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Adaptive Mechanisms in *Zilla spinosa* and *Leptadenia pyrotechnica* Plants to Sever Aridity in the Egyptian Deserts

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Abstract

In the present study two species were selected based on their highest presence values to study the response to the severe drought conditions in desert: these were *Zilla spinosa* and *Leptadenia pyrotechnica*. The results showed that soil water content and organic matter of Wadi El-Assiuty were very low over the study period. The estimated pH values in the soil solution at the different studied stands tended to be slight alkaline. Total soluble salts were generally higher during summer versus winter. The water content in the studied plants increased significantly during summer. The selected species increased their content of chlorophyll *a* and *b* in summer. The stability index of chlorophyll *a* and *b* was significantly higher in summer than that estimated in winter. Calcium and magnesium were accumulated in considerable amounts. Ca^{+2} was the main accumulated cation whereas its concentration were higher than magnesium. *Z. spinosa* accumulated more sulphates in summer than in winter. Phosphates appeared in low amounts in all the investigated plants. In *L. pyrotechnica* tissue, Na^+ concentration correlated negatively with those found in soil during summer. In winter Na^+ and SO_4 correlated positively and K^+ correlated negatively in *Z. spinosa*. The studied species showed slightly increase in soluble sugars accumulation. Soluble protein content in *Z. spinosa* and *L. pyrotechnica* decreased significantly during winter season. Amino acids content was low and varied between the two investigated species. It seemed that the *Z. spinosa* is better adapted than *L. pyrotechnica* to drought conditions, prevailing in the area under study. This judgement can be concluded by the average metabolic potentiality in the species, whereas soluble metabolites (soluble sugars and soluble proteins) were relatively much higher than in the case of *L. pyrotechnica*.

Keywords: aridity, osmoregulation, chlorophyll stability, carbon metabolites, nitrogen metabolism, drought resistance

Introduction

Drought resistance is a complex trait involving several interacting properties. Xerophytic plant species adapt to drought due to their ability to maintain turgidity and water uptake (Martynez *et al*., 2005). Adjustment provides the means to avoid cellular dehydration, which is essential for maintaining cellular activity (Bartels and Ramanjulu, 2005). Initially, it was thought that osmotic adjustment occurred only in plants subjected to high salinities; however, later studies on plants grown on dry soils showed that this response is also common in conditions of water stress (Cushman, 2001; Sayed *et al*., 2013). According to Mile *et al*. (2002), the ability of plants to accumulate the inorganic ions in high quantities inside their tissues is the most important mechanism to maintain the plant water potential more negative than the external medium in order to maintain the water uptake.

Plants tend to accumulate the most compatible solutes in cytoplasm to balance the osmotic pressure inside the cells, especially by increasing their content of organic solutes (Khan *et al*., 2000; Mile *et al*., 2002) to avoid the injury that may result from the high accumulated inorganic solutes. Soluble sugars play an important role in keeping water balance under drought stress in plants (Prado *et al*., 2000). The accumulation of soluble sugars is strongly correlated to the acquisition of drought tolerance in plants (Hoekstra and Buitink, 2001; Mohammadkhani and Heidari, 2008). Proteins also play a significant role in the metabolic change under drought stress as they have considerable hydrophilicity, which are readily absorbed or dissolved in water and help cells to keep cellular water from damage under drought stress and dehydration. It has been proposed that those proteins have important functions in protecting cells from damage under stress conditions (Du Jinyou *et al*., 2004). Yadav *et al*. (2005) results showed that the accumulation of free amino acids under stress at all the growth stages indicates the possibility of their involvement in osmotic adjustment. Similar results were obtained in pepper (Nath *et al*., 2005), coconut (Kasturi and Rajagopal, 2000), wheat (Hamada, 2000) and *Arachis hypogaea* (Asha and Rao, 2002).

Salama *et al*. (2012b) reported that *Ochradenus baccatus* Delile in Wadi Qena, Eastern Desert, Egypt, tend to increase their soluble sugars, soluble proteins and total free amino acids significantly during summer season than winter. Proline

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concentrations were higher in winter than in summer. They also found close relationships between concentration of K^+, Na^+ and Cl^- in plants during the dry season as well as accumulation of soluble sugars and soluble proteins. This could be primarily related to metabolism of drought resistance in such desert resistant plants. Sayed *et al.* (2013) reported that osmotic adjustment in three desert species growing in Wadi Natash, Eastern Desert, Egypt, was the main water relationship adaptation to cope with drought. Accumulation of soluble sugars, soluble proteins, K^+, Cl^- and SO_4^{-2} at higher concentration often assist in turgor maintenance and help to enhance drought tolerance. Salama *et al.* (2015a) reported that *Calligonum polygonoides* plants are better adapted to drought conditions than *Artemisia judaica*, more tolerant to drought and more favorable to the conditions of arid desert.

The Eastern Desert of Egypt extends between the Nile Valley and the Red Sea. It is traversed by numerous canyon-like depressions (wadis) running to the Red Sea or to the Nile Valley. Wadi El-Assuity is one of the most notable features of the Egyptian Eastern Desert (Salama *et al.*, 2014b). Relatively little information is known about the eco physiology of the vegetation found in Wadi El-Assuity area. In this context, questions might be raised about what would be the eco physiological adaptations common among members of such vegetation? What would be the relation between such adaptations and prevailing ecological factors? Such questions and others are open to speculation in the absence of concrete data about such particular types of habitats and their vegetation. Accordingly, the present study aimed to study the physiological behaviour of two common desert plant species in order to identify and understand their drought resistance mechanisms.

Materials and Methods

Soil analysis

Soil was sampled where great abundance of plants was observed. Samples were collected from 50 stands in the wet (winter) and dry (summer) seasons. Three replicates were taken from each stands and carried to the laboratory in plastic bags. *Z. spinosa* were collected from 48 stands only and absent from stands 1 and 2, thus these samples were further skiped form analyses.

Organic matter determination

Organic matter was determined in the soil samples by the dichromate oxidation method according to Walkley and Black (1934).

Determination of soil water content and soil extract

Water content of the soil samples was determined by weighing the fresh soil sample, drying it in an oven at 105 °C for 24 hours, and then the dry weight was determined. The water content of the sample was calculated as percent of the dry weight. Soil extracts (1:5) were prepared by shaking 20 g of soil with 100 ml of distilled water for one hour and filtration was undertaken to obtain a clear filtrate.

Determination of water soluble ions

Chloride was determined volumetrically according to Jackson (1967) while sulphate was determined by turbid metrically as $BaSO_4$ according to procedures described by Bardsley and Lancaster (1965). Sodium and potassium was measured by flame photometry according to Williams and Twine (1960). Calcium and magnesium were determined volumetrically by the Versene method as described by Johnson and Ulrich (1959). Phosphorus was determined calorimetrically as phospho-molybdate according to Jackson (1967). Carbonates and bicarbonates were estimated according to method described by Piper (1947).

Electric conductivity, total soluble salts and pH value

Electric conductivity (EC) and total soluble salts (TSS) of the soil were determined using conductivity meter (model 4310 JEN WAY), according to Jackson (1967). Electric pH-meter (model pH-206 Lutron) was used to determine the soil reaction of the collected samples.

Plant analysis

Leptadenia pyrotechnia and *Zilla spinosa* were assessed to their eco physiological behaviour. *L. pyrotechnia* (family Apocynaceae) is a leafless shrub of 1.2-4 m; stems are erect, much-branched, terete, green, ± spinescent; leaves (on juvenile branches) have 0.5-1.5 × 0.2-0.35 cm, linear-lanceolate, sessile, acute, glabrous, flowers in axillary. *Zilla spinosa* (family Brassicaceae) is a perennial spiny shrub, with stems richly branched, fleshy leaves, glabrous, spathulate, sinuate-crenate, few on young plants or new branches and mature plants almost leafless (Boulos, 2000).

Determination of chlorophyll

Chlorophyll was extracted in test tubes, in 10 ml of 80% aqueous ethanol (Welfare *et al.*, 1996). To estimate chlorophyll stability the standard procedure was undertaken, as a definite weight of fresh healthy leaves was put in 10 ml of distilled water and heated in a water bath at 56±1 °C for 30 minutes. Chlorophyll stability index (CSI) was expressed as percentage of chlorophyll content in the heated sample to that of fresh sample. Chlorophyll "*a/b*" ratio was also calculated.

Estimation of soluble active metabolites in plant extract

Soluble sugars (as carbon metabolites), total free amino acids and soluble proteins (as nitrogen metabolites) were determined according to procedures described by Dubois *et al.* (1956), Lee and Takahashi, (1966) and Lowry *et al.* (1951) respectively.

Determination of different constituents of the ionic fraction

The contents of different anions and cations in plant extracts were determined as previously mentioned for soil extract.

Statistical analysis

Statistical inferences necessary to evaluate the effects and relative role (shares) of single factor and their interactions on the parameters tested included analysis of variance (F value), coefficient of determination (η^2) and simple linear correlation coefficient (r). Data were statistically analysed using SAS, SPSS programs. The coefficient of determination (η^2) has been devised to evaluate the relative effect of each single factor and interaction in contribution to the total response. The simple linear correlation coefficient (r) was used to elucidate the relationship between the internal mineral element contents in plants.

Results

Physical and chemical properties of the studied stands soil

Soil water content and total soluble salts

Generally, soil water content (Fig. 1) of the soil samples in winter season was higher than in summer in most of the studied stands. It ranged between 0.11% and 0.89% in summer and between 0.12% and 0.99% in winter. Stands 7 and 10 recorded the highest values of water content during winter. The lowest values of water content were recorded in stands 45 and 48 during summer.

In most studied stands inhabited by the studied plants the total soluble salts (TSS %) of soil extracts during summer was higher than in winter season (Fig. 1). The highest value during summer was recorded at stand 7 and lowest value was detected at stand 13 in winter. TSS values in summer ranged between 0.04 and 0.30%, while in winter it ranged between 0.05 and 0.30%.

Organic matter

Organic matter content (%) of soil samples was generally higher in summer than in winter except at 11 stands where opposite trend was noticed (Table 1). Organic matter content fluctuated between 0.03% and 0.74%. Maximum value of the organic matter content was at stand 7 during summer, whereas the minimum value was recorded at stand 29 during winter.

pH value

pH values of soil solutions was illustrated in Table 1. The soil solution in these habitats is in neutral or slightly alkaline range. The values ranged between 6.23 and 8.42 in summer season and between 6.23 and 7.64 in winter. The highest value of pH was recorded in stand 13 during summer and the lowest value was at stand 26 during winter.

Electric conductivity

As shown in Table 1, the values of electric conductivity (EC) of soil solutions were higher in summer than in winter in most of the studied stands. Its values ranged between 0.13 and 0.92 mS cm^{-1} during summer, but in winter it ranged between 0.14 and 0.93 mS cm^{-1}. The highest value of EC was recorded in winter at stand 3. The lowest value was measured during summer at stand 29.

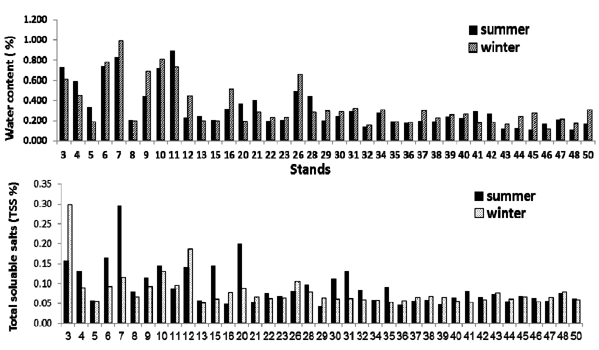

Fig. 1. Water content (%) and total soluble salts (TSS %) in soil samples of the studied stands inhabited by *L. pyrotechnia* and *Z. spinosa* in Wadi El-Assiuty during summer and winter

Table 1. pH values, electric conductivity (EC) and organic matter content (OM) at different stands in Wadi El-Assiuty, during summer and winter seasons

Stand	pH		EC (mS cm^{-1})		OM (%)	
	Summer	Winter	Summer	Winter	Summer	Winter
3	7.88	6.60	0.49	0.93	0.20	0.19
4	7.87	6.81	0.48	0.28	0.26	0.12
5	8.15	6.45	0.18	0.17	0.14	0.11
6	7.65	6.78	0.51	0.29	0.43	0.13
7	7.69	6.91	0.92	0.36	0.74	0.21
8	8.04	6.73	0.25	0.21	0.09	0.10
9	7.99	6.62	0.36	0.29	0.07	0.07
10	8.14	6.91	0.45	0.41	0.12	0.11
11	8.14	6.60	0.27	0.30	0.45	0.23
12	8.22	6.43	0.44	0.58	0.18	0.16
13	8.42	6.60	0.18	0.16	0.23	0.13
15	7.86	6.63	0.45	0.19	0.24	0.15
16	8.04	6.76	0.15	0.24	0.10	0.09
20	7.95	6.66	0.69	0.28	0.41	0.04
21	8.38	6.84	0.17	0.21	0.14	0.08
22	8.1	6.52	0.23	0.20	0.20	0.09
23	8.2	6.49	0.21	0.20	0.18	0.14
26	8.4	5.23	0.25	0.33	0.14	0.08
28	8.03	6.68	0.30	0.24	0.07	0.08
29	8.02	6.62	0.13	0.20	0.05	0.03
30	7.92	6.75	0.35	0.19	0.10	0.07
31	7.99	7.26	0.41	0.20	0.05	0.07
32	8.05	7.15	0.26	0.19	0.14	0.14
34	8.00	6.68	0.18	0.18	0.09	0.10
35	8.04	7.21	0.29	0.16	0.09	0.05
36	7.92	6.74	0.14	0.18	0.18	0.12
37	8.11	6.83	0.17	0.20	0.18	0.07
38	8.14	6.69	0.18	0.21	0.10	0.07
39	8.03	6.75	0.15	0.20	0.09	0.12
40	7.88	6.99	0.20	0.18	0.07	0.08
41	7.93	7.18	0.25	0.17	0.12	0.10
42	7.85	6.74	0.20	0.19	0.08	0.11
43	7.84	7.13	0.23	0.24	0.13	0.09
44	7.92	7.29	0.17	0.19	0.16	0.11
45	7.87	7.64	0.21	0.21	0.12	0.07
46	7.88	7.52	0.20	0.17	0.10	0.12
47	7.86	7.24	0.17	0.20	0.09	0.09
48	7.84	7.21	0.23	0.25	0.07	0.09
50	7.63	6.91	0.19	0.19	0.09	0.05

Concentration of major ions in the soil

Concentrations of major soluble cations and anions in soil samples of the stands inhabited by the studied plants were illustrated in Figs. 2 and 3, respectively. Generally, concentrations of sodium during summer were higher than those from winter. The highest values were recorded during summer in stands 7 and 6.

Potassium was higher in summer than in winter in all stands. It ranged between 0.01 and 0.13 mg g^{-1} soil. The highest concentration was recorded at stands 7 during summer.

Calcium concentrations of the soil samples were higher in winter than in summer in most stands. Calcium concentrations in the soil samples in summer ranged between 0.10 and 0.73 mg g^{-1} soil. Stand 3 had the highest concentrations of calcium.

Concentrations of magnesium in soil samples fluctuated between 0.04 and 0.25 mg g^{-1} soil. The highest value of magnesium was recorded in stand 8 during winter season.

Chlorides concentrations showed high values during summer in most stands (Fig. 3). Concentrations of chlorides varied from 0.04 mg g^{-1} soil at stand 38 to 0.46 mg g^{-1} soil at stand 3. The highest concentration of chlorides was recorded in stand 3 during the winter season.

Generally, sulphates were higher during summer than during winter months (Fig. 3). Its concentration ranged between 0.15 µg g^{-1} soil and 4.86 µg g^{-1} soil in summer. The highest concentrations were recorded at stands 10 during summer.

Phosphates contents in soils samples were appeared in small quantities during both summer and winter seasons (Fig. 3). In general, phosphates concentrations during winter were higher than during summer.

Bicarbonates contents in soil samples of the studied stands inhabited by the studied species were generally higher in summer than in winter (Fig. 3). It did not exceed 1.83% (stand 37) in summer and 0.16% (stands 21, 22 and 26) in winter.

Plant analysis

Water content

As shown in Fig. 4 in winter, shoot water content of *Z. spinosa* ranged between 28.38% and 75.30%. In summer, it ranged between 23.05% and 84.44%. In some stands, the

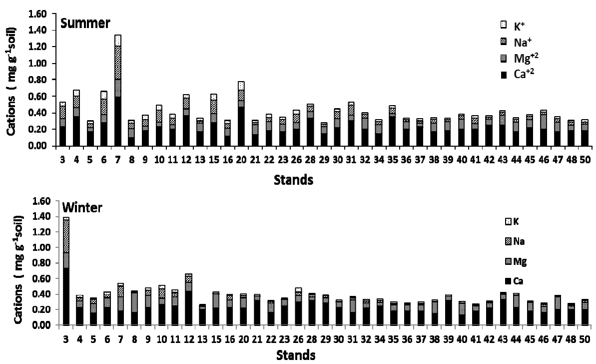

Fig. 2. Concentration of major soluble cations (Na^+, K^+, Ca^{+2}, Mg^{+2}), expressed in mg g^{-1} soil of the different studied stands inhabited by studied plants in Wadi El-Assiuty in winter and summer seasons

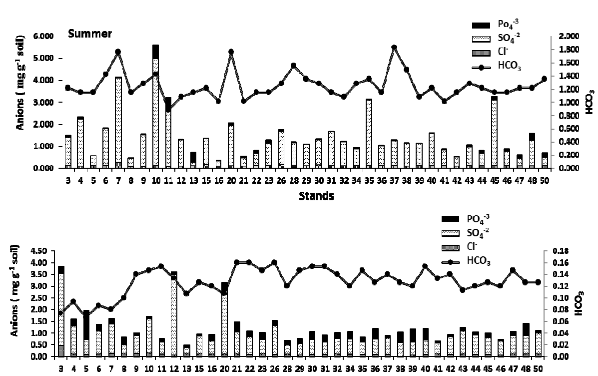

Fig. 3. Concentration of Cl^- (expressed in mg g^{-1} soil), SO_4^{-2}, PO_4^{-3} (expressed in µg g^{-1} soil) and HCO_3 (%) of the different studied stands inhabited by studied plants in Wadi El-Assiuty in winter and summer season

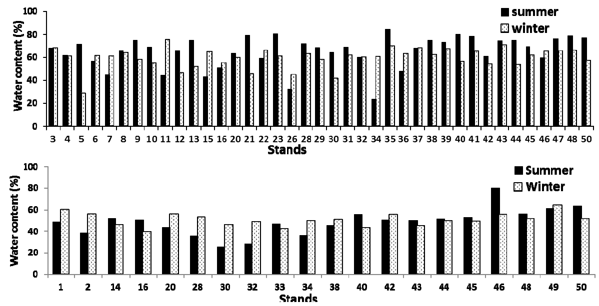

Fig. 4. Water content (%) of *Zilla spinosa* and *Leptadenia pyrotechnica* plants collected from different studied stands in Wadi El-Assiuty during summer and winter seasons

water content of plant tissues was higher during winter than in summer.

Statistical analysis for data revealed that regionality, seasonality and the interaction between both factors had highly significant effect (Table 2). The regionality and interaction between them had the equal dominant effect, followed by seasonality as sub dominant.

Water content of *L. pyrotechnica* shoots was higher in summer within the collected stands 14, 16, 33, 40, 43, 44, 45, 46, 48 and 50 (Fig. 4). In winter, shoot water content ranged between 39.46% and 64.56%. Even more, during summer, the water content ranged between 25.37% and 79.89%.

Statistical analysis revealed that regionality, seasonality and their interaction had highly significant effects (Table 2). The regionality had the greatest effect, followed by the interaction of the two factors, while the role of seasonality was the minor one.

Chlorophyll content and chlorophyll stability index

The concentrations of chlorophyll *a* and chlorophyll *b* in *Z. spinosa* were illustrated in Table 3. Chlorophyll *a* was higher in summer than those of winter in most of the studied stands. The concentrations of chlorophyll *a* in summer ranged between 0.19 and 0.90 mg g^{-1}f. wt., while in winter it ranged between 0.09 and 0.66 mg g^{-1} f. wt.

Concentration of chlorophyll *b* during the summer was higher than in winter except in 4 stands. In winter, chlorophyll *b* ranged between 0.053 and 0.234 mg g^{-1} f. wt., while in summer it ranged between 0.095 and 0.633 mg g^{-1}f wt. Total chlorophyll *a+b* in summer was higher than winter except in stands 8 and 45. Chlorophyll a/b ratio in winter ranged between 0.86 and 2.85, while the ratio varied from 0.49 to 2.98 in summer.

The concentrations of chlorophyll *a* and chlorophyll *b* in *L. pyrotechnica* were illustrated in Table 4. Chlorophyll *a* and *b* in summer were higher than those of winter in all stands. The concentrations of chlorophyll *a* in summer ranged between 0.20 and 0.45 mg g^{-1} f. wt., but in winter it ranged between 0.14 and 0.28 mg g^{-1} f. wt. In winter, chlorophyll *b* ranged between 0.06 and 0.18 mg g^{-1} f. wt., while in summer it ranged between 0.08 and 0.19 mg g^{-1} f. wt.

Stability index (CSI) of chlorophyll *a* in *Z. spinosa* (Table 3) was higher in winter than in summer except in 6 stands which showed the reversed trend. The stability

Table 2. Statistical analysis for water content, chlorophyll and organic components of *Zilla spinosa* and *Leptadenia pyrotechnic* showing analysis of variance (F-value) and determination coefficient (η^2)

Plant species		*Zilla spinosa*		*Leptadenia pyrotechnic*	
Parameters	S.O.V	F	η^2	F	η^2
Water content	Seasonality	53.6**	0.06	19.19**	0.02
	Regionality	11.73**	0.47	44.19**	0.57
	Interaction	11.69**	0.47	31.64**	0.41
Chlorophyll *a*	Seasonality	1668.7**	0.52	340.55**	0.48
	Regionality	22.3**	0.26	10.50**	0.28
	Interaction	18.78**	0.22	8.55**	0.24
Chlorophyll *b*	Seasonality	543.8**	0.29	46.68**	0.15
	Regionality	20.96**	0.43	7.40**	0.45
	Interaction	14.00**	0.28	6.55**	0.40
Chl *a+b*	Seasonality	2241**	0.54	283.63**	0.47
	Regionality	27.6**	0.25	8.70**	0.28
	Interaction	22.2**	0.21	7.91**	0.25
Chl *a/b* ratio	Seasonality	293.4**	0.31	41.38**	0.19
	Regionality	7.27**	0.30	5.00**	0.43
	Interaction	9.52**	0.39	4.50**	0.38
CSI *a*	Seasonality	427.5**	0.20	163.93**	0.33
	Regionality	22.0**	0.38	10.09**	0.39
	Interaction	23.7**	0.42	7.17**	0.28
CSI *b*	Seasonality	106.7**	0.08	50.17**	0.10
	Regionality	14.99**	0.45	12.88**	0.45
	Interaction	15.53**	0.47	12.87**	0.45
Soluble sugars	Seasonality	15.9**	0.02	0.02 ns	0.00
	Regionality	8.50**	0.44	8.75**	0.40
	Interaction	10.44**	0.54	13.00**	0.60
Soluble proteins	Seasonality	7.80	0.06	0.01 ns	0.05
	Regionality	1.35	0.40	1.14 ns	0.50
	Interaction	1.81	0.54	1.03 ns	0.45
Total amino acids	Seasonality	584.6**	0.29	11.84**	0.18
	Regionality	18.22**	0.34	1.94*	0.42
	Interaction	19.45**	0.37	1.84*	0.40

**Significant at 0.01 confidence level; *Significant at 0.05 confidence level

index of chlorophyll *a* ranged between 19.95% and 97.79% in summer and 37.68% and 98.26% in winter. Chlorophyll *b* stability was generally higher in summer than in winter. It ranged between 26.13% and 97.64% in summer, but in winter it varied from 32.11% to 98.37% (Table 3).

Statistical analysis represented in Table 2 showed that the effect of single factors and their interaction on chlorophyll *a* were highly significant. The seasonality had dominant effect followed by regionality. In the case of chlorophyll *b*, two factors as well as their interaction had highly significant effect. Regionality had the dominant effect, followed by the seasonality. The interaction role was the minor one.

Stability index (CSI) of chlorophyll *a* in *L. pyrotechnica* (Table 4) was higher in winter than in summer except for stands 1, 32 and 43 which showed the reversed trend. The stability index of chlorophyll *a* ranged between 28.95% and 92.35% in summer and 63.80% and 98.35% in winter. Chlorophyll *b* stability was generally higher in summer than in winter in most of the studied stands. It fluctuated between 48.42% and 95.73% in summer, but in winter the percentage ranged between 45.12% and 92.92% (Table 4).

Statistical analysis represented in Table 2 showed that: the effect of single factors and their interaction were highly significant for chlorophyll *a*. The seasonality had dominant effect, followed by regionality. In the case of chlorophyll *b*, the two factors as well as their interaction had highly significant effect; regionality had the greatest impact, followed by the interaction and the seasonality.

In *Z. spinosa* the effect of single factors on chl. *a/b* ratio were highly significant. The interaction had the dominant effect followed by seasonality, while regionality had the minor role.

Seasonality and regionality interaction had the dominant role in affecting CSI *a,* followed by regionality, while seasonality role was subdominant. In case of CSI *b*, the interaction had dominant effect, followed by regionality.

In *L. pyrotechnica*, the effect of the two single factors were highly significant for chl. *a/b* ratio. Regionality had the dominant effect, followed by the interaction, while seasonality role was minor.

In the case of CSI *a*, the regionality had the highest effect, followed by seasonality. Never the less, for CSI *b* the regionality and interaction had an equal dominant effect, followed by seasonality as subdominant.

*Ionic composition of the plant tissue*s

Concentrations of major ions in *Z. spinosa* collected from different stands are given in Figs. 5 and 6. In general, sodium ions were found in higher concentrations inside the plant tissues compared with soil sodium content. Concentrations of sodium in *Z. spinosa* were higher in winter than in summer in 16 stands. It ranged between 0.50 and 8.80 mg g^{-1}d.wt. in summer and between 0.50 to 12.13 mg g^{-1}d.wt. in winter. The highest concentrations were recorded in stand 3 during winter and stand 29 during summer. The statistical analysis (Table 5) revealed that the effect of single factors and their interaction were significant. Regionality had the dominant effect followed by the interaction, while seasonality had a more minor role.

Major ions concentrations in *L. pyrotechnica* at different stands are given in Fig. 5 and 6. Concentrations of sodium in *L. pyrotechnica* were higher in winter than in summer. It ranged between 0.50 and 4.26 mg g^{-1} d. wt in summer and between 0.67 to 6.17 mg g^{-1} d. wt in winter. The highest concentrations were recorded in stand 42 during summer and stand 33 during winter. The statistical analysis (Table 5) showed the effects of single factors and their interactions were highly significant. The interaction between seasonality and regionality had the dominant effect followed by the regionality, and seasonality.

Potassium concentrations in *Z. spinosa* were higher in summer than in winter in all stands except at 6 stands. Concentrations of potassium ranged between 2.64 and 22.77 mg g^{-1}d.wt. in summer and between 3.64 and 8.55 mg g^{-1}d.wt. in winter. The highest concentration was recorded at stand 42 during summer, while the lowest one was reported at stand 26 during winter. The single factors effects were highly significant (Table 5). Seasonality had the dominant effect followed by regionality, while the interaction role was minor.

Potassium concentrations in *L. pyrotechnica* were higher in summer than in winter in ten stands while in the other stands the reverse held true. The highest

Table 3. Chlorophyll (Chl *a*, Chl *b* and Chl *a+b*) concentrations (mg g^{-1} f. wt.), chlorophyll *a/b* ratio and chlorophyll stability index (CSI , %) at different stands inhabited by *Zilla spinosa* plants, in summer and winter seasons

St.	Chl *a*		Chl *b*		Chl *a+b*		Chl *a/b*		CSI *a*		CSI *b*	
	S	W	S	W	S	W	S	W	S	W	S	W
3	0.72	0.13	0.29	0.11	1.00	0.24	2.79	1.20	68.2	94.3	85.0	98.4
4	0.37	0.17	0.19	0.11	0.55	0.28	1.99	1.62	76.1	97.7	80.6	94.0
5	0.63	0.14	0.22	0.12	0.85	0.26	2.94	1.22	71.5	98.3	92.3	94.0
6	0.27	0.10	0.10	0.12	0.37	0.23	2.87	0.87	93.7	95.0	90.4	94.5
7	0.50	0.16	0.18	0.13	0.67	0.28	2.84	1.27	50.1	96.3	71.9	91.8
8	0.26	0.21	0.10	0.16	0.36	0.37	2.54	1.29	97.2	93.3	94.5	93.9
9	0.51	0.18	0.18	0.14	0.68	0.32	2.89	1.32	56.4	90.1	84.0	52.8
10	0.47	0.20	0.18	0.13	0.65	0.34	2.66	1.55	70.6	94.9	68.5	94.0
11	0.44	0.27	0.18	0.17	0.63	0.44	2.45	1.80	82.9	91.9	94.3	95.9
12	0.68	0.09	0.26	0.07	0.94	0.16	2.75	1.27	57.4	85.5	82.0	54.7
13	0.25	0.09	0.12	0.05	0.38	0.14	2.14	1.73	91.7	92.0	88.8	77.0
15	0.71	0.20	0.27	0.14	0.98	0.34	2.64	1.41	78.7	81.1	73.5	87.9
16	0.65	0.16	0.24	0.16	0.89	0.32	2.69	1.01	76.7	90.0	74.1	76.0
20	0.62	0.13	0.27	0.12	0.89	0.25	2.27	1.04	40.5	96.9	26.1	84.0
21	0.41	0.13	0.18	0.13	0.59	0.26	2.30	1.00	91.7	94.7	96.9	90.9
22	0.57	0.19	0.23	0.20	0.80	0.40	2.46	0.96	89.4	91.3	96.7	71.4
23	0.33	0.19	0.28	0.19	0.61	0.38	1.22	1.00	96.5	96.9	97.6	70.0
26	0.19	0.13	0.12	0.09	0.31	0.22	1.58	1.45	97.8	93.0	95.9	85.7
28	0.53	0.17	0.21	0.16	0.74	0.34	2.58	1.04	73.4	73.4	95.1	32.1
29	0.83	0.24	0.29	0.20	1.12	0.45	2.88	1.19	49.7	84.9	95.1	88.4
30	0.73	0.12	0.32	0.09	1.05	0.22	2.29	1.34	67.4	86.2	91.4	54.5
31	0.64	0.19	0.28	0.13	0.91	0.32	2.31	1.45	34.7	93.2	71.3	75.9
32	0.20	0.19	0.43	0.14	0.63	0.33	0.49	1.30	96.3	84.2	62.6	64.3
34	0.61	0.19	0.29	0.13	0.91	0.33	2.09	1.45	50.6	72.3	97.2	49.7
35	0.60	0.20	0.22	0.13	0.82	0.33	2.92	1.55	70.6	91.5	91.0	73.4
36	0.31	0.23	0.15	0.17	0.46	0.39	1.98	1.37	90.0	75.7	92.8	45.7
37	0.47	0.16	0.19	0.16	0.66	0.31	2.46	1.01	46.4	97.7	90.9	65.7
38	0.55	0.14	0.25	0.16	0.79	0.29	2.24	0.86	62.5	98.2	96.0	92.0
39	0.34	0.21	0.14	0.09	0.48	0.30	2.44	2.23	52.1	98.2	93.1	81.5
40	0.46	0.39	0.43	0.23	0.89	0.63	1.08	1.20	44.0	91.1	75.5	67.1
41	0.65	0.66	0.28	0.23	0.93	0.89	2.55	1.62	40.1	93.6	94.9	77.9
42	0.79	0.27	0.27	0.16	1.05	0.43	2.98	1.22	60.6	87.9	96.4	69.2
43	0.51	0.16	0.27	0.09	0.78	0.24	1.89	0.87	53.3	69.8	82.0	43.3
44	0.90	0.18	0.34	0.10	1.24	0.28	2.68	1.27	20.0	94.2	75.1	83.8
45	0.27	0.30	0.15	0.16	0.42	0.46	1.76	1.29	95.4	81.6	97.6	80.9
46	0.47	0.27	0.49	0.23	0.96	0.50	0.98	1.32	82.5	56.9	79.4	50.4
47	0.58	0.40	0.20	0.14	0.78	0.54	2.85	1.55	40.9	49.1	91.0	86.2
48	0.47	0.30	0.63	0.12	1.10	0.41	0.74	1.80	93.7	37.7	61.5	61.0
50	0.28	0.19	0.15	0.07	0.43	0.26	1.85	1.27	48.1	60.3	92.2	93.5

concentration was recorded in stand 14 during summer with value equal 4.78 mg g^{-1} d. wt, while the lowest concentration was recorded in stand 28 during winter where the values did not exceed 1.44 mg g^{-1} d. wt. Statistical analysis for data of potassium concentrations (Table 5) revealed that the single factor effect was highly significant. Regionality had a great effect followed by the interaction, while seasonality role was less effective.

Calcium was more concentrated in *Z. spinosa* tissue during summer than winter, while magnesium showed an opposite trend. Concentrations of calcium in plants ranged between 10.67 and 23.67 mg g^{-1}d.wt. in summer, while in winter it varied from 6.33 to18.00 mg g^{-1}d.wt.. The highest concentration was recorded in plants sampled from stand 35 during summer. Statistical analysis (Table 5) revealed that the effect of single factors were highly significant. Seasonality had the dominant effect followed by regionality, and interaction.

L. pyrotechnica plants had more calcium in summer than in winter, while magnesium showed opposite trend. Concentrations of calcium in plants ranged between 3.33 and 6.76 mg g^{-1} d.wt. in summer, while in winter it fluctuated between 3 and 12.33 mg g^{-1} d.wt. The highest value of calcium concentrations was recorded in plants at stand 49 during winter. Statistical analysis (Table 5) revealed that the effect of the two single factors were highly significant. Regionality had the major effect followed by the interaction, while seasonality was less effective.

Concentrations of magnesium in *Z. spinosa* tissues varied from 1.20 mg g^{-1}d.wt. and 8.60 mg g^{-1}d.wt. in summer and from 1.60 mg g^{-1}d.wt. to 9 mg g^{-1}d.wt. in winter. The highest concentration was detected in stand 43 during winter. Statistical analysis (Table 5) indicated that single factors significantly affected Mg^{+2} concentrations. Regionality had the greatest effect followed by the interaction, and seasonality.

Concentrations of magnesium in *L. pyrotechnica* plants ranged between 0.60 and 4 mg g^{-1} d.wt. in summer and between 3.40 and 7 mg g^{-1} d.wt. in winter. The highest concentration was detected in stand 45 during winter. The effect of single factor was highly significant (Table 5). Seasonality had the dominant effect followed by regionality, and their interaction was less effective.

Chlorides concentrations in *Z. spinosa* tissues were higher in winter season than those obtained during summer, except at 10 stands where the reverse was true. Its concentrations ranged between 4.37 and 22.48 mg g^{-1}d.wt. during summer and between 7.10 and 31.95 mg g^{-1}d. wt. during winter. Regionality had the dominant effect (Table 5) followed by their interaction, and seasonality.

In *L. pyrotechnica* plants chlorides concentrations were also higher in winter season than in summer, except at stands 1, 2, 14 and 20 where their values were higher in summer than in winter. The concentrations of Cl^- ranged between 4.37 and 17.75 mg g^{-1} d.wt. during summer and between 9.47 and 24.85 mg g^{-1} d.wt. during winter. The single factors as well as their interaction (Table 7) were highly significant in affecting chlorides contents. Regionality had dominant effect followed by the interaction, and then seasonality.

Both sulphates and phosphates in *Z. spinosa* had low values in summer and winter compared with Cl^-. Sulphates fluctuated between 0.02 and 0.08 mg g^{-1}d.wt. in winter and between 0.04 and 0.16 mg g^{-1}d.wt. in summer. The highest value of sulphates in plants was recorded at stand 30 during summer. Single factor effects in table 5 were highly significant. Seasonality had the dominant effect followed by the interaction and regionality role was subsidiary.

Sulphates concentration in *L. pyrotechnica* fluctuated between 0.09 and 0.01 mg g^{-1} d.wt. in winter and between 0.08 and 0.01 mg g^{-1} d.wt. in summer. The highest concentration in plants was recorded in stand 49 during winter. The effect of single factor was highly significant (Table 5). Regionality had the dominant effect followed by the interaction, but seasonality effect was negligible.

Phosphates concentrations of *Z. spinosa* plants ranged between 0.01 and 0.06 mg g^{-1}d.wt. in winter, while in summer it ranged between 0.02 and 0.05 mg g^{-1}d.wt.. Seasonality and regionality had highly significant effects on phosphate concentration. The interaction had the great effect, while the regionality role was subdominant and seasonality role was the minor ones.

In *L. pyrotechnica* phosphates concentrations ranged between 0.02 and 0.03 mg g^{-1} d.wt. in winter, while in summer it ranged between 0.02 and 0.05 mg g^{-1} d.wt. The effect of a single factor was not significant (Table 5). The dominant role was occupied by the interaction.

The correlation analysis was carried out between the concentrations of major soluble ions in *Z. spinosa* shoots and that in soil samples. Table 6 shows that concentrations of Ca, Mg and SO_4 in plant shoots correlated negatively (non-significant) with those in the soil in both winter and summer. PO_4 showed the opposite trend (non-significant positive correlation) in both season. Cl was negatively correlated (non-significant) in winter and positively correlated in summer (non-significant). Na had positive non-significant correlation in summer and positive highly significant correlation in winter. K had positively non-significant correlation in summer and negative significant ones during winter.

For *L. pyrotechnica* Table 6 shows that the concentrations of Mg^{+2} in plant shoots correlated negatively (non-significant) with those in the soil in both

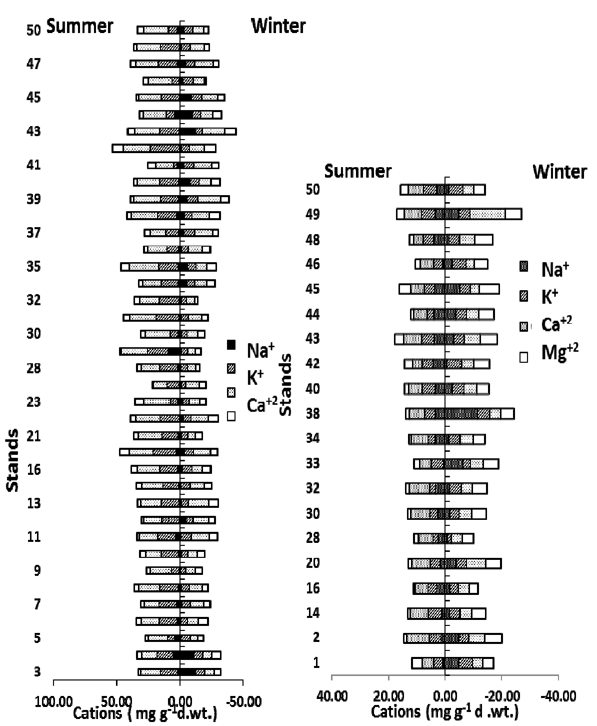

Fig. 5. Concentrations of major soluble cations (Na^+, K^+, Ca^{+2}, and Mg^{+2}) expressed in mg g^{-1} d.wt. in *Zilla spinosa* and *Leptadenia pyrotechnica* plants in summer and winter seasons

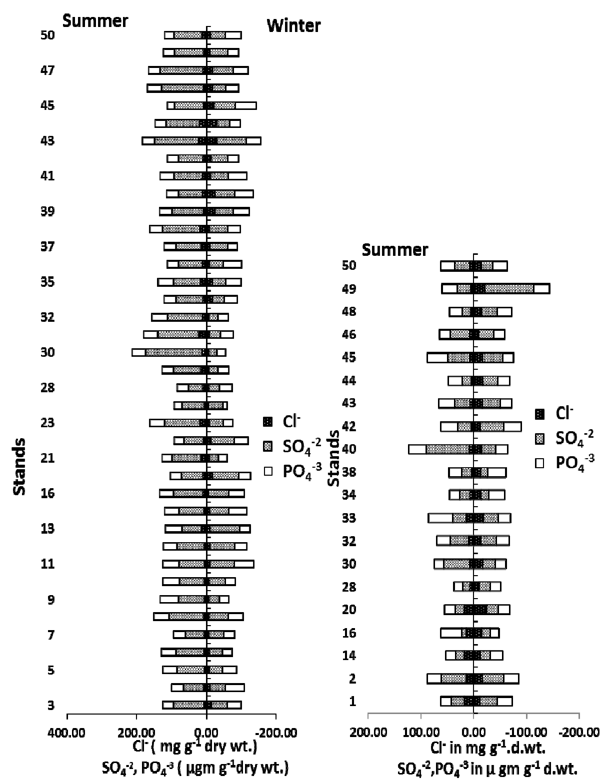

Fig. 6. Concentrations of Cl- (in mg g-1d.wt.) and SO4-2 and PO4-3 (in µgm g-1 d.wt.) in *Zilla spinosa* and *Leptadenia pyrotechnica* plants collected from different studied stands in summer and winter seasons

Table 4. Chlorophyll (Chl *a*, Chl *b* and Chl *a+b*) concentrations (mg g-1 f.wt.), chlorophyll *a/b* ratio (Chl *a/b* ratio) and chlorophyll stability index (CSI, %) at different stands inhabited by *Leptadeina pyrotechnica* plants, in summer and winter seasons

St.	Chl *a*		Chl *b*		Chl *a+b*		Chl *a/b*		CSI *a*		CSI *b*	
	S	W	S	W	S	W	S	W	S	W	S	W
01	0.23	0.22	0.08	0.18	0.30	0.40	2.96	1.26	92.35	72.31	94.45	45.12
02	0.29	0.16	0.10	0.13	0.39	0.40	2.93	1.30	66.24	97.70	93.28	81.66
14	0.23	0.14	0.13	0.07	0.35	0.39	1.80	2.09	59.91	96.88	48.42	81.37
16	0.31	0.22	0.13	0.18	0.45	0.38	2.37	1.25	50.77	65.53	67.24	45.12
20	0.44	0.17	0.19	0.10	0.62	0.38	2.32	1.90	92.00	95.28	81.34	89.43
28	0.40	0.21	0.14	0.10	0.54	0.36	2.85	2.20	34.16	90.22	77.49	91.49
30	0.27	0.24	0.15	0.12	0.42	0.33	1.85	2.08	70.64	70.97	89.14	54.99
32	0.20	0.16	0.11	0.09	0.31	0.31	1.76	1.85	71.97	69.85	80.98	50.44
33	0.45	0.18	0.17	0.09	0.62	0.30	2.69	1.96	31.08	82.16	72.73	71.37
34	0.31	0.26	0.14	0.11	0.45	0.30	2.46	2.28	35.71	63.80	56.67	73.15
38	0.24	0.20	0.09	0.08	0.33	0.29	2.70	2.47	58.75	70.10	77.04	58.93
40	0.35	0.22	0.14	0.08	0.50	0.29	2.48	2.70	36.80	90.25	86.90	73.62
42	0.32	0.28	0.11	0.10	0.43	0.28	2.98	2.85	77.59	87.01	91.08	76.88
43	0.24	0.18	0.08	0.07	0.31	0.27	2.96	2.48	87.58	86.78	94.58	81.70
44	0.37	0.22	0.14	0.08	0.52	0.27	2.63	2.93	52.95	95.65	86.39	91.91
45	0.40	0.17	0.15	0.06	0.55	0.25	2.75	2.72	61.62	68.94	91.63	89.04
46	0.32	0.23	0.11	0.10	0.43	0.25	2.94	2.41	35.00	65.59	92.57	77.61
48	0.33	0.28	0.11	0.12	0.45	0.23	2.95	2.36	28.95	67.04	88.14	66.12
49	0.33	0.20	0.13	0.09	0.46	0.21	2.56	2.20	47.95	98.36	95.73	85.41
50	0.29	0.22	0.10	0.07	0.39	0.29	2.92	2.89	48.18	74.11	86.31	90.51

Table 5. Statistical analysis for the inorganic components (anions and cations) of *Zilla spinosa* and *Leptadenia pyrotechnica* plants, showing analysis of variance (F-value) and determination coefficient (η^2)

Plant species		*Zilla spinosa*		*Leptadenia pyrotechnica*	
Parameters	S.O.V	F	η^2	F	η^2
Na^+	Seasonality	144.3**	0.05	3.84*	0.01
	Regionality	40.33**	0.50	31.02**	0.31
	Interaction	35.91**	0.45	67.71**	0.68
K^+	Seasonality	4628.4**	0.47	7.08*	0.10
	Regionality	70.05**	0.27	28.95**	0.59
	Interaction	69.04**	0.26	16.14**	0.31
Ca^{+2}	Seasonality	740.8**	0.53	11.22**	0.03
	Regionality	9.8**	0.27	17.49**	0.61
	Interaction	7.32**	0.20	10.47**	0.36
Mg^{+2}	Seasonality	51.2**	0.25	367.31**	0.75
	Regionality	2.47**	0.44	4.24**	0.17
	Interaction	1.73*	0.31	1.98*	0.08
Cl^-	Seasonality	63.8**	0.05	113.80**	0.27
	Regionality	17.98**	0.58	9.93**	0.43
	Interaction	11.52**	0.37	6.76**	0.30
SO_4^{-2}	Seasonality	242.67**	0.44	0.16 ns	0.02
	Regionality	3.48**	0.24	3.14**	0.56
	Interaction	4.62**	0.32	2.36*	0.42
PO_4^{-3}	Seasonality	5.56*	0.02	1.04 ns	0.04
	Regionality	9.43**	0.46	1.47 ns	0.40
	Interaction	10.74**	0.52	2.07*	0.56

**Significant at 0.01 confidence level; *Significant at 0.05 confidence level

winter and summer. Ca^{+2}, K^+ and SO_4 showed the opposite trend in both season. Cl^- and PO_4 were negatively correlated in summer and positively in winter, but both correlations were statistically non-significant. Na^+ had negatively significant correlation in summer and positively non-significant ones in winter.

Metabolic components

As shown in Fig. 7, the concentrations of soluble sugars in the *Z. spinosa* measured in summer season were higher than those in winter in most studied stands. The highest value of soluble sugars in the plants collected from 26 stands was 132.83 mg g^{-1}d. w.t, and was obtained in summer. The lowest value recorded in winter was 24.52 mg g^{-1}d. w.t, at stand 43. Statistical analysis (Table 2) revealed that the effects of single factor and their interaction were highly significant. The interaction had the dominant effect followed by regionality.

The concentrations of soluble sugars in the *L. pyrotechnica* measured in winter season were higher than those in summer except in 7 stands. The highest value of soluble sugars reported in the plant samples collected from stands was 120.4 mg g^{-1} d.wt. in summer (Fig. 7). The lowest value was recorded also in summer, in stand 48. In the summer, the concentrations of soluble sugars ranged between 20.6 and 120.4 mg g^{-1} d. wt, while in winter it ranged between 29.37 and 79.92 mg/g d. wt. The effects of the two factors (Table 2) were highly significant. The interaction had the greatest effect, followed regionality.

Concentrations of soluble proteins in *Z. spinosa* are shown in Fig. 7. In summer, the concentrations of soluble proteins were higher than in winter except in 4 stands. Concentrations of soluble proteins ranged between 8.68 and 29.13 mg g^{-1}d. wt. during summer. During winter, it fluctuated between 7.48 and 23.43 mg g^{-1}d. wt. The highest value was recorded during summer at stand 15, while the lowest value was recorded during winter in stand 34. Statistical analysis revealed that the effects of single factors and their interaction were not significant (Table 2).

During summer, the concentrations of soluble proteins in *L. pyrotechnica* plants were significantly higher than in winter (Fig. 7). The highest value was recorded during winter in stand 49 and it was equal with 12.32 mg g^{-1} d. wt, while the lowest value was recorded during summer in stand 16. There were small variations in the plants soluble protein contents in *Leptadenia.* Soluble protein content showed irregular changes with stand differences. The plants in stands 16 had the lowest protein content over the year under srudy. Statistical analysis showed that the effects of single factors and their interaction were not significant (Table 2).

Comparing with the other metabolites, the content of total free amino acids in *Z. spinosa* (Fig. 7) was higher in summer than in winter except in 8 stands. The values ranged between 2.61 and 9.37 mg g^{-1}d.wt. in winter and between 2.41 and 17.63 mg g^{-1}d. w.t in summer. The highest values of amino acids content was recorded at stand 35 and in stand 45 during winter. Statistical analysis (Table 2) indicated that the single factors and their interaction had highly significant effect. The interaction had the dominant effect followed by regionality, and the seasonality.

As shown in Fig. 7, the content of total free amino acids in *Leptadenia* shoot showed lower values than other metabolites. The concentration ranged between 1.29 and 6.61 mg g^{-1} d.wt. in winter, and between 0.89 and 3.15 mg g^{-1} d.wt. in summer. The highest values of amino acids content was recorded at stand 20 during winter, and stand

Table 6. Correlation coefficient values (r) between the internal mineral elements in the *Zilla spinosa* and *Leptadenia pyrotechnica* and their contents in the soil samples in both summer and winter seasons

Summer		
Sp. Para.	*Leptadenia pyrotechnica*	*Zilla spinosa*
Ca^{2+}	0.129	-0.214
Mg^{2+}	-0.133	-0.139
Na^{+}	-0.587**	0.059
K^{+}	0.040	0.116
Cl^{-}	-0.304	0.026
SO_4^{2-}	0.268	-0.249
PO_4^{3-}	-0.065	0.215
Winter		
Sp. Para.	*Leptadenia pyrotechnica*	*Zilla spinosa*
Ca^{2+}	0.074	-0.159
Mg^{2+}	-0.106	-0.003
Na^{+}	0.243	0.359*
K^{+}	0.137	-0.333*
Cl^{-}	0.133	-0.019
SO_4^{2-}	0.017	-0.046
PO_4^{3-}	0.234	0.060

* Significant at 0.05 confidence level. ** Significant at 0.01 confidence level.

28 during summer. The effects of single factors as well as their interaction, were statistically significant (Table 2). The regionality had dominant effect, followed by the interaction between both regionality and seasonality.

Discussion

The obtained data showed that soil water content of Wadi El-Assiuty stands under study was very low over the year of experiment. It suffered from severe aridity. Although rain fall rarely, a rise in ground water table may magnify the chance for serving perennials. On the other hand, unless rainfall occurs, the underground water is considered the main resource for surviving plants in the main channel of the Wadi (Salama *et al*., 2013a, 2013b, 2013c, 2013d; Monier *et al*., 2013; 2014; Salama *et al*., 2015b and Salama *et al*., 2016). However, the situation is different in the deltaic plain where there are two ways for water supply. Firstly, the Nile water seeped into the porous deposits, and secondly, the ground water pumped up in the newly reclaimed lands, and thus plays a main role to increase the water content of the deltaic soil.

The soil organic matter is correlated with the vegetation. The very scattered vegetation and high temperature in summer affected the soil content of organic matter. Therefore, the soil organic matter was low. The estimated pH values in the soil solution at the different studied stands in Wadi El-Assiuty tended to be slightly alkaline. In arid regions, where soluble salts of sodium (such as Na_2CO_3) may accumulate, and thus an alkaline pH is usually attained (El-Khatib, 1993). These results were consistent with the general characteristics of soils from arid regions and their relationships with climate and vegetation, which was described by many authors (Kassas and Imam 1954; Ayyad and Ammar 1974; Younes *et al*., 1983; Zahran and Willis, 1992; El-Khatib, 1993; Salama *et al*., 2015; Salama *et al*., 2016). Such studies indicated that the soils of arid lands had a low level of organic matter, alkaline in reaction (pH) at the surface, as well as a low biological activity.

El-Khatib (1993) stated that the soil depth is an important factor restricting the type of vegetation in the Egyptian desert wadis. A thin soil will be moister during the rainy season, but will be dried by the approach of the dry season, here ephemeral vegetation appear. A deep soil allows the storage of some water in the subsoil. This will provide a continuous supply of moisture for the deeply seated roots of the herbaceous perennials, under-shrubs, shrubs and trees.

Total soluble salts were generally high during summer. This may be due to the severe aridity and low moisture content in the wadi. Total soluble salts in the soil were affected by the evaporation and precipitation rate. High rates of evaporation lead to salt accumulation in the unsaturated zone, which can be dissolved by infiltrating water (Tizro and Voudouris, 2007). Consequently, electric conductivity of the soil solutions of the studied area was also relatively high. This reflects the richness of these habitats with soluble salts. Therefore, evaporation process in semi-arid areas leads to ionic enrichment of ground water, resulting in an increase in salinity.

The estimated soluble salts in the soil were dominated by Ca^{+2} and Cl^{-}. The salts concentration was high in summer, whereas this could be due to high evaporation which concentrated the soil solution. The present data are in agreement with the results obtained by Badri *et al*., (1996), Salama *et al*. (2012b). In general, phosphates were the lowest estimated anion in the soil of all stands and in both seasons. Also, the bicarbonate content in the soil samples was generally very low.

There are two adaptive strategies, which have been developed in plants to overcome the external stress. Plant cells tend to readjust their osmotic potential to prevent water loss that can be achieved by uptake of inorganic ions from the exterior, and by de novo synthesis of compatible solutes as soluble proteins, amino acids and soluble sugars acting as osmolytes (Bohnert *et al*., 1995; Bohnert and Shen, 1999; Serrano *et al*., 1999; Kamel, 2002; Du Jinyou *et al*., 2004; Sayed *et al*., 2013). The osmotic readjustment is quickly induced by the changes in ion fluxes compared with the synthesis of compatible solutes (Wyn Jones and Pritchard, 1989; Lew, 1996).

Under the effect of high temperatures in summer and the limited water resources, the water content in *Z. spinosa* and *L. pyrotechnica* increased significantly than that in winter. Under the effect of high temperatures, plant transpiration continued through cuticle when stomata can be closed (Schreiber, 2001).

The selected species for the current stufy tended to increase significantly their content of chlorophyll *a* and chlorophyll *b* in summer; such results agreed with what was found by Elhaak *et al*. (1992).

Studied plants maintained their chlorophyll *a/b* ratio above 2. According to Quarmby and Allen (1989), the two main essential (chlorophyll *a*) and accessory (chlorophyll *b*) pigments are normally present in the ratio of about 3:1. The decreased ratio of clorophyll *a/b* in the leaves may be due to an increase in chlorophyll *b* relative to chlorophyll *a*, or due to degradation of chlorophyll *a*.

It has been demonstrated that in higher plants chlorophyll *b* is converted into chlorophyll *a* as part of chlorophyll *a*,*b* inter-conversion cycle, which permits plants to adapt to changing light condition (Ito *et al*., 1996).

The chlorophyll stability index reflects how plant pigments can tolerate the severe high temperatures. So, it can be considered as a good indicator for desert plants. Generally, chlorophyll *a* and *b* stability index in the hereby study was higher in summer than that estimated in winter. The present data indicated also that chlorophyll *b* showed more stability than chlorophyll *a* in summer in response to both higher temperature levels and soil moisture depletion, and this result coincide with what was found by Radwan (2007). Stability index of chlorophyll is higher in the studied plants under high temperatures, and that agreed with Farghali (1998b), who reported that the decreased of chlorophyll content is compensated by an increased chlorophyll stability index. He also found a significant correlation between both chlorophyll content and CSI with water content, soluble proteins, Mg, K and Fe. The chlorophyll stability index did not decrease beyond 60%, and these results agreed those of Elhaak *et al*. (1992).

Al-Tantawy (1983) and Abd El- Maksoud (1983; 1987) reported that desert plants attained higher concentrations of chlorophyll and carotenoids due to their adaptive mechanisms under dry conditions.

Osmoregulation is the easier way to overcome the external stress. There are two ways to face the environmental stress. The first is quickly and depends on the inorganic solutes. The absorption, excluding or extraction on the most familiar osmo-regulator inorganic ions as Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and Cl^{-} is very helpful to readjust the osmotic gradient through environment and stressed plants (Bohnertand Shen, 1999; Serrano *et al*., 1999; Kamel, 2002; Du Jinyou *et al*., 2004, Kamel, 2008; Sayed *et al*., 2013). The effect can occur immediately. The second way depends on the accumulation of organic compatible solutes as soluble sugars, soluble proteins, amino acids etc.; this process needs longer time, to synthesize the different organic solutes (Wyn Jones and Pritchard, 1989).

Under drought conditions, plants tend to raise their osmotic pressure to overcome the external condition; also, the high temperature in deserts increases the rate of evaporation, which concentrates the salt in the soil solution. Even more, increases of the rate of transpiration will increase the trend of dragging of more salts into the shoots, and will increase the cells turgidity. The accumulation of inorganic solutes is the easy and quick response, but may cause hazards which can lead to the plants' death. So, the plants must absorb, exclude and translocate the solutes, inside the different organs, to ensure the charges balance and to avoid the toxicity (Sunkar, 2010).

Generally the molar summation of accumulated cations was more than that of accumulated anions, whether in winter or summer. In summer, the plants decrease their biological activity. So, they accumulate the necessary amounts of organic solutes to maintain the cell turgidity in the live branches. On the other hand, in winter the biological activity will start again and the accumulated organic solutes will be used. So, the plants will tend to

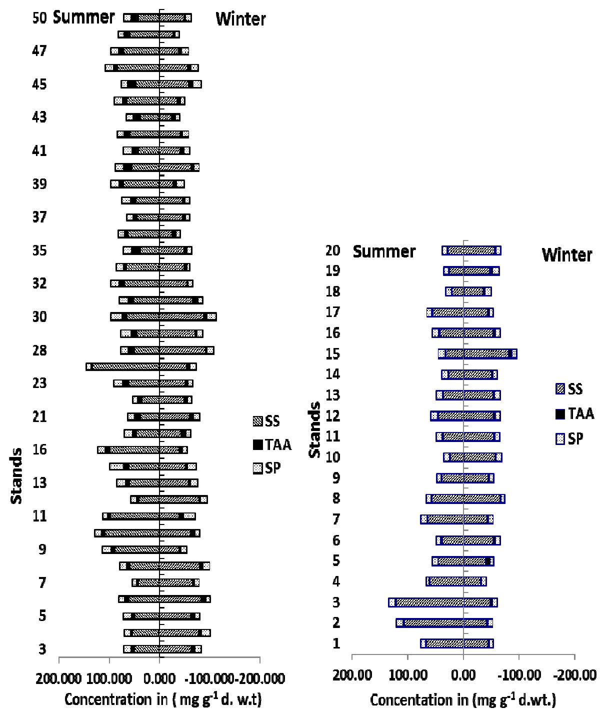

Fig. 7. Concentrations of soluble sugars (SS), soluble proteins (SP), and total free amino acids (TAA) expressed as mg g^{-1}d.wt. in *Zilla spinosa* and *Leptadenia pyrotechnica* plants growing in Wadi El-Assiuty during summer and winter seasons

accumulate inorganic solutes instead of organic solutes which are needed in biological processes.

Apparently, the control of Ca^{+2} and Cl^{-}uptake from soils, and the partitioning of these ions within plants, is an essential component tolerance. Thus, the studied species depended more on Ca^{+2} and K^{+}. These results agreed with what was found by Kamel (2008). According to Wyn Jones (1981), Na^{+} and Cl^{-} are mostly accumulated in the vacuole, which leads to an increase in vacuole osmotic pressure.

Due to the limited available amounts in the soil, sodium accumulated in fewer amounts compared with potasium. *L. pyrotechnica* had the lowest K^{+} concentration. K^{+} is preferred in the cytoplasm due its beneficial effect on enzymes activity and protein synthesis and less toxicity on the metabolism (Wyn Jones *et al*., 1979).

The results indicate that calcium and magnesium were accumulated in considerable amounts in the studied plants. *Z. spinosa* tended to accumulate Ca^{2+} in higher amounts compared to *L. pyrotechnica*. Kamel (2008) reported that succulent species accumulated considerable amounts of Ca^{2+} and Mg^{2+} under drought stress.

To avoid chloride toxicity, the plants were resorted to accumulate sulfate. *Z. spinosa* accumulated more sulphates in summer than in winter. It is known that plants tend to accumulate more sulphates in dry seasons or habitats, to maintain their succulence. In addition, sulphate is needed for biosynthesis of amino acids which contain thiol (-SH) group.

Phosphorus is found in the soil as phosphates. Uptake of phosphates correlates with plant productivity and growth (Nye and Tinker, 1977). Phosphates appeared in the studied plants in small amounts. This may be due to the rapid incorporation of phosphates in the plant metabolism, or poverty of the soil with phosphates.

Contents of some inorganic solutes inside plants were correlated significantly with their contents in the soil solution. In summer, a negative correlation was detected between Na^+ concentration in *L. pyrotechnica* and soil solution. In winter, Na^+ correlated positively in *Z. spinosa*. Also in winter K^+ correlated negatively in *Z. spinosa*. These varied correlations reflected the effect of prevailing environmental condition on the plants' strategy of each species to overcome the external stress (El-Sharkawi, 1977a, 1977b).

The studied species are frequently adapted against drought conditions, prevailing in their habitats during summer season, by accumulation of considerable amounts of soluble sugars, soluble proteins and amino acids than in winter, when the prevailing ecological conditions may be fairly more favorable for such plants. These results agreed with what was found by Salama *et al*. (2012b) on *Ochradenus baccatus* in Wadi Qena and Sayed *et al*. (2013) in three desert plants in Wadi Natash.

The studied plants showed a slightly increase in soluble sugars accumulation. *Z. spinosa* plants tended to increase their soluble sugars, more than *L. pyrotechnica*, especially during summer. Irigoyen *et al*. (1992) and Mohammadkhani and Heidari (2008) found that plants under heat or water stress tend to accumulate soluble sugars high enough for generating considerable osmotic potential. Prado *et al*. (2000) stated that soluble sugars play an important role in keeping water balance under drought stress in plants.

The response of plants to their environmental stress may take two ways, either by increasing their water binding molecules, or by preventing the incorporation of amino acids into proteins. Some of the xerophytic species may adjust osmotically to stress by the contribution of nitrogen metabolites (Rayan and Farghali, 2007). Soluble protein content in the studied species decreased significantly during winter. This supported the observation of Dhindsa (1991), who reported that the drought stress induced inhibition of protein synthesis. Meanwhile, low concentrations of soluble proteins in both seasons, could be associated with low K^+ content.

Generally, amino acids content in the studied plants was low and varied from one species to another. Low content of TAA may be due to the enhancement of its incorporation into proteins (Huffaker and Peterson, 1974). Generally, total free amino acids content, in the studied species, was significantly higher in summer than the data reported for winter. These results are in accordance with what was found by Migahid (2003). The marked differences in concentration of amino acids among species investigated were either due to regionality or seasonality and were attributed to the decline in some amino acids during water, temperature or salt stress (Palfi, 1965; Mohamed, 1988). The adaptive response against such decline is an overall increase in the concentration of other soluble nitrogenous compounds (Barnett and Naylor, 1966; Hsiao, 1973).

Thus from the previous observations about soil elements and metabolic constituents in the studied species, there are close relationships between the presence of soluble K^+, Na^+ and Cl^- in high concentrations in the plants during the summer season on one hand and the presence of soluble sugars and soluble proteins in plant species on the other hand. Although such a relationship is not quite clear, especially concerning the mechanisms and nature of metabolic relations, yet it can be at least a new point worthy to investigate later on. The presence of such soil components may stimulate the synthesis of great amounts of metabolic constituents in such plants e.g., carbohydrates, proteins and amino acids, which certainly help their osmo-regulation under drought conditions. Such metabolites might serve as energetic materials for plants to persist (e.g. respiratory material) or as raw material for metabolic processes that enable plants to maintain a fair rate of growth during the dry season. Based on data hitherto presented in the current study, it is quite clear that *Z. spinosa* is better adapted to drought conditions than *L. pyrotechnica*, prevailing in the area under study. This is judged by the average metabolic potentiality of *Z. spinosa*, where soluble metabolites (soluble sugars and soluble proteins) are relatively much higher than in *L. pyrotechnica*.

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