. Plant Physiology (4th edition). Sunderland, Sinauer Associates, Inc. ISBN 0-87893-856-7.

Therios I. 2008. Olives. Osfordshire. CAB International Wallingford. ISBN 9781845934583.

Ucan K, Killi F, Gencoglan C, Merdun H. 2007. Effect of irrigation frequency and amount on water use efficiency and yield of sesame (*Sesamum indicum* L.) under field conditions. Field Crops Research, 101: 249-258. doi: 10.1016/j.fcr.2006.11.011