Pak. J. Bot., 53(2): 517-523, 2021. DOI: http://dx.doi.org/10.30848/PJB2021-2(5)

ECOPHYSIOLOGICAL RESPONSES OF THE GENUS *SARCOCORNIA* A. J. SCOTT GROWING AT THE MEDITERRANEAN SEA COAST, EGYPT.

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Abstract

Two *Sarcocornia* species, *Sarcocornia fruticosa* and *Sarcocornia perennis* growing at the Mediterranean Coast of Egypt were collected from two salt marshes locations; Port Said and Borg Elarab to study the effect of seasonal variations on secondary metabolites. Total phenols, total flavonoids, organic compounds, fatty acids and antioxidant activity were determined during dry (July, 2017) and wet (March, 2018) seasons. The results revealed that total phenols, total flavonoids, organic compounds and antioxidant activity were increased while fatty acids were decreased in dry season in the two species. *S. fruticosa* was higher in total phenols, total flavonoids and antioxidant activity than *S. perennis* specially those growing at Port Said.

Key words: *Sarcocornia*, Phenolic compounds, Antioxidant, Medterranan sea coast.

Introduction

The genus *Sarcocornia* is incorporated in Amaranthaceae family (formerly Chenopodiaceae). It was arisen by Scott (1977), who separated from *Salicornia* L. and *Arthrocnemum* Moq. According to morphological characters, 28 species are belonging in genus *Sarcocornia* of succulent halophytes distributed worldwide, in saline, warm-temperate and sub-temperate environments (Steffen *et al*., 2015).

In Egypt, only two species; *S. fruticosa* and *S. perennis*are distributed in coastal salt marshes of the Mediterranean Sea (Boulos, 1999). *Salicornia* and *Sarcocornia* are closest to each other and can be distinguished by life form which is always perennials in *Sarcocornia* and annuals in *Salicornia* (Kadereit *et al*., 2007). *Salicornia* species as many halophytes have great important as phytoremidation of saline soil and oil seed production (Oliveira *et al*., 2015).

ROS (reactive oxygen species) are molecules continuously produced in plants as by-products of aerobic metabolism, the present of these compounds in high concentration are toxic for cell and oxidize amino acid residues in proteins, the unsaturated fatty acids in the cell membranes, thus causing cellular damage (Halliwell, 2006). At abiotic stress conditions, the concentrations of ROS are largely increase in a plant cell, cause oxidative stress (Abd El-Maboud & Eisa, 2016; Abd El-Maboud, 2019). Antioxidant including flavonoids and phenolic compounds is the first line of defense against ROS (Appel & Hirt, 2004).Changes in phenolic and flavonoid levels were correlated with the environmental conditions of the plants and were found to depend on both the taxonomy and ecology of the investigated species (Bautista *et al*., 2016).

Salinity is one of the major stresses responsible for changes in metabolic activity of plants. There are several adaptive mechanisms, by plants to handle with but understanding these mechanisms need more studies (Singh *et al*., 2013). The aim of current study try to understand the one of these adaptive mechanisms, accumulation of secondary metabolites under drought and salt stress in *Sarcocornia fruticosa* and *Sarcocornia perennis* growing naturally at Borg Elarab and Port Said.

Materials andMethods

Plant material: Fresh samples of aerial parts of the two species *Sarcocornia fruticosa* and *Sarcocornia perennis* and their associated soil were collected from two coastal areas; Borg Elarab, the GPS reading is 30 55.454N 29 31.553E 9m Alt and Port Said, the GPS reading is 31 12.259N 32 16.923E -2mAlt along the Mediterranean Sea, Egypt. Plant and soil samples were collected in two seasons; dry season (July, 2017) and wet season March, 2018. Meteorological data for the two studied areas were collected from the nearest station from each one during three months before samples collection represented in Table 1 according to (Francisco, 2017, 2018). The soil samples supporting plants were collected at 0-20 cm depths. These soil samples were air dried and then powdered gently with wooden wallet and passed through 2 mm sieve. The plant samples were weighted freshly then oven dried at 55 C° till constant weight after that ground to fine powder to determine the chemical constituents.

Table 1. Meteorological data covering studied areas.

Areas	Seasons	Total precipitation	Max temp. °C	Minimum temp. °C	RH %	Wind speed m/s
Borg Elarab	Wet	57.41	17.8	8.3	65.7	3.43
	Dry	31.97	32.0	25.7	56.2	4.33
Port Said	Wet	38.82	19.2	12.7	67.0	3.38
	dry	12.04	29.8	22.6	63.0	3.82

Soil analysis: Mechanical analysis of soil (without $CaCO_3$ restriction) was carried out by pipette method (Kilmer & Alexander, 1949), Electrical conductivity (EC), pH value, Na^+, K^+, Ca^{++}, Mg^{++}, Cl^- and $SO4^{--}$ were estimated in soil water extract (1:5). Soil moisture content, EC, Na^+ and K^+,Ca^{++} and Mg^{++} were determined according to (Rowell, 1994). Chlorides were determined by titration with 0.01N $AgNO_3$ in presence of drops with indicator potassium chromate 5% as described by (Jackson, 1967). Sulphates were determined by the turbidity method (Rainwater & Thatcher, 1960). Bicarbonate was determined by titration with sulphuric acid 0.01N (Reitemeier, 1943). Cations and anions were expressed as meq/L.

Phytochemical screening: The phytochemical constituents of methanol and chloroform extracts were screened as mentioned by Gumienna *et al*., (2007). Total phenolics was determined using Folin-Denis (Shahidi & Naczk, 1995) and total flavonoids were determined according to (Xu *et al*., 2006).

Extraction and analysis of fatty acids and volatile fraction: 30g of plant samples were powdered and extracted by percolation in organic solvent petroleum ether: diethyl ether (1:1). The extract was concentrated under reduced pressure by rotary evaporator. 1 ml concentrated extract was dissolved in 20 ml petroleum ether and 10 ml methanolic KOH, the mixture was shaken for 2 min and allowed to stand for 10 min, removed upper layer and washed with water, the oil (methyl ester of fatty acids) was analyzed by GC/MS using a Hewlett-Packard 6890/5972 system with HP-5MS capillary column (30 m \ 0.25 mm; 0.25 μm film thickness). The compounds were identified by comparison of retention indices with literature values (Adams, 1995).

Extraction of phenolic compounds: Phenolic compounds were extracted from plant material three times into 80% (v/v) acetone and then three times into 80% (v/v) methanol for 15 min at 80C. Extraction was carried out in water bath. The solutions from all extractions were combined. After evaporating the organic solvent in a rotary evaporator at 45C, the prepared crude extracts were stored at -20C in the dark until further analysis (Esmaeili *et al*., 2011).

Analysis of phenolic compound: Analysis was carried out by gas chromatography-mass spectrometry (GC-MS) after silylation by N-methyl-N-trimethylsilyl trifluroacetamide (MSTFA) + %1 trimethyliodosilane (TMIS).

The compounds were identified by analyzingand comparing the mass spectra with a database of Wiley 7 libraries and also by comparing the RI with those of the literature (Adams, 1995; Elsharkawy & Shiboob, 2017).

Statistical analysis

The experiment included two locations with three replicates, two species and two seasons is randomized complete block design with combined analysis. Data obtained for total phenols and total flavonoids were analyzed according to MSTAT software program (1991). Means values were differentiated using Duncan at 5% level as mentioned by (Duncan, 1955).

Results and Discussion

Soil analysis: Data in (Table 2) showed that soil supporting *Sarcocornia* plants was sandy loam at Borg Elarab and loamy sand at Port Said areas. Soil moisture content was slightly increased during wet season. *Sarcocornia* growing at Borg Elarab were supported by higher moisture content than those growing at Port Said and the two locations slightly increased during wet season. Salinity degree, soluble cations and soluble anions were higher in Port Said than in Borg Elarabespecially in wet season.

Phenolic compound: Seasonal changes have been demonstrated as potential causes of quantitative changes in total phenols, total flavonoids of the two studied species growing at Borg Elarab and Port Said areas as represented in (Table 3). All singles, doubles and triple interactions in total phenols and total flavonoids were significant. Generally, *S. fruticosa* was higher in both totals phenols and flavonoids than *S. perennis*. Total phenols and total flavonoids were increased during dry season. *Sarcocornia* species growing at Port Said was higher in totals phenols and flavonoids than those growing at Borg Elarab. The highest value in both total phenols and total flavonoids was recorded in *S. fruticosa* growing at Port Said in dry season (13.89 mg/g dry weight and 32.5 mg/ml), respectively.

Table 2. Soil characters supporting *Sarcocorniafruticosa* and *Sarcocorniaperennis*.

A. Soil particle distribution (%)

Season	Area	Sand %	Silt %	Clay %	Texture
Wet	Borg Elarab	78.55	8.65	12.8	Sandy loam
	Bort Said	87.6	1.85	10.55	Loamy sand
Dry	Borg Elarab	76.32	7.55	16.13	Sandy loam
	Bort Said	89.31	0.75	9.94	Loamy sand

B. Soil chemical characteristics

Season	Area	Moisture %	pH	EC ms cm^{-1}	Soluble cationsmeq\ L				Soluble anions meq\ L		
					Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-
Wet	Borg Elarab	26.36	8.8	7.8	40.87	2.05	15.8	7.6	45	20	0.7
	Bort Said	14.24	8.9	11.13	88.69	1.79	11	12.6	95	16.3	0.7
Dry	Borg Elarab	24.34	8.1	3.04	3.91	0.97	18	4.0	10	12.8	0.3
	Bort Said	13.32	8.5	5.83	34.78	1.02	3	4.5	40	4.8	0.8

Table 3. Total phenols and total flavonoids of *Sarcocornia fruticosa* and *Sarcocornia perennis*.

Parameters	Total phenols (mg/g dry weight)	Flavonoids (mg/ml)
Species effect		
Sp1	10.04[a]	27.90[a]
Sp2	4.20[b]	21.28[b]
Seasons effect		
Wet	6.33[b]	23.91[b]
Dry	7.91[a]	25.27[a]
Locations effect		
L1	5.64[b]	20.58[b]
L2	8.60[a]	28.61[a]
Species *Locations		
Sp1*L1	7.11[b]	24.45[c]
Sp2*L1	4.16[c]	16.7[d]
Sp1*L2	12.96[a]	31.35[a]
Sp2*L2	4.24[c]	25.87[b]
Seasons *Locations		
Wet*L1	4.85[d]	19.89[d]
Dry*L1	6.42[c]	21.27[c]
Wet*L2	7.80[b]	27.94[b]
Dry*L2	9.40[a]	29.28[a]
Species *Seasons		
Sp1*Wet	8.90[b]	26.84[b]
Sp2*Wet	3.75[d]	20.99[d]
Sp1*Dry	11.17[a]	28.97[a]
Sp2*Dry	4.65[c]	21.58[c]
Species *Seasons *Locations		
Sp1*Wet*L1	5.77[d]	23.47[e]
Sp2*Wet*L1	3.92[g]	16.30[g]
Sp1*Dry*L1	8.46[c]	25.44[d]
Sp2*Dry*L1	4.39[f]	17.10[f]
Sp1*Wet*L2	12.03[b]	30.21[b]
Sp2*Wet*L2	3.58[g]	25.68[cd]
Sp1*Dry*L2	13.89[a]	32.50[a]
Sp2*Dry*L2	4.91[e]	26.06[c]

Sp1= *S. fruticosa* Sp2= *S. perennis*

Our results indicated that totals phenols and flavonoids were more synthesized in *Sarcocornia* species by the influence of drought stress which was associated with higher in temperature and wind speed. The highest accumulation of totals phenols and flavonoids in *Sarcocornia* species growing at Port Said indicates that as soil moisture content decrease as the totals phenols and flavonoids increase. In addition that higher salinity of soil supporting *Sarcocornia* growing at Port Said can induce accumulation of total phenols and total flavonoids. That means phenols and flavonoids (major components of secondary metabolites in plants) are not only important in drought response but also salinity response mechanisms. The results are in agreement with previous studies,Abd El-Maboud & Eisa (2016) found higher accumulation of total phenols in *Salsola tetrandra* during dry season; Sarker & Oba (2018) observed elevation in bioactive compounds, vitamins, phenolics, flavonoids and antioxidant activity in *Amaranthus tricolor* by drought stress; Parida & Jha (2012) concluded that polyphenols is one of the main compatible solutes in *Salicornia brachiate* for maintenance of osmotic balance, protection of cellular macromolcules, detoxification of the cells, and scavenging of free radicals under drought stress); Nakabayashi *et al*., (2014) declared that flavonoids are drought stress responsive metabolites that can be used as positive markers and potential mitigative for drought stress. Total phenols were increased by 30% and 43.6% in *Menthaspicata* subjected to 50 mM and 100 mMNaCl, respectively, as compared to control (0 mMNaCl) (Chrysargyris *et al*., 2019).

Phenolic fraction: The phenolic fraction methanol extract was subjected to GC-MS which has detected six organic compounds as represented in (Table 4), (succinic anhydride, benzoic acid ester, cinnamic acid ester, cinnamaldehyde, ferulic acid methyl ester and diethylene glycol dibenzoate). All these compounds were detected in *S. fruticosa* except diethylene glycol dibenzoate which was unique in *S. perennis* growing at Borg Elarab location. Cinnamaldehyde and benzoic acid ester were non-detected in *S. perennis*in addition to succinic anhydride except those growing at Port Said. Both benzoic acid ester and ferulic acid methyl ester were increased in dry season. The results agreed with those obtained by (Sarker & Oba, 2018) on *Amaranthus tricolor*. Benzoic acid ester was the highest concentration among recorded organic compounds in *S. fruticosa*, which was higher in those growing at Borg Elarab than those growing at Port Said area especially in dry season. Benzoic acid has a regulatory role in inducing drought, heat and chilling stress tolerance in bean (*Phaseolus vulgaris* cv Brown Beauty) and (*Lycopersicum esculentum* cv Romano) plants (Senaratna *et al*., 2003). Plant benzoic acids (BAs) are pivotal regulators of a plant's interaction with its environment. Those are synthesized either from phenylalanineor directly from shikimate/ chorismate in plants (Wildermuth, 2006). Cinnamaldehyde was low in concentration in *S. fruticosa* in addition to succinic anhydride in both species tended to increase generally during dry season. Cinnamaldehyde has been used as flavoring agents in food, chewing gums and cosmetics (Chen *et al*., 2014). Ferulic acid was the most abundant among analyzed organic compounds in *S. perennis*, recording the highest concentration in those growing at Borg Elarab during dry season. Similar results were recorded in *Salsola kali* by (Sokolowska *et al*., 2009). Regarding *S. fruticosa*, ferulic acid was detected only in those growing at Port Said area which is affected by high saline soil, low moisture content and low rainfall precipitation. In this respect, (Minh *et al*., 2016), deducted that ferulic acid and its derivatives are effective to be exploited as promising agents to reduce deleterious effects of salinity stress on rice production. Ferulic acid has been used as anti-cancer, anti-thrombosis and anti-inflammatory. Moreover, it decreases lipids level and cholesterol synthesis and protects against coronary disease. Owing to these properties beside its low toxicity, ferulic acid is commonly used in food and cosmetic industries (Ou & Kwok, 2004).

Table 4. GC-Ms of phenolic fraction and methanol extracts of *Sarcocorniafruticosa* and *Sarcocornia perennis*.

A. Phenolic fraction of *S. fruticosa* and *S. perennis*

Compounds	Rt	Locations	*S. fruticosa*		*S. perennis*	
			Wet conc %	Dry conc %	Wet conc %	Dry conc %
Succinic anhydride	22.49	Borg Elarab	0.25	0.85	-	-
		Port Said	0.23	0.29	0.01	0.03
Benzoic acid Ester	25.08	Borg Elarab	3.0	3.56	-	-
		Port Said	2.2	2.5	-	-
cinnamaldehyde	25.26	Borg Elarab	-	0.15	-	-
		Port Said	0.7	0.11	-	-
Cinnamic acid ester	27.23	Borg Elarab	0.023	0.027	0.011	0.012
		Port Said	0.23	0.27	-	-
Ferulic acid methyl ester	30.35	Borg Elarab	-	-	0.45	0.55
		Port Said	2.3	2.5	0.07	0.08
Diethylene glycol dibenzoate	40.2	Borg Elarab	-	-	1.22	1.32
		Port Said	-	-	-	-

B. Methanol extracts of *S. fruticosa* and *S. perennis*

Compounds	Rt	Locations	*S. fruticosa*		*S. perennis*	
			Wet conc %	Dry conc %	Wet conc %	Dry conc %
Linalyl acetate	7.15	Borg Elarab	-	-	4.12	5.78
		Port Said	10.15	13.24	15.25	23.40
Geranylisovalerate	12.73	Borg Elarab	-	1.28	-	0
		Port Said	-	0.10	-	0.40
Ethanol	18.50	Borg Elarab	2.31	3.92	0.12	0.27
		Port Said	0.23	0.46	0.05	0.03
isocitronellol	23.14	Borg Elarab	-	0.20	-	-
		Port Said	-	0.20	-	0
(+) Ascorbic acid	31.82	Borg Elarab	4.60	5.05	8.32	11.22
		Port Said	6.33	6.18	1.2	0.02
Phytol, acetate	33.70	Borg Elarab	-	-	-	-
		Port Said	0.23	0.79	0.24	4.50
Formic acid	35.30	Borg Elarab	-	-	0.43	0.64
		Port Said	0.21	0.24	0.05	0.06
Glycerol-Palmitate	41.62	Borg Elarab	0.45	1.46	0.23	0.74
		Port Said	1.22	1.30	0.21	0.24
α-Tocopheryl	42.28	Borg Elarab	1.20	2.30	0.50	1.20
		Port Said	2.33	3.98	1.22	1.45
Campesterol	44.12	Borg Elarab	1.20	2.00	2.00	2.20
		Port Said	2.30	3.50	3.20	3.95
psi.,.psi.Carotene,	44.80	Borg Elarab	-	-	0.23	0.56
		Port Said	0.23	0.02	0.25	0.26

GC-Ms of phenolic fraction and methanol extracts: Analysis of Methanol extract revealed the presence of many organic compounds most of them were increased during dry season in *S. fruticosa* and *S. perennis* except ascorbic acid in those growing at Port Said as shown in Table 4. The four compounds; linalyl acetate, phytol acetate, α tocopheryl and campestrol were higher in the two species growing at Port Said than those growing at Borg Elarab, while the reverse was observed in ethanol. Isocitronellol and geranylisovalerate were none detected in the two species during wet season. In addition to formic acid, linalyl acetate and psi, psi -carotene were disappeared in *S. fruticosa* growing at Borg Elarab.

From the above results, the investigated compounds are response positively to drought stress by higher accumulation in the two studied species.

Increasing salinity at Port Said enhanced the biosynthesis of linalyl acetate, phytol acetate, α tocopheryl and campesterol in both studied species, in addition to the biosynthesis of formic acid and psi, psi carotenein *S. fruticosa* growing at Port Said and miss-detected in those growing at Borg Elarab indicate that these secondary compounds may have a pivotal role in salinity resistance. These results agreed with Valifard *et al*., (2014) who observed a high increase in biosynthesis of linalyl acetate in *Salvia mirzayanii* treated with 9.1 ds m^{-1} salinity. Phytol can be used as a precursor for the manufacture of synthetic forms of vitamin E and K1 (Thomas, 2007). Also, it has been reported to have antioxidant activity (Santos *et al*., 2013). Campestrol is one of phytosterols which play a vital role in plant growth and development, including cell division, cell elongation, embryogenesis, cellulose biosynthesis, and cell wall formation (Deng *et al*., 2016). Formate metabolism is closely related to serine synthesis and to all subsequent reactions originating from serine. Formate may have a role in biosynthesis of many compounds, in energetic metabolism and in signal transduction pathways related to stress response (Igamberdiev *et al*., 1999).

Table 5. GC-Ms of fatty acidof *Sarcocornia fruticosa* and *Sarcocornia perennis*.

Compounds	Locations	*S. fruticosa*		*S. perennis*	
		Wet	Dry	Wet	Dry
Arachidonic acid	Borg Elarab	-	-	0.03	0.02
	Port Said	0.12	0.10	0.70	0.16
Linolenic acid	Borg Elarab	0.22	0.11	0.52	0.30
	Port Said	1.20	0.70	0.83	0.10
Cis-Vaccenic-acid	Borg Elarab	0.95	0.87	0.12	0.08
	Port Said	0.92	0.08	0.75	0.06
Erucic acid	Borg Elarab	0.92	0.72	-	-
	Port Said	-	-	0.27	0.23

Table 6. Antioxidant of *Sarcocornia fruticosa* and *Sarcocornia perennis*.

Test	*S. fruticosa*				*S. perennis*				References	
	Borg Elarab		Port Said		Borg Elarab		Port Said			
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	AC	Q
IC50 (g/l)	0.035	0.250	0.032	0.035	0.05 ± 0.02	0.15	0.27±0.01	0.43±0.02	0.061 ± 0.001	0.017 ± 0.001

AC, ascorbic acid : Q: querctine

Fatty acid: Data in (Table 5) showed fatty acids fractionation by GC MS of *S. fruticosa* and *S. perennis*. Four fatty acids; arachidonic, linolenic, cis-vaccenic and erucic were detected. Generally, the four fatty acids were increased during wet season in both studied *Sarcornia*. Arachidonic and linolenic were higher in the two species growing at Port Said than those growing at Borg Elarab. Erucic acid was recorded only in *S. fruticosa* at Borg Elarab and *S. perennis* at Port Said.

The increase of fatty acids in wet season means that they response positively to salinity stress in both studied *Sarcocornia*. Salt stress is an effective for inducing total lipids and omega-3 fatty acid production in *Dunaliella salina* (Rismani & Shariati, 2017). Linolenic and palmitic acids were increased significantly at higher salinities in the model microalgal species *Chlamydomonas reinhardtii* (Hounslow *et al*., 2016). On the other hand, (Grieve *et al*., 1997) found the fatty acid composition in *Lesquerella fendleri* exposed to salinity did not change except in linolenic acid which decreased as salinity increased. Linolenic and linoleic are the major unsaturated fatty acids in photosynthetic tissue (Harris & Jaines, 1965). Linolenic acid was a major fatty acid found in plant *S. perennis* growing at Port Said during wet season (1.2%). A similar trend in the fatty acids profile was observed in *Sarcocornia persica* and *Sarcocornia fruticosa* (Ventura *et al*., 2011), linolenic acid was the most abundant fatty acid of the total fatty acids content in *Sarcocornia ambigua* (Bertin *et al*., 2014). Phospholipids represent the main lipid class in lipid membranes of plant leaves. The lipid membrane permeability decreases by increasing saturated fatty acids as response to salt stress. As salinity increase as the amount of linolenic acid increase, but not as much as linoleic acid (Ivanova *et al*., 2006).

Antioxidant activity: The anti-oxidative activity of plant shoot is mainly contributed by the active compounds present in them. In this study, the anti oxidative activity of *S. fruticosa* and *S. perennis* species was measured using the DPPH scavenging capacity method as presented in (Table 6). The results of study showed the increase of antioxidant activity during dry season in the two species and the highest antioxidant activity, was noticed in *S. fruticosa* growing at Port Said with IC_{50} (0.032) in dry season. However, the standards substances used in this study (Ascorbic acid) present an antioxidant activity of 0.061 ± 0.001 g/l and qurectine 0.017 ± 0.001 g/l.

As indicated from results, both plant *S. fruticosa* and S. *perennis* in the two locations have relatively high anti-oxidant activity, however, *S. fruticosa* had higher antioxidant than *S. perennis*. The increase of antioxidant in dry season associated with high accumulation of total phenols and total flavonoids. Literature data show correlation between antioxidant activity and total phenolic content (Miliauskas *et al*., 2004).

Screened antioxidant compounds which are responsible for antioxidant activity could be isolated and then used as antioxidants for the prophylaxis and treatment of free radical-related disorders (Bautista *et al*., 2016). Therefore, research to identify anti-oxidative compounds is an important issue. Although it remains unclear which of the compounds of medical plants are the active ones, polyphenols recently have received increasing attention because of some interesting new findings regarding their biological activities. From pharmacological and therapeutic points of view, the antioxidant properties of polyphenols, such as free radical scavenging and inhibition of lipid peroxidation, are the most crucial.

Conclusion

Polyphenols and flavonoids are the common antioxidant natural products found in medicinal plants. Total phenols and total flavonoids as secondary products can play an effective role as droughtand/ or salinity tolerance metabolites in *Sarcocornia* species. Also, they are correlated positively with the antioxidant activity in *Sarcocornia* species. Fatty acids such as arachidonic, linolenic, cis-vaccenic and erucic in *Sarcocornia* species may contribute in salinity tolerance mechanism. The diversity in climatic factors and soil analysis reflect the change in the accumulation of secondary metabolite of the two *Sarcocornina* species that reflect the role of phenolic compounds in adaptation of such condition.

Acknowledgment

The authors introduce grateful acknowledgment to Desert Research Center to support us with available car in field visiting and King Abd Al-Aziz University, Central Lab for all support in helping analysis by GC-MS. This research did not receive any specific funding.

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(Received for publication 28 April 2019)