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Effect of Drought and Habitat Condition on some Physiological and Biochemical Constituents of *Ficus carica L.* Fruits

Amal M. Abdel –Rahman
Department of botany, Faculty of Science, Alexandria University, Alexandria, Egypt

ABSTRACT

The current study aimed to explore the variation in some physiological and biochemical constituents in *Ficus carica* L. fruits under the influence of two irrigation systems (irrigated and rainfed) and habitat conditions (non saline depression and sand dunes). Samples of syconium were collected from four orchards at Burg El-Arab and Omayed North West of Alexandria. The soil moisture and texture was widely differed from one locality to another. Carbohydrates, proteins, amino acids and proline attained their higher concentration in rainfed orchards under the conditions of the two habitats. On the other hand, the photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) and fruit dry weight (economic yield) attained the highest values in irrigated orchards under the two different habitats (sand dunes > non-saline). Leaf area attained slightly higher values in irrigated orchards which may reflect the highest economic yield of these trees. Concerning the nutrient content, generally, Ca exhibited the highest concentration in syconium in most studied orchards followed by Na and K while Fe showed the lowest concentration. This possibly will reflect the ability of fig trees to accumulate Ca in their tissues and this is one of the adaptative responses to the habitats with high concentration of $CaCO_3$ (sand dunes).

Key words: *Ficus carica L.* - syconium - drought – habitat – economic yield – metabolic constituents.

INTRODUCTION

Drought is the most important limiting factor for crop production in many regions of the world (Passioura, 2007). The percentage of drought affected land areas is more than doubled from 1970 to the early 2000 in the world (Isendahl and Schmidt, 2006). With increasing population and global climatic changes the situation will become more serious (Hongbo *et al*., 2005).

Fig tree (*Ficus carica* L.) is one of the most important drought resistant crop that grows in the coastal Mediterranean desert of Egypt (Keleg *et al*., 1981). The area cultivated by fig in this region was estimated at about 5900 ha with a mean expansion rate of 220 ha/year (Abdel-Razik *et al*., 1987).

The optimum rain fall to achieve maximum productivity is 500-700 mm annually. It can survive and produce reasonably well with 300-400mm, but below this the productivity is surely affected (Rebour, 1968). To improve crop productivity, it is necessary to understand the mechanism of plant responses to drought conditions in the vast areas of the world where rain fall is limiting or unreliable (Mostajeran and Rahimi-Eichi, 2009). One mechanism utilized by the plants for overcoming the water stress effects might be via accumulation of compatible osmolytes, such as proline (Vendruscolo *et al*., 2007 and Cattivelli *et al*., 2008), soluble sugars (Izanloo *et al*., 2008).

The main objective of this study was to emphasize the effect of two irrigation systems (irrigated and rainfed) and two different habitats (non saline depression and sand dunes) on some physiological and biochemical parameters of *Ficus carica* syconium in the Western Desert of Egypt, in order to validate the subsequent effect of drought and habitat conditions on quantity and quality of syconium.

MATERIALS AND METHODS

Two different habitats (non-saline depression and sand dune) were selected at Burg El-Arab and Omayed (50 and 80 km west of Alexandria respectively) to carry out the present study. At each habitat two fig (*Ficus carica* cv. sultani) orchards, one irrigated and the other rainfed were selected. Fruit (syconium) samples were collected at maturity stage during summer 2008 from random trees more or less at the same age to undergo measurements and analysis. All samples were prepared and analyzed for the determination of total available carbohydrates (TAC) and total soluble sugars (TSS) (Naguib, 1964; Murata *et al*., 1968); total proteins (TP) and soluble protein (SP) (Lowery *et al*., 1951; Hartree, 1972), total free amino acids (Ya and TuneKazu, 1966), proline (Bates *et al*., 1973), and some nutrient elements (Allen *et al*., 1974). Fruit biomass was determined after drying at 75ºC for constant weight. Samples of leaves were collected for determination of pigment content according to Metzner *et al*., (1965), and the average leaf area was measured using a digital planimeter with sensitivity of 0.1cm ^{2}.

Soil samples were collected underneath the trees in each orchard for estimation of some physical and chemical characteristics. Particle size distribution was carried out by the dry sieving method of Kilmer and Alexander (1949). Soil reaction was determined in the soil paste (1:5) using a Beckman bench type pH meter, Electric conductivity (EC) in the soil saturation extract was determined conductimetrically (Richards, 1954). Cations and anions of the soil extract were accomplished according to the methods described by Jackson (1962).

* Corresponding Author: *elmasry_amal@yahoo.com*, Present Address: Faculty of Education for Girls - Umm-Al-Qura University, Makkah, KSA

Treatment of data

The student t-test applied to assess the significance of variations in different variables of syconium under water stress and habitat conditions according to Snedecor and Cochran, 1980.

RESULTS

Data illustrated in Table 1 show that the dominant soil texture in non-saline depression is loamy sand, while in sand dunes distinguished by sandy soil. Additionally, soil moisture content was remarkably higher in the irrigated than in the rainfed orchards in the two different habitats.

Table (1): Variations in soil texture and moisture (%) in irrigated and rainfed orchards under the two different habitat conditions.

	Habitat			
	I-Non-saline		II- Sand dunes	
	Irrigated fields	Rainfed fields	Irrigated fields	Rainfed fields
Texture	Loam sand	Loam sand	Sandy	Sandy
Soil moisture (%)	0.79	0.48	1.69	1.09

The chemical analysis of soil samples in irrigated and rainfed orchards under the two different habitats is presented in Table 2. Values of pH were mildly alkaline in all studied orchards and moderately decreased in rainfed ones in non-saline depression (7.8). EC was lower in the rainfed than in the irrigated orchards in the two different habitats. The highest value (4.45 dS/m) was attained in the soil of the irrigated orchards in non saline depression while the lowest one (0.75 dS/m) was recorded in the rainfed orchards in the same habitat. Na^+ was dominated the chemical composition where it represents the highest cation content followed by Mg^+ and Ca^{++}, while K^+ was the lowest. On the other hand, Cl^- was the highest anion content followed by HCO_3^- and SO_4^{-2}.

Expectedly, water content (% d wt) and fruit phytomass (economic yield) Kg d wt /tree was higher in irrigated orchards than in those of rainfed in the two different habitats (Table 3). The maximum water content (% d wt) in the irrigated and rainfed orchards were attained in sand dunes (634.75 and 481.01, respectively). Furthermore, the maximum fruit phytomass (economic yield) in both irrigated and rainfed orchards were attained in sand dunes (9.52 and 6.89 Kg d wt /tree, respectively).

The variations in pigment content (chl a, chl b, and carotenoids) and leaf area of *Ficus carica* are illustrated in Table 4a. The pigment content (chlorophyll a, b, and carotenoids) in leaves of fig plants were slightly higher in irrigated orchards than in those of rainfed ones in the two different habitats. In sand dunes, the content in both irrigated and rainfed orchards were slightly higher than those recorded in non saline depression. The highest content of chl a, chl b, and carotenoids, (1.57, 0.58, 0.39 mg/g f wt respectively) was recorded in irrigated orchards in sand dunes, while the lowest content (0.88, 0.34, 0.22 mg/g f wt respectively) was recorded in rainfed orchards in non saline depression. Statistical analysis (Table 4.b) showed that the differences in chl a and carotenoids between irrigated orchards in the two different habitats are significant at $p \leq 0.05$, whereas that between irrigated and rainfed ones in non saline depression and sand dunes is non-significant. The variation in leaf area between irrigated and rainfed orchards from one side and the different habitats from the other side in the two different habitats were non-significant (Table 4.b.) The area attained slightly higher values in the irrigated orchards than those obtained in rainfed ones in the two different habitats.

Table (2): Chemical analysis of the soil samples in irrigated and rainfed orchards under the two different habitat conditions.

		Habitat			
		I-Non-saline		II- Sand dunes	
		Irrigated orchards	Rainfed orchards	Irrigated orchards	Rainfed orchards
	pH	8.1	7.8	8.0	8.0
	EC (dS/m)	4.45	0.75	1.33	0.9
Cation (meq/L)	Na^+	34.3	3.3	8.3	5.4
	K^+	2.0	1.1	1.0	1.0
	Ca^{++}	3.6	1.0	1.6	2.0
	Mg^{++}	4.9	2.2	2.6	1.6
Anion (meq/L)	Cl^-	38.5	5.5	10.1	6.2
	HCO_3^-	6.0	2.0	3.0	2.5
	CO_3^{-2}	tr.	–	tr.	tr.
	SO_4^{-2}	0.3	0.1	0.4	0.3

Table (3): Variations in water content (% d wt) and phytomass (Kg d wt/tree) of syconium at maturity stage in irrigated and rainfed orchards under the two different habitat conditions.

Variable	Habitat			
	I- Non-saline		II- Sand dunes	
	Irrigated orchards	Rainfed orchards	Irrigated orchards	Rainfed orchards
Water content (% d wt)	581.7	375.81	634.75	481.01
	Phytomass			
On dry wt. basis (Kg d wt /tree)	7.33±1.4	4.20±1.0	9.52±2.4	6.89±1.7
On fresh wt. basis (kg f wt /tree)	50±10	20±5	70±10	40±10

The variations in different metabolites (carbohydrate, proteins, total free amino acids and proline) between irrigated and rainfed orchards in the two different habitats are highly significant as evaluated by t test except for SP between rainfed orchards (Figure 1 and Table 4.b). The concentration of TAC, TSS was higher in rainfed orchards compared to irrigate ones in the two different habitats except for TAC in non saline depression which exerted slightly higher value in irrigated orchards. The maximum concentration of TSS (289.3 mg/g d wt) was attained in rainfed orchards in non saline depression, while the maximum of TAC

(354.6 mg/g d wt) was attained in rainfed ones in sand dunes. The minimum concentration of TSS (185.3mg/g d wt) was attained in irrigated orchards in non-saline depression, while the minimum concentration of TAC (302.9 mg/g d wt) was attained in the rainfed orchards in the same habitat. The concentration of proteins (TP, SP) was higher in rainfed orchards than in those of irrigated ones in the two different habitats. The maximum concentration of TP and SP (228.9 and 167.4 respectively) were attained in rainfed orchards in non saline depression, while the minimum concentrations were attained in irrigated orchards in sand dunes (157.8 and 121.6 respectively). The concentration of amino acids and proline were higher in rainfed orchards than those recorded in irrigated orchards in the two different habitats. In non saline depression, the concentrations of amino acids and proline in irrigated and rainfed orchards were much more than those obtained in sand dunes. The maximum concentrations of amino acid and proline (41.12 and 11.32 respectively) were attained in rainfed orchards in non saline depression while the minimum concentrations of the same two metabolites (20.14 and 3.94 respectively) were attained in irrigated orchards in sand dunes.

The variations in the element concentrations between irrigated and rainfed orchards in the two different habitats are highly significant (Figure 2 & Table 4.b). The differences between habitats are also significant at $p \leq 0.05$ except for Fe. In general, Ca attained the highest concentration in syconium in studied orchards in the two different habitats followed by Na and K. Ferrous showed the lowest concentration. The maximum concentration of Fe, Mg and Na (0.572, 1.663 and 10.195 mg/g d wt respectively) was attained in sand dunes.

DISCUSSION

Drought is one of the major types of water stress that dramatically limit plant growth and productivity (Skriver and Mundy, 1990). The present study evaluated the effect of drought stress on quantity and quality of *Ficus carica* syconium as a potential crop in the north western desert of Egypt.

From the present result, it is noticed that, the water content was higher in fig fruits in the irrigated orchards than those recorded in the rainfed ones in the two different habitats.

Table (4a): Variations in the mean concentration ± SE of pigment contents and leaf area of *Ficus carica* in the irrigated and rainfed orchards under the two different habitat conditions.

	Habitat			
	I-Non-saline		II- Sand dunes	
	Irrigated orchards	Rainfed orchards	Irrigated orchards	Rainfed orchards
Chlorophyll a (mg/g f wt)	0.97 ± 0.02	0.88 ± 0.07	1.57 ± 0.20	1.13 ± 0.10
Chlorophyll b (mg/g f wt)	0.39 ± 0.01	0.34 ± 0.04	0.58 ± 0.08	0.45 ± 0.05
Catranides (mg/g f wt)	0.26 ± 0.02	0.22 ± 0.04	0.39 ± 0.04	0.34 ± 0.04
Leaf area (cm²)	251.67 ± 20.00	202.51 ± 12.41	252.120±12.23	224.74±10.08

Table (4b): Results of t-test

	p_{1a}	p_{1b}	p_{2a}	p_{2b}
TAC (mg/g d wt)	<0.001*	0.007*	0.033*	<0.001*
TSS (mg/g d wt)	<0.001*	<0.001*	<0.001*	0.002*
TP (mg/g d wt)	0.032*	0.014*	<0.001*	0.001*
SP (mg/g d wt)	0.008*	<0.001*	0.001*	0.327
Amino acids (mg/g f wt)	<0.001*	<0.001*	<0.001*	<0.001*
Proline (mg/g f wt)	<0.001*	<0.001*	<0.001*	<0.001*
Chl a (mg/g f wt)	0.293	0.121	0.043*	0.113
Chl b (mg/g f wt)	0.241	0.217	0.080	0.152
Cart. (mg/g f wt)	0.427	0.369	0.029*	0.102
Leaf area (cm²)	0.051	0.101	0.985	0.181
Fe (mg/g d wt)	<0.001*	<0.001*	0.746	<0.001*
Mg (mg/g d wt)	<0.001*	<0.001*	<0.001*	<0.001*
Na (mg/g d wt)	<0.001*	<0.001*	<0.001*	<0.001*
Ca (mg/g d wt)	<0.001*	<0.001*	<0.001*	<0.001*
K (mg/g d wt)	<0.001*	<0.001*	<0.001*	<0.001*

* : Significant at $p \leq 0.05$

p_{1a} : p value for student t-test between irrigated fields and rainfed fields in non saline depression

p_{1b} : p value for student t-test between irrigated fields and rainfed fields in sand dunes

p_{2a} : p value for student t-test between irrigated fields in non saline depression and irrigated fields in sand dunes

p_{2b} : p value for student t-test between rainfed fields in non saline depression and rainfed fields in sand dunes

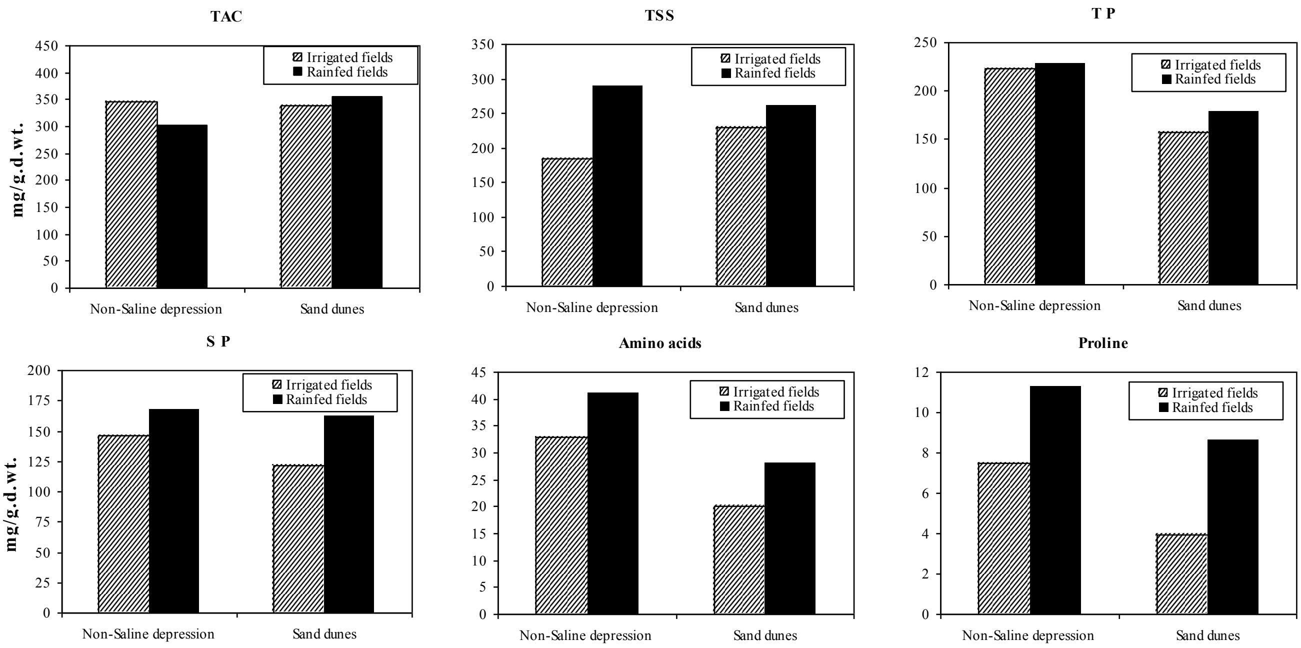

Figure (1): Variations in the mean concentration of some metabolites in syconium of Ficus carica in irrigated and rainfed orchards in two different habitats (non saline depression and sand dunes).

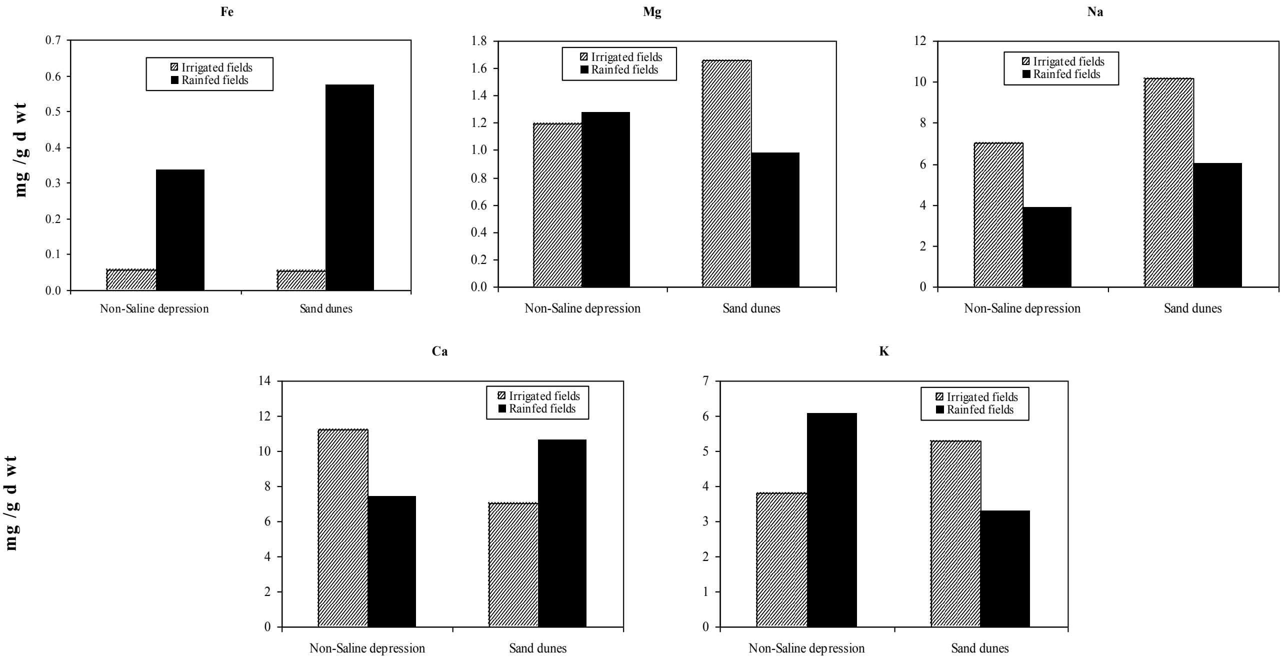

Figure (2): Variations in the mean concentration of some nutrient elements in syconium of Ficus carica in the irrigated and rainfed orchards in two different habitats (non saline depression and sand dunes).

(Rascio *et al*., 1992) found that, at low moisture content, water stress decreased the water content of the plant, and attributed this to the absence of components that bind water followed by a reduction in turgid weight to dry weight ratio, or to their physical alteration.(Morgan, 1977). demonstrated that when leaf water potential in wheat plant were reduced by soil or atmospheric water deficits, the water content was also reduced and may be partially conserved by solute accumulation or osmoregulation. Osmotic stress has an adverse effect on the growth rate of plants and consequently their final yield (Bejaoui, 1985). The standing crop phytomass in desert ecosystems varies much from one habitat to the other (El-Darier, 1988). In the present study, the mean economic yield in the irrigated orchards (7.33, 9.52 kg d wt / tree) were higher than those noticed in the rainfed ones (4.2, 6.89 kg d wt /tree) in non saline depressions and sand dunes respectively. These results coincided with those of many investigations on different plant species (Virgona and Barlow, 1991). The reduction in yield under drought could be attributed to the reduction in photosynthesis and or to the reduction in the storage capacity of the syconium and cell size.

Plants in desert ecosystems exhibit various adaptations and develop strategies that enable them to withstand or evade arid environmental conditions. Crop plants in these ecosystems may acquire physiological adaptations and exhibit morphological and anatomical features similar to those of the indigenous species. The variation in leaf area is one of the most important morphological features that change with time and habitat (El-Darier, 1988). Leaves are the plant organ which shows the first signs of water stress. Leaf expansion is known to be very sensitive to water stress. The present study demonstrated that water shortage affected the area of leaves. Slightly higher values were attained by fig individuals in the irrigated orchards than by those in the rainfed ones at maturity phase in the two selected habitats. The results are in concurrence with those affirmed by (El-Haak, 1990). and (Nautiyal *et al*., 1994). The growth reduction arise with stress could be attributed to the reduction in cell division and/or in cell enlargement (Terry *et al*., 1971). Furthermore water stress may cause growth reduction either by restricting wall loosening or by reducing solute import into the embryo (Spyropoulos, 1986).

The consequences obtained in the present study demonstrated that, the content of photosynthetic pigments (Chlorophyll a, b and Carotenoids) in fig leaves were slightly higher in fig plants of the irrigated orchards than those of the rainfed ones. These results agreed with those achieved by (Dwivedi *et al.,* 1979) and (Abdel-Rahman, 1996). It was also noted that there was an increase in the content of photosynthetic pigments in sand dunes than in non saline depression (Walters, 2005). This reduction in chlorophyll by water stress could be attributed to the strong impairment of its precursor protochlorophyll (Virgin, 1965). (Murray and Thomas, 1974). suggested that either the conversion of chl a from chl b is influenced little by the osmotically imposed stress and the reduction in carotenoid accumulation in leaves of plants under stress compared to well-watered. (Johnson *et al*., 1993) stated that, the precursors for carotenoid synthesis became increasingly limited in stressed leaf tissues. Production and accumulation of free amino acids, especially proline by plant tissue during drought, salt and water stress is an adaptive response. In the present study, amino acids increased in rainfed orchards than in those irrigated orchards in both non saline depression and sand dunes. Similar results were recorded by (Raggi, 1994). who concluded that with increasing water stress, there was a progressive increase in the free amino acid pool. This increase in amino acids concentration may provide some protection against dehydration injury. (Nikolopoulos and Manetas, 1991). reported that amino acids could play a role as osmotic regulators and as protective agents for cytoplasmic enzymes. Proline has been proposed to act as a compatible solute that adjusts the osmotic potential in the cytoplasm. Thus, proline can be used as a metabolic marker in relation to stress (Caballero *et al*., 2005).

In the present study, the concentration of proline was higher in the syconium in rainfed orchards than in those of the irrigated ones. These results are in agreement with those of many investigations on different plant species (Mostajeran and Rahimi-Eichi, 2009). The role of proline in adaptation and survival of plants has been observed by (Watanabe *et al*., 2000). and (Saruhan *et al*., 2006). Osmotic adjustment through the accumulation of cellular solutes, such as proline, has been suggested as one of the possible means for overcoming osmotic stress caused by loss of water (Caballero *et al*., 2005). Proline acting as an osmo-protectant, also serves as a sink for energy to regulate redox potentials, as a hydroxyl radical scavenger (Sharma and Dietz, 2006) as a solute that protects macromolecules against denaturation and as a mean of reducing acidity in the cell (Kishor *et al*., 2005). Proline accumulation was regarded by (Serrano and Gaxiola, 1994). to play a role as nitrogen reserve, to protect protoplasm from dryness and to play an important role in osmoregulation imbalance as a buffer against osmotic imbalance caused by salinity and drought stresses.

Carbohydrates have been connected with various roles in the metabolic and physiological responses of plants to water stress. In the present study, syconium attained higher concentration of total soluble sugar (TSS) in plants of the rainfed orchards than in those of the irrigated ones in the two different habitats (non-saline depression and sand dunes). These results are in agreement with those attained by (Mostajeran and Rahimi-Eichi, 2009) who found that the concentration of soluble sugars increased under drought stress in three rice cultivars. The accumulation of sugars in response to drought stress is also quite well documented (Izanloo *et al*., 2008 and Watanabe *et al*., 2000). A complex essential role of soluble sugars in plant metabolism is well known as products of hydrolytic processes, substrates in biosynthesis processes, energy production but also in a sugar sensing and signaling systems. (Raggi, 1994). considered soluble carbohydrates as osmoregulators. The increase in the concentration of TSS in syconium of the plants of the rainfed orchards in the present study must have produced a significant change in the osmotic pressure. This accumulation could be the result of a greater degree of conversion of starch into soluble sugars (Turner *et al*., 1978). and/or to low sugar utilization.

The study of production and accumulation of total available carbohydrates (TAC) in plants are often utilized for gaining insight into the mechanisms of maintenance of plant vigor and forage yield. In the present study, in sand dunes the concentration of TAC was higher in syconium in rainfed orchards than those estimated in the irrigated ones; this may be attributed to increase in the level of carbohydrate assimilation with drought, apparently by delaying the transfer of sugars into the conducting vessels (Wardlaw, 1967). On the other hand, in non-saline depression TAC concentration was higher in syconium in irrigated orchards than those recorded in the rainfed ones.

In the present study, high concentrations of soluble protein (SP) and total protein (TP) in syconium of *Ficus carica* in the rainfed orchards in the two different studied habitats. These results are in agreement with those of (Migahid, 1989) who recorded a notable increase in soluble protein with drought in some desert species, and also with (Wu *et al*., 1997) who reported that, proteins induced by water stress. Additionally, (Orcutt and Nilson, 2000) found that, plants produce a number of unique proteins as a part of their response to environmental stresses. The results of the present study may be due to adjust or adaptation of plant to stress conditions, whereas the rate of protein synthesis increased while hydrolysis decreased with stress (Cook *et al*., 1979).

Plants require a large number of inorganic elements derived from minerals or mineralized by decay of organic matter. The minerals are taken up in the form of ions and are incorporated into the plant mass or stared in the cell sap. Mineral nutrients in arid and semiarid zones are the major limiting factor to plant productively (El-Darier, 1988). K, for example is involved in the electron transport system on the thylacoids, and Mg are components of chlorophyll, various enzymes include Fe (Walker, 1962). Some desert vegetation can accumulate significant quantities of K and Ca in the above-ground organs (El-Darier, 1988). In the present study, Ca attains the highest concentration in most studied sites compared to other elements followed by Na and K. These results coincide also with those obtained by (Keleg *et al*., 1981). on almond and sultani fig trees. These plants can maintain themselves on calcareous soils, and this high concentration of Ca may reflect the ability of fig trees to accumulate Ca in their tissues and their adaptation to the habitats with high concentrations of $CaCO_3$ (sand dunes) in irrigated and rainfed orchards.

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تأثير الجفاف وظروف الموطن البيئى على بعض المكونات الفسيولوجية والكيميائية الحيوية فى ثمار نبات التين

آمال محمد محمد عبدالرحمن
قسم النبات – كلية العلوم – جامعة الأسكندرية – الأسكندرية – مصر

يعتبر التين من الزراعات الهامة بمنطقة الساحل الشمالى الغربى لمصر وينمو تحت الظروف المروية والمطرية وفى ظل الزيادة السكانية الحالية يصبح من الضرورى التوسع فى زراعة هذا المحصول فى البيئات المختلفة وتحت ظروف الرى المختلفة.

وتهدف الدراسة الحالية إلى تقييم بعض العمليات الفسيولوجية والبيوكيميائية فى ثمار التين (صنف السلطانى) والتى تستجيب لعامل الجفاف من ناحية وظروف الموطن البيئى من ناحية أخرى للحصول على أفضل نوعية وكمية للثمار.

وقد أوضحت الدراسة أن أعلى إنتاجية لثمار التين كانت فى البساتين المروية إذا قورنت بالبساتين المطرية فى موطنى الكثبان الرملية والمنخفض غير الملحى. وقد وجد أن محتوى الثمار من الكربوهيدات الكلية المتاحة والذائبة والبروتينات الكلية والذائبة والأحماض الأمينية والبرولين كان أعلى فى البساتين المطرية عنها فى البساتين المروية وهذا يضفى صفات تكيفية لهذا النبات للحصول على أفضل نوعية من الثمار فى هذه الحقول.

وقد ارتبط زيادة الإنتاج فى الثمار بزيادة مساحة الأوراق ولوحظ ذلك فى البساتين المروية. وبدراسة العناصر الهامة فى ثمار التين تبين أن أكثر العناصر تركيزاً هو عنصر الكالسيوم يليه البوتاسيوم والصوديوم وهذا أيضاً صفات تكيفية للثمار التى تنتج فى المواطن التى تحتوى على نسبة عالية من كربونات الكالسيوم.

وقد أظهرت الدراسة أيضاً أن الإنتاج فى موطن الكثبان الرملية كان أفضل من الإنتاج فى موطن المنخفضات غير المحلية من حيث الجودة وكذلك كمية الثمار. وقد خلصت الدراسة إلى أن زراعة أشجار التين فى موطن الكثبان الرملية سواء فى حقول مروية أو مطرية كانت أفضل من غيرها.