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**SURVEY THE EFFECTS OF DROUGHT STRESS ON GROWTH CHARACTERISTICS  
AND YIELD OF ARTICHOKE (*CYNARA SCOLYMUS* L.) IN DIFFERENT  
VEGETATIVE AND REPRODUCTIVE HARVESTS**

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**ABSTRACT**

Drought stress is one of the major constraints in crop production. Morphological and physiological understanding of drought resistance has a great importance in improving the problems caused by drought conditions. To survey the effects of drought stress on the medicinal plant artichoke (*Cynara scolymus* L.) a test had been done at the Center of Agricultural Research and Natural Resources of Isfahan province. The experiment was consisted of three treatments of 20, 50 and 80% of drought stress as the main plots and the numbers of harvests in both vegetative and reproductive stages were considered as the subplots. Some indicators such as the number of leaves, leaf fresh weight, leaf dry weight, flower fresh weight, flower dry weight, total dry weight, chlorophyll and carotenoids were measured. The indicators of leaf dry weight, leaf fresh weight, flower fresh weight and total dry weight during the reproductive stage and under the stress condition and also the number of harvests were significant and the results showed that at this stage with beginning of flowering, the plant performance indicators were decreased. In the vegetative stage, indicators of leaf fresh weight, leaf dry weight, the number of leaves were

significant at the level of 1% of the number of harvest treatments. The stress effect at this stage of growth was significant only on 1% of leaf numbers which indicates that artichoke plant during the vegetative state has a better resistance to the applied stress. Chlorophyll and Carotenoid contents were significant in terms of applied stresses. With increasing of stress, chlorophyll a decreased, chlorophyll b increased and also total chlorophyll decreased. Meanwhile, carotenoid content with increasing of stress from mild stress (50% of drought) to severe stress (80% of drought) was significantly reduced.

**Keywords: Carotenoid, performance indicators, physiological indicators, Artichoke.**

## INTRODUCTION

Drought is one of the main factors limiting plant growth around the world and is the most common environmental stress. It is well known that the effect of water stress on the plant growth depends on the plant genotype (Bannayan et al, 2008).

Water is a scarce resource in Iran that is influenced by the rainfall. Effect of water stress depends on time, durability and the amount of its deficit. Identification of critical time and timing based on a precise and basic plan for plants is a key to keep water and improve the irrigation practices and plant tolerance to water deficit in agriculture. Water deficit can cause a severe damage on vegetative stage and active ingredients of medicinal plants (Omidbeigi, 2000).

Plant of artichoke (*Cynara scolymus* L.) is a perennial plant of the family Astraceae with an average life of 4 years and a height of about 2 meters. Mediterranean countries are the main origin of this plant. Artichoke has

the highest yield in areas with mild winters and moist and cool summers. Dried leaves of artichoke contain about 9 to 11 percent of water and 12 to 15% of minerals and rich in Potassium and Magnesium salts. Many phenolic, flavonoids (0.1 to 1%) and acidic compounds are found in artichoke. In terms of biomass, this plant may have 3-4 tons of biomass in each harvest and the fresh weight around 70-90 tons per hectare (Sabahi, 2006., Hammouda et al, 1993). This plant is one the most important medicinal plants and is used in different countries as a lipid lowering drug and affects by preventing of oxidative LDL reduction that has been confirmed in several articles, also it is known as a liver supporter (Bonomi et al, 1999), (Meneses et al, 2007) and (Zhang and Zhu, 2004). Research conducted on artichoke plant by Boari et al (2012) showed that applying of drought stress in 80, 60 and 20% cause reduction in biomass and edible flowers at 60 and 80%.

Saleh et al (2007) also found that irrigation with improper and saline water and applying of 20, 50 and 80% stress caused decreasing in the yield of edible green flowers of the plant. Also, the lack of soil moisture especially during bud formation causes loss of buds (Schrader and Maybery, 1994). Today, regarding the understanding and awareness of its medicinal effect and due to the low amount of artichoke cultivation in Iran, it is necessary that this plant is considered as a medicinal and forage crops (due to high biomass production at the plant).

#### **MATERIALS AND METHODS:**

This trial was done at the research station of Research Center and Natural Resources of Isfahan province with longitude of 51° 26' and latitude of 32° and 33' and the height of 1612 meters above the sea, in 2013. According to Coupon classification, the test area has a dry and very hot climate with hot and dry summers. The average of rainfall is 125 mm and the soil class of this station is 2 and its texture is clay. The minimum temperature is -14 degrees and the maximum one is 35 degrees of centigrade.

Split-plot experiment in a randomized complete block design with three replications was conducted. Each experimental unit consisted of a 30×60 cm Crete with 9 cultivation lines. Stack distance from each

other was 60 cm, distance between plants on each line was 30 cm and plant cultivation in March of the last year (2011) had been done as seed on ridges. Fighting weed was as hand weeding and insecticides for pest control in two stages (Diazinon 2/1000) were used.

Treatments of drought stress were considered at 3 levels of irrigation after 20, 50 and 80 percent of water depletion from the depth of 0-30 and 30-60 cm of the soil as the major factor (80% severe stress, 50% moderate and 20% low stress) and the number of harvests at four levels as sub-plots to assess the performance under stress conditions. To control the soil moisture, soil samples were taken from the depth of 0-30 and 30-60 cm and transferred to the oven with 100°C. After determining the moisture content of the soil at arable farm capacity, moisture content of the soil in order to apply for the stress treatments has been recognized.

Harvest was done manually and to evaluate the performance of the four harvests in vegetative stage with an interval of 2 and two harvests at 80% flowering stage was performed within 3 months and the samples were dried in a dryer.

The measurement of plant pigments at vegetative stage with method of (Arnon, 1949) and using the formulas was performed.

$$chla (Mg/L) = (12/25 \times a663) - (2/79 \times a647)$$

$$chlb (Mg/L) = (21/5 \times a647) - (5/1 \times a663)$$

$$chla+b (Mg/L) = (7/15 \times a663) - (1871 \times a647)$$

In this equation Chl a, Chl b, Chla+b are the contents of Chlorophyll a and b and the sum of a+b in terms of milligrams per liter fresh weight respectively and a is absorbed by the extracts in corresponding wavelength.

#### Measuring of Carotenoid content:

To measure the carotenoid content, Lichtenthaler method (1987) was used. Leaf discs were prepared from fresh leaves of

plants in Chinese mortar containing 80% acetone and after filtration, its absorption was read with a spectrophotometer model 2001WPA-UV-visible and in wavelengths of 470, 663 and 647 nm.

$$\text{Carotenoids } (\mu\text{g/ml}) = (1000A_{470} - 3.27(\text{chl a}) - 104(\text{chl b})) / 227$$

## RESULTS AND DISCUSSION

### The weather conditions of the area

Weather conditions during the test period are presented in Table 1.

Table 1- Temperatures, minimum, maximum and average monthly (°C) during the growing season.

1391	Temperature °C				
Month	Max.Average	Min.Average	Daily Average	Absolute maximum	Absolute minimum
April	19.7	6.5	13.1	27	-5
May	26.5	12.3	19.4	30.6	8
June	32.3	17	24.6	36	12.6
July	36.1	20.1	28.1	41	13.6
August	35.3	19.4	27.3	38	17.2
September	32.9	16.9	24.9	35.4	14
October	27.2	12.2	19.7	32.6	7
November	19.7	7.2	13.5	24.6	2.6

### Growth characteristics during the vegetative stage

In consideration of performance indicators in vegetative stage and according to (Table 2), the impact of harvest numbers on leaf fresh weight was significant at the 1% level. The first harvest had the highest amount and the second one the lowest. But in general, the leaf fresh weight decrease by increased stress. According to Tait et al (1994) results, leaf dry weight was significant at the level of 1%. First and second harvests had the highest and lowest amounts respectively, and tests by

AsghariTaheri et al (2010) are consistent with these results. The effect of stress on fresh and dry weights was not significant. In conclusion, we can say the treatment of harvest numbers in maximum temperature had a sharp drop effect on yield components and with temperature recovery (Table 1) the larger amounts were allocated to yield components, but also it was decreasing trend related to the first harvest and this reduction was significant (Table 3) number of leaves in the vegetative stage in treatment of number of harvests and stress at the level of 1% was

significant, the number of leaves decreased with increasing number of harvests. The highest number of leaves in the first harvest and the lowest number of leaves were obtained in the second harvest. One reason for excessive reduced number of leaves is likely being simultaneously of this harvest stage with the maximum temperature in July (Table 1) and then in third and fourth harvests, these amounts increased and their difference with the treatment of low stress was significant (Table 3). Tait et al (1994)

studied the effects of different intensities of harvesting on re-growth of perennial grass species and concluded that re-growth of the species in high intensity of drought stress decreased a lot. Water stress decreases the elongation of leaves, leaf area index and the number of leaflets. One of the ways for plant in the stress conditions is to reduce the area and number of leaves. Arshi et al (2005) found in their research on Asteraceae, concluded that drought stress reduced the number of branches and leaves.

Table 2- Analysis of variance in the vegetative stage

Sources of Variations	Degree of Freedom	Mean Square		
		Leaf fresh weight	Leaf dry weight	Number of leaves
Block	2	80358642.00	2285042.11	151.91
Stress	2	364714378.00	4669483.49	745.43**
Error A	4	15988104.00	108404.02	138.28
Harvest	3	2923786088.00**	32751700.56**	8795.65**
Stress x Harvest	6	142448953.00	2488935.44	1087.71
Error B	18	66777254.00	983485.30	935.94

\*and\*\* indicate the likely significance at the levels of 5 and 1%, respectively.

Table 3- Mean comparison of simple effects in vegetative period

Treatment	Leaf fresh weight (kg/hectare)	Leaf dry weight (kg/hectare)	Number of leaves (leaf in bush)
Drought Stress			
20%	30807.00 <sup>a</sup>	4589.80 <sup>a</sup>	175.69 <sup>a</sup>
50%	26519.00 <sup>a</sup>	39.57.9 <sup>a</sup>	140.25 <sup>b</sup>
80%	19866.00 <sup>a</sup>	3342.30 <sup>a</sup>	129.35 <sup>b</sup>
Harvest			
1	49841.00 <sup>a</sup>	6264.80 <sup>a</sup>	184.28 <sup>a</sup>
2	7252.00 <sup>d</sup>	2043.00 <sup>c</sup>	108.23 <sup>c</sup>
3	18673.00 <sup>c</sup>	2808.40 <sup>c</sup>	147.35 <sup>b</sup>
4	27158.00 <sup>b</sup>	4737.20 <sup>b</sup>	153.76 <sup>b</sup>

Numbers in each column which are common in a letter, have no significant difference based on (LSD) test on the probability of 5%.

### Growth characteristics in reproductive stage

In consideration of some performance indicators in reproductive stage, the effect of numbers of harvests on leaf fresh weight was

not significant (Table 4). We had more leaf fresh weight in the first harvest in comparison to the second and third ones (Table 5). On the other hand, the stress effect on leaf fresh weight was significant on the

level of 1%, and treatment with low stress had the maximum leaf fresh weight. The effect of harvest treatment on stem fresh weight was significant on the level of 5%, higher level was allocated to the first harvest, and the effect of stress on stem fresh weight was significant on level of 1%. The effect of number of harvests on flower fresh weight was significant on level of 5% and we had more flower fresh weight at the second harvest, and the effect of stress on flower fresh weight was significant on the level of 1% (Table 4). In this stage of growth, we lost more leaves for entering to the reproductive stage because of delay in harvesting as probably the cultured sap has been led to the flowering (Saleh, 2007). The stress effect on total dry weight was significant at 1% level (Table 4), low stress treatment had the maximum amount and a significant difference with two other treatments, the difference between 50% and 80% treatments was not significant (Table 5). Also, the stress effect on leaves numbers in this phase was

significant on the level of 1% (Table 4). The maximum and minimum amounts were related to the low stress treatment and the 80%-drought stress, respectively. In the reproductive stage, the effect of harvest numbers on leaf number was significant on the level of 5%. The most leaf numbers were seen at the first harvest and according to the results of Tait et al (1994), number of harvests caused the reduction of vegetative growth. This results suggest the effects of stress and number of harvests on the number of leaves (Arshi et al, 2005). It is likely that plant leads the available nutrients to flowering during the entering to the reproductive stage and due to the increased flowering in the second harvest, this is likely to increase and plant will decrease its other yield components facing with other moderate and severe stresses and it shows that enough irrigation up to 20% of drought is really necessary in this phase (Boary et al, 2012) Saleh (2007) and Saleh et al (2003) on artichoke.

Table 4- Analysis of variance in reproductive phase

Sources of Variation	Degree of freedom	Mean square					
		Leaf fresh weight	Leaf dry weight	Leaf No./bush	Stem fresh weight	Flower fresh weight	Total dry weight
Block	2	5808356.90	16563.33**	756.13	730403.02	772297.08**	318308.19**
Stress	2	35415640.00**	6756311.00	11264.45*	5019057.77**	31422930.43**	24630327.45**
Error A	4	982373.90	1446159.20	1242.24	26922.20	992723.02	453770.58
Harvest	1	78932632.10	1514743.74**	32834.40**	1722917.11*	11191219.92*	5987966.59
Stressx Harvest	2	74979094.02	1102413.66	3376.38	793222.68	497403.51	1197892.08
Error B	6	16440307.00	627810.80	709.07	270372.01	872397.79	14478.90

\*and\*\* indicate significance in probability levels of 1 and 5%.

Table 5- Mean comparison of simple effects in reproductive period

Treatment	Leaf fresh weight (kg/hectare)	Leaf dry weight (kg/hectare)	leaf number (kg/hectare)	Stem fresh weight (kg/hectare)	Flower fresh weight (kg/hectare)	Total dry weight (kg/hectare)
<b>Drought stress</b>						
20%	18310.90 <sup>a</sup>	3673.20 <sup>a</sup>	200.65 <sup>a</sup>	2279.90 <sup>a</sup>	5411.50 <sup>a</sup>	6008.70 <sup>a</sup>
50%	6241.50 <sup>b</sup>	2194.20 <sup>b</sup>	151.35 <sup>ab</sup>	835.60 <sup>b</sup>	1803.10 <sup>b</sup>	3133.90 <sup>b</sup>
80%	4039.40 <sup>ac</sup>	1615.60 <sup>b</sup>	114.28 <sup>b</sup>	585.60 <sup>b</sup>	1168.90 <sup>b</sup>	2098.00 <sup>b</sup>
<b>Harvest</b>						
1	11625.00 <sup>a</sup>	3411.70 <sup>a</sup>	198.14 <sup>a</sup>	1543.10 <sup>b</sup>	3583.00 <sup>a</sup>	4323.69 <sup>a</sup>
2	7437.00 <sup>a</sup>	1577.00 <sup>b</sup>	112.72 <sup>b</sup>	924.00 <sup>a</sup>	2006.00 <sup>b</sup>	3170.10 <sup>b</sup>

Numbers of each column are common in one letter and have no significant difference based on LSD Test on probability levels of 1 and 5%.

### Chlorophyll content

The stress effect on chlorophyll a, chlorophyll b and total chlorophyll was significant at levels of 5 and 1%, respectively (Table 6). The maximum and minimum amounts were related to low stress and 80% of drought stress treatments for chlorophyll a, 50% and 80% of drought stress treatments for chlorophyll b and 20% and 80% of drought stress treatments for total chlorophyll, respectively (Table 7). These results are according to the results of several tests by Yueda et al (2003) and Antolin et al (1995). They found that chlorophyll content will decrease while stress increases. It is concluded that chlorophyll content of the leaf is decreased with the increased stress.

### Carotenoid content

The stress effect was significant on carotenoid content at the level of 5% (Table 6).

The maximum and minimum carotenoid contents were in 20% and 80% drought stress treatments, respectively (Table 7). Jeyramaja et al (2007) found that mild water deficit causes carotenoid content increasing while severe water deficit causes carotenoids to be decreased in addition to the chlorophylls. Munne-Bosch & Penuela (2004) found that under severe stress, chlorophyll and carotenoid contents decrease 63% and 75%, respectively. They believe that the sharp decline of carotene can be related to the produced singlet Oxygen in Tylacoids. It is concluded that increased stress will be followed by decreasing trend of carotenoid contents.

Table 6- Analysis of variance of chlorophyll, anthocyanin and carotenoid

Sources of Variations	Degree of freedom	Mean square			
		Chlorophyll a	Chlorophyll b	Total chlorophyll	Carotenoid
Block	2	1.07	0.344	2.364	0.147
Stress	2	35.09*	19.44**	53.64**	2.039*
Error	4	1.81	0.012	0.493	0.124

\*and\*\* indicate the significance in probability levels of 1 and 5%.

Table 7- Mean comparison of simple effects of chlorophyll, anthocyanin and carotenoid contents

Treatment	Chlorophyll a(mg/l)	Chlorophyll b(mg/l)	Total chlorophyll(mg/l)	Carotenoid(mg/l)
<b>Drought stress</b>				
20%	179.80 <sup>a</sup>	192.95 <sup>b</sup>	375.26 <sup>a</sup>	215.97 <sup>a</sup>
50%	175.49 <sup>b</sup>	196.78 <sup>a</sup>	372.36 <sup>b</sup>	215.76 <sup>b</sup>
80%	174.32 <sup>b</sup>	191.96 <sup>c</sup>	366.90 <sup>c</sup>	214.45 <sup>c</sup>

Numbers of each column are common in one letter and have no significant difference based on LSD Test on probability levels of 1 and 5%.

## CONCLUSION

From the test results, it seems that although artichoke plant needs to be irrigated desirably, but it has the ability to keep its function to the upper limit of 50% in drought stress. It seems that harvesting in the vegetative phase is better than harvesting in reproductive phase because of more leaves, fresh and dry weights and better performance at the end. In regards to harvestings and how doing it, it is thought that for better performance, we need to coordinate the harvest intervals to give the plant its required time for restoration of its green, flowering do not occur or delay.

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