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Amino Acids Content of Different Plants from South Sinai as Affected by Different Habitat Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The objectives of this work were to determine the amino acids contents of ecophysiologically different plants on a seasonal basis and the relationship among amino acids and soil properties. The plant species investigated were Zilla spinosa and *Peganum harmala* in the spring and autumn seasons during Wadi El-Arbaeen (WAR) and Wadi Ghrandal (WGH). The values of pH and electric conductivity (EC) of soil solutions at the up, mid and down streams were higher in WGH than in WAR, while unlike of mineral analysis i.e., S-, Cl-, Ca2+, Mg2+, Na+ and K+. Amino acids content in the two studied species were different in the spring and autumn seasons under the two locations. According to the rank method, the amino acids (proline, aspartic acid, glutamic acid, leucine, isoleucine and alanine) concentrations of the autumn season were greater than those of the spring season in Z. spinosa under WAR, and in P. harmala in WAR and WGH., while the spring season were higher than autumn season in Z. spinosa under WGH. While the amino acids histidine, cysteine and methionine were the least. Based on PCA, the amino acids can be classified into four groups. The amino acids i.e. aspartic acid, cysteine, methionine, phenylalanine,

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tryptophan and proline were positively correlated with pH, K+, Na+, S-, Ca2+, Cl-, EC and Mg2+ in the spring and autumn seasons in WAR. On the other hand, the amino acids aspartic acid, methionine and isoleucine with pH, K+, Na+, water content (WC) and EC, as well as the amino acid tryptophan with S-, Cl- and Ca2+ showed positive correlation in the spring and autumn seasons in WGH. It seemed that the Z. spinosa and P. harmala were adapted with drought conditions in WAR and WGH.

Key words: Amino acids; soil analysis; Zilla spinosa; Peganum harmala.

1. INTRODUCTION

South Sinai, an arid to extremely arid region, is characterized by an ecological uniqueness due to its diversity in landforms, geologic structures, and climate that resulted in a diversity in vegetation types, which is characterized mainly by the sparseness and dominance of shrubs and sub-shrubs and the paucity of trees [1,2], and a variation in soil properties [3]. Two plants, namely, the *Zilla spinosa* L. (*Z. spinosa*) and *Peganum harmala* L. (*P. harmala*) are herbs that have been widely used in animal forage or medicinal purposes particularly in South Sinai.

Z. spinosa has important uses in the folk medicine and is one of the most common plant species of *Crucifereae* family. It is used as a drink against kidney and gall bladder stones. Previous phytochemical study of *Z. spinosa* led to the separation of glucosinolates of progotrin, goitrin, free sinapine, and some other chemical constituents which have biological activities comprising antioxidant, hepatoprotective, cytotoxic and antiviral activities [4]. *P. harmala* is the only salt-tolerant perennial herb in the *Peganum* genus of the family *Zygophyllaceae* [5]. Also, it is a drought tolerant plant in arid parts of Middle East and North Africa, which thrives in poor sandy or gritty soils [6]. *P. harmala* is used as traditional medical herb since earliest times as a remedy for a wide range of complaints [7]. Traditionally, the seeds have been used to relieve pain, to promote blood circulation, and to treat rheumatism and illnesses such as cough and asthma [8]. It is also effective in the treatment of dermatosis, hypothermia, and cancer; in addition, it has a hepatoprotective effect [9].

Amino acids are organic molecules that contain nitrogen, carbon, hydrogen, and oxygen, and have an organic side-chain in their structure, a characteristic that distinguishes the different amino acids [10]. Proteins are derived from amino acids and are essentially the basic component of all living cells [11]. Amino acids can play different roles in plants; they can act as stress-reducing agents, source of nitrogen and hormone precursors [12]. Also, they regulate ion transport and stomatal opening and affect the synthesis and activity of enzymes, gene expression, and redox homeostasis, helping the plants to cope with the harmful effects of osmotic stress [13]. In the soil, they can be found in different forms, however, their half-life is short and their absorption by plants is only possible due to the presence of transporters in the roots [14]. The main amino acids synthesized by plants are the glutamate, glutamine, and aspartate, and from these other amino acids may be formed. Glutamate stands out for being the first amino acid in which the nitrogen absorbed by the plants is incorporated and from it, a range of amino acids can be obtained through the activity of aminotransferases [10,15]. Proline is one of the most common compatible osmolytes in water-stressed plants. Such metabolism of Proline is inhibited when Proline accumulates during dehydration and it is activated when rehydration occurs [16]. The objective of this study was to compare the amino acids of two plants *Z. spinosa* and *P. harmala* in their natural habitats under spring and autumn conditions at Wadi El-arbeen and Wadi Gharndal in South Sinai, Egypt.

2. MATERIALS AND METHODS

2.1 Study Area

Two locations Wadi El-Arbaeen (WAR) and Wadi Ghrandal (WGH) in South Sinai were studied. Samples of the two studied plants and soil were collected from these two locations. In order to assess the results seasonally, the plant and soil samples were collected from the two locations on the 23rd of March 2015 during spring and 27rd of September 2015 during autumn.

2.2 Plant Material

Two plants were used in this study, namely, *Zilla spinosa* L. (*Z. spinosa*) and *Peganum harmala* L. (*P. harmala)*. *Z. spinosa* L. (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 [17]. *P. harmala* (*Zygophyllaceae*) is a perennial herbaceous, glabrous plant, which may grow to 30-100 cm in height. It has alternately spaced thong-like leaves, which have a strong deterrent odor when rumpled. Opposite to the leaves are solitary white flowers with green veins. The flowering period is March to April. The fruits are globose capsules with 3 chambers containing many angular blackish seeds [18].

2.3 Soil and Amino Acids Analysis

Soil samples were collected from a soil profile at a depth of 0 to 40 cm during the spring and autumn seasons in the two locations WAR and WGH. Three replicates were taken from each stands and carried to the laboratory in plastic bags. The physical and chemical properties of soil analyzed included pH of the soil extract, electrical conductivity (EC), and mineral content (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- and S^-) estimated using a saturation paste [19]. Total amino acids contents were estimated using Clait Amino Acid Analyzer SW [20] at Central Laboratories, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

2.4 Statistical Analysis

The data collected in this study was analyzed using Rank sum and principal component analysis (PCA). Rank sum (RS) = Rank mean ($\bar{R}$) + Standard deviation of rank (SDR) and SDR= $(S_i^2)^{0.5}$ [21]. The PCA was performed for better understanding of the relationships among amino acids and soil properties using a computer software program PAST version 2.17c.

3. RESULTS AND DISCUSSIONS

3.1 Soil Properties

Mechanical and chemical properties of soil at 0-40 depth from up, mid and down streams in Wadi El-Arbaeen (WAR) and Wadi Ghrandal (WGH) are shown in Table 1. The coarse sand and fine sand percentages of soil at 0-40 depth from up, mid and down at WGH were higher than in WAR. The highest values of silt content were registered in the upstream for WGH, as well as in mid and down streams for WAR. Meanwhile, the clay content had the highest values in up and mid streams at WGH, and downstream at WAR. The values of soil water content in winter season were higher than in the summer at the three streams in the two studied wadis. The values of pH and electric conductivity (EC) of soil solutions were higher in the three streams of WGH than in WAR. On the other hand, the values of mineral elements (S^-, Cl^-, Ca^{2+}, Mg^{2+}, Na^+ and K^+) in the three streams of WAR were higher than WGH. The pH values fluctuated in the basic range at the three streams during the two wadis (greater than 7), except downstream in WAR where it was less than 7 (acidic). Therefore, the two locations tended to be slightly alkaline. The estimated soluble salts in the soil were dominated by Ca^{+2} and Cl^- [22]. Soil characteristics are the main factors influencing plant growth and the distribution of plant communities. Several researchers have proven that there is a relationship between vegetation and soil features [23,24,25]. El-Khatib [26] 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.

3.2 Amino Acids

The concentration of amino acids present in *Z. spinosa* and *P. harmala* at the spring and autumn seasons under WAR and WGH are given in Table 2.The concentrations of eleven out of eighteen amino acids in the spring season were higher than the autumn season for both species in WAR. Comparatively, the twelve and eleven amino acids concentrations of *Z. spinosa* and *P. harmala* in theautumn season were higher than in the spring season in WGH, respectively. Proline was the amino acid with the highest accumulation compared to the rest of amino acids in the two studied species at the spring and autumn seasons in the two studied locations. This agrees with the earlier findings of El-Absy [27] and Kasim et al. [28] in *Artemisia judaica* and *Achillea fragrantissima* in the wet and dry seasons in WAR. On the other hand, the amino acid Histidine recorded the lowest accumulation in our study. Generally, amino acids content in the two studied species were different the spring and autumn seasons under the two locations. Similar findings were mentioned by Salama et al [22]. Proline is believed to act as an osmoprotectant in plants subjected to drought conditions, whereas it plays an important role in the stimulation of root elongation at low water potentials [29]. Study on fourteen grasses, eleven annuals and three perennials by Bawa [30], revealed a multifold increase in free proline content from stress free to moisture stress conditions, whereas some well adapted grasses showed insignificant amount of proline under similar conditions.

During WAR in the spring and autumn seasons, *Z. spinosa* had the highest values of aspartic acid, cysteine, methionine, phenylalanine, tryptophan , proline, while *P. harmala* showed the highest content of serine, histidine, threonine , arginine, tyrosine, valine, isoleucine, leucine. The highest values of glutamic acid, glycine and alanine were found for *Z. spinosa* at spring season and for *P. harmala* at autumn season. Lysine concentration of *Z. spinosa* and *P. harmala* were increased in autumn and spring seasons, respectively. In WGH, serine, glycine, threonine , phenylalanine, leucine and tryptophan were the amino acids which showed highest accumulation in *Z. spinosa* under the spring and autumn season; whilst, the amino acids aspartic acid, methionine and isoleucine recorded highest accumulation in *P. harmala* at spring and autumn seasons. The amino acids glutamic acid, histidine, arginine and lysine had the highest values of *Z. spinosa* and *P. harmala* in autumn and spring seasons, respectively, unlike of the amino acids alanine, tyrosine, cysteine, valine and proline. Migahid [31] and Salama et al. [22] reported that, the total free amino acids content in *Z. spinosa* was significantly higher in the summer than the winter. The main amino acids identified at the organic acid and amino acid region were isoleucine, valine, threonine, alanine, proline, lysine, 4-hydroxyisoleucine, and asparagine in the different *P. harmala* parts [32].

To determine the highest concentration of amino acids in this study, the mean rank and standard deviation of ranks for all factors study (species, seasons and locations) were calculated and results presented in Table 3. Based on rank method, the amino acids proline, aspartic, glutamic, leucine, isoleucine and alanine showed the lowest values of rank mean, standard deviation and rank sum. Thus, these amino acids were identified as the most accumulated amino acids in the two species. The concentration percentages of these amino acids in the two plants ranged from 54.00 to 70.33% in the two seasons under the two different locations. These amino acids concentrations of the autumn season were greater than those of the spring season in *Z. spinosa* under WAR, and in *P. harmala* under WAR and WGH., while the spring season were higher than autumn season in *Z. spinosa* under WGH. El-Absy [27] and Kasim et al. [28] stated that in WAR the amino acids values in the dry season were greater than the wet season in *Achillea fragrantissim*a. On the other hand, the amino acids histidine, cysteine and methionine showed the highest values of rank mean, standard deviation and rank sum. Therefore, the lowest concentrations of amino acids were histidine, cysteine and methionine. The concentrations of other amino acids were moderate in the two studied species at the spring and autumn seasons in WAR and WGH. Movafeghia et al. [33] reported that, the concentration of proline was high, followed by glutamic acid and tyrosine, while, the amino acids cysteine and methionine, lysine and arginine, leucine and isoleucine, threonine and asparagine were low in *P. harmala*. On the other hand, Ahmed et al. [34] stated that, the highest content was recorded for tyrosine, whereas the lowest levels were recorded for arginine, alanine, and histidine in *P. harmala*.

The principal component analysis (PCA) was performed to better understand the relationship among amino acids and the two species in the spring and autumn seasons within the two locations. Eigenvalues can be defined as those values showing the significance of ordination axes where the highest eigenvalues is the most significant one [2]. In Table 4, the first main principal component (PCA1) extracted had eigenvalues larger than one (Eigen value >1) with value 7.50, thus, the eigenvalue can be used as an inclusion criterion. While, the other PCAs had eigenvalues less than one (Eigen value < 1). According to Helmy et al. [2]the eigenvalues had lower than one for the first four axes of CCA ordination. The analysis showed that the PCA1 contributed 93.74% of the variance of the original variables with amino acids proline, aspartic, glutamic, leucine, isoleucine, alanine, arginine and phenylalanine, and indicate that these amino acids had maximum loadings on PCA in the two species during the spring and autumn seasons in the two locations. Therefore, the PC1 can be regarded as the high amino acids content in the the two species. As for the PC2 explained 3.54% of the total variance with other studied amino acids in our study. Thus, the PCA2 can be named a least content of amino acids in the two species in the studied environments. The PC1 and PC2 explained 97.28% of the total variance of the original variables. The first three principal components (PC1, PC2, and PC3) accounted for92.07% of the original variable information in P. harmala (PC1: 62.77%, PC2: 19.81%, and PC3: 9.49%).

Table 1. Physical and chemical properties of soil at 0-40 depth from up, mid and down streams in Wadi El-Arbaeen and Wadi Ghrandal

Location	Sites	Physical properties						Chemical properties							
		Coarse sand (1-0.5)	Fine sand (0.25-0.1)	Silt (0.05-0.002)	Clay <(0.002)	Water content		pH	EC	S^-	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
						Summer	Winter								
Wadi El-Arbaeen	Up	18.61	7.43	3.14	3.11	8.12	12.11	7.31	1.31	3.45	15.31	5.90	170.21	10.12	0.87
	Mid	22.45	8.69	4.15	4.12	9.01	14.13	7.10	0.81	1.91	2.91	3.92	120.12	4.90	0.42
	Down	20.41	15.12	11.13	17.16	12.11	16.12	6.80	0.91	1.79	3.12	3.80	142.10	4.32	0.32
Wadi Ghrandal	Up	46.23	41.31	3.42	6.71	2.41	4.16	7.60	1.44	0.80	2.51	1.80	0.68	0.62	0.05
	Mid	47.13	45.13	3.13	8.10	4.22	8.15	7.90	2.36	0.70	2.69	1.85	0.69	2.31	0.12
	Down	50.16	48.40	3.12	9.12	9.14	12.11	7.80	8.12	0.63	0.72	1.00	3.20	3.10	0.13

Table 2. The amino acids content (mg/g) of *Z. spinosa* and *P. harmala* during the spring and autumn seasons in WAR and WGH

Species	*Z. spinosa* L.				*P. harmala* L.			
Locations	WAR		WGH		WAR		WGH	
Seasons / Amino acids	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Aspartic acid	13.40	15.30	9.17	10.70	11.40	9.18	11.10	12.60
Glutamic acid	9.60	7.90	8.17	11.12	8.20	10.16	11.12	10.12
Serine	2.60	1.90	4.10	2.80	4.20	4.30	3.20	2.40
Histidine	0.86	0.73	0.84	1.80	1.82	1.33	0.93	0.90
Glycine	3.70	1.70	1.90	4.20	2.80	1.86	1.73	3.30
Threonine	1.96	2.20	2.56	3.60	6.20	4.70	1.78	1.90
Arginine	5.10	3.94	4.63	8.10	7.30	6.80	6.20	3.92
Alanine	7.22	6.12	7.30	5.37	6.10	7.32	5.60	6.10
Tyrosine	2.90	1.88	3.20	3.30	4.60	4.12	2.82	3.60
Cysteine	1.20	1.12	1.21	0.72	0.94	0.90	0.96	1.10
Valine	3.20	2.70	4.80	3.40	5.42	3.60	3.40	4.72
Methionine	1.30	1.62	1.22	0.92	1.20	1.30	1.40	1.66
Phenylalanine	6.10	6.30	6.13	6.90	5.20	4.30	5.60	4.26
Isoleucine	7.19	7.30	5.90	6.80	8.12	7.60	6.30	7.66
Leucine	8.03	8.90	8.93	9.10	8.30	9.66	8.12	8.80
Lysine	4.06	3.70	3.81	4.12	4.60	3.68	4.15	3.80
Tryptophan	2.20	1.88	2.06	2.60	1.72	1.86	1.62	2.50
Proline	19.38	24.81	24.11	14.45	11.88	17.31	23.29	21.11

The accumulation of amino acids that have high PCA1 in the two species are suitable at spring and autumn seasons under the two locations. Thus, Proline, Aspartic, Glutamic, Leucine, Isoleucine, Alanine, Arginine and Phenylalanine are superior amino acids in the two species with their high PCA1 under these studied environments. PCA was applied to the amino acid contents of different plants by Kumar et al. [35] and they stated that the first four components of PCA explained 86.33% of the total variance, and the amino acids i.e., alanine, lysine, cysteine, leucine and arginine had maximum loadings on PCA.

The relationships (similarities and dissimilarities) among amino acids based on the two species and the studied environments are graphically displayed in a biplot of PC1 and PC2 (Fig. 1). The PC1 and PC2 mainly distinguish the amino acids into four groups (Fig. 1a). The first group (G1) contained proline, indicating that proline concentrations were higher than the other amino acids in the two species during the spring and autumn seasons in the two locations. The proline concentration in nine plant species had the highest concentration in autumn and the lowest in spring. This can be attributed to both salinity and water stress in the halophytes, and water stress alone in the psammophytes [35]. The second group (G2) consists of the most abundant amino acids after proline in decreasing order; aspartic acid, glutamic acid, leucine, isoleucine, alanine, arginine and phenylalanine. The third group (G3) comprised of the amino acids lysine, valine, tyrosine, serine, threonine and glycine, while, the fourth group include the amino acids tryptophan , methionine, cysteine and histidine. In general, the two species at the spring and autumn seasons in the two locations have the highest concentration of proline, moderate concentrations of the amino acids in G2 and G3 groups, and finally the lowest concentration from amino acids in G4 group. According to biplot analysis in Fig. 1b, the smallest acute angles (positive and significant correlations) were observed among serine, valine, tyrosine and threonine and were located in the first quadrant with *P. harmala* at the spring and autumn seasons in WAR. In the spring season under WGH, the amino acids alanine, cysteine, methionine and proline in *Z. spinosa* were located in the second quadrant and showed positive and significant correlations. The *Z. spinosa* in WAR was similar (the fourth quadrant) at the spring and autumn seasons and suitable for the two amino acids aspartic acid and phenylalanine (positive and significant correlations). The other amino acids of *Z. spinosa* in the dry seasons in WGH are grouped into the third quadrant and showed significant correlations in positive direction. The positive correlation between methionine and cysteine in *Z. spinosa* at the spring season in WGH and between proline and aspartic in *P. harmala* at the spring and autumn seasons in WGH were found. The positive correlation between the amino acids indicates that an increase in the concentration of one amino acid leads to the increase of the other amino acid under the studied environments. Kumar et al. [36] mentioned that all the amino acids showed positive correlation with each other except GABA and citrulline, and highest correlation existed between valine and aspartic acid. Amino acids are involved in the synthesis of other organic compounds, such as protein, amines, alkaloids, vitamins, enzymes, terpenoids and plant hormones that control various plant processes [37]. Gzik [38] reported that, the composition of free amino acids estimated by reversed phase high pressure liquid chromatography (HPLC) was changed by different stress conditions. In contrast to aspartic and glutamic acids that were only slightly influenced by the stress, the contents of acid amides and basic amino acids increased sharply. Most levels of the other free amino acids, except serine, were enhanced. The concentrations of serine, glycine and glutamate increased upon water stress, their total amount in severely stressed leaves ranging 5- to 6-fold higher than the total amount of valine, tyrosine, leucine and isoleucine at this stage of water deficit [39].

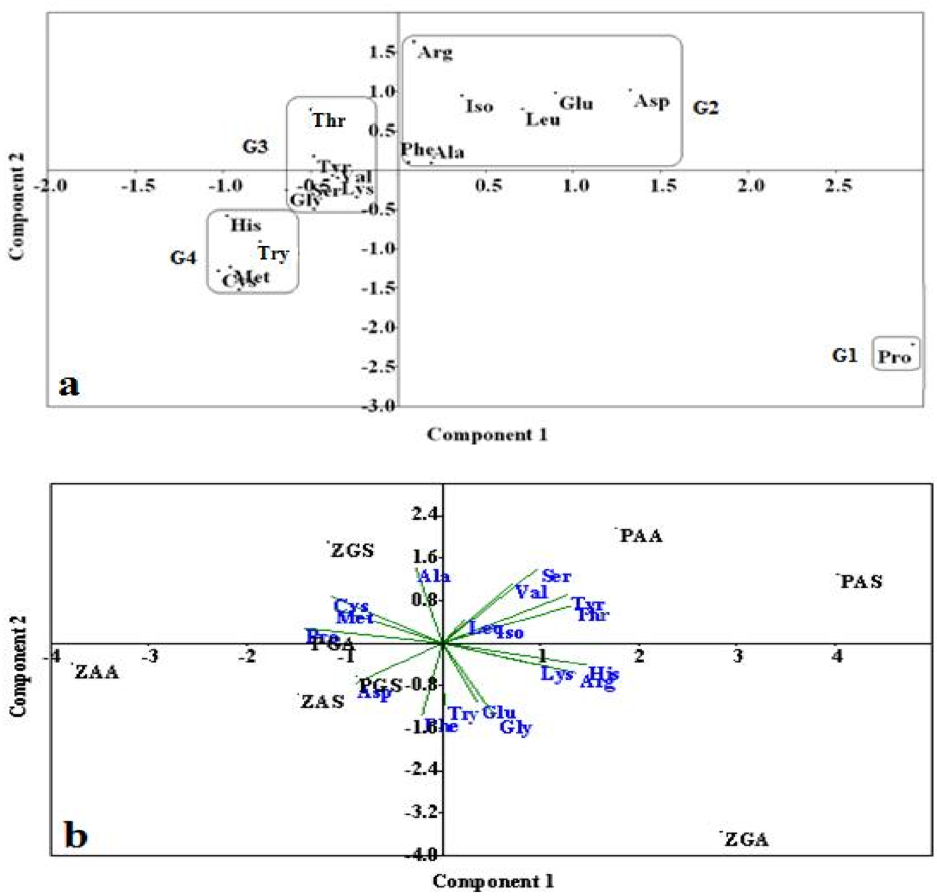

Fig. 1. Principal component analysis of the amino acids in *Z. spinosa* and *P. harmala* at the spring and autumn seasons during WAR and WGH

Asp: aspartic; Glu: glutamic; Ser: serine; His: histidine; Gly: glycine; The: threonine ; Arg: arginine; Ala: alanine; Tyr: tyrosine; Cys: cysteine; Val: valine; Met: methionine; Phe: phenylalanine; Iso: isoleucine; Leu: leucine; Lys: lysine; Trp: tryptophan ; Pro: proline. ZAS and ZAA: Z. spinosa in WAR at the spring and autumn seasons, respectively; ZGS and ZGA: Z. spinosa in WGH at the spring and autumn seasons, respectively; PAS and PAA: P. harmala in WAR at the spring and autumn seasons, respectively; PGS and PGA: P. harmala in WGH at the spring and autumn seasons, respectively

Table 3. Ranks of amino acids in the two species during the spring and autumn seasons in WAR and WGH

Species	***Z. spinosa* L.**				***P. harmala* L.**				**MR**	**VR**	**SDR**	**RS**
Locations	**WAR**		**WGH**		**WAR**		**WGH**					
Seasons / Amino acids	**Spring**	**Autumn**	**Spring**	**Autumn**	**Spring**	**Autumn**	**Spring**	**Autumn**				
Aspartic acid	2	2	2	3	2	4	3	2	2.50	0.57	0.76	3.26
Glutamic acid	3	4	4	2	4	2	2	3	3.00	0.86	0.93	3.93
Serine	13	12	10	14	13	9	11	14	12.00	3.43	1.85	13.85
Histidine	18	18	18	16	15	16	18	18	17.13	1.55	1.25	18.37
Glycine	10	15	15	9	14	14	14	12	12.88	5.27	2.30	15.17
Threonine	15	11	13	11	7	8	13	15	11.63	8.84	2.97	14.60
Arginine	8	8	9	5	6	7	6	9	7.25	2.21	1.49	8.74
Alanine	5	7	5	8	8	6	7	6	6.50	1.43	1.20	7.70
Tyrosine	12	13	12	13	11	11	12	11	11.88	0.70	0.83	12.71
Cysteine	17	17	17	18	18	18	17	17	17.38	0.27	0.52	17.89
Valine	11	10	8	12	9	13	10	7	10.00	4.00	2.00	12.00
Methionine	16	16	16	17	17	17	16	16	16.38	0.27	0.52	16.89
Phenylalanine	7	6	6	6	10	9	7	8	7.38	2.27	1.51	8.88
Isoleucine	6	5	7	7	5	5	5	5	5.63	0.84	0.92	6.54
Leucine	4	3	3	4	3	3	4	4	3.50	0.29	0.53	4.03
Lysine	9	9	11	10	11	12	9	10	10.13	1.27	1.13	11.25
Tryptophan	14	13	14	15	16	14	15	13	14.25	1.07	1.04	15.29
Proline	1	1	1	1	1	1	1	1	1.00	0.00	0.00	1.00

MR: mean rank; VR: variance rank; SDR: standard deviation of ranks; RS: rank sum

Table 4. Results of Principal Component Analysis (PCA) for amino acids of the two species based on wet and dry seasons during the two locations

Amino acids	PCA1	PCA2
Aspartic acid	3.64	0.54
Glutamic acid	2.48	0.52
Serine	-1.41	-0.07
Histidine	-2.67	-0.30
Glycine	-1.74	-0.13
Threonine	-1.36	0.65
Arginine	0.25	0.87
Alanine	0.51	-0.05
Tyrosine	-1.31	0.10
Cysteine	-2.80	-0.68
Valine	-0.97	0.03
Methionine	-2.62	-0.65
Phenylalanine	0.01	-0.03
Isoleucine	1.00	0.50
Leucine	1.96	0.42
Lysine	-0.94	-0.05
Tryptophan	-2.15	-0.48
Proline	8.13	-1.18
Eigen value	7.50	0.28
Percent of variance	93.74	3.54
Cumulative variance	93.74	97.28

3.3 Relationship between Amino Acids and Soil Properties

The amino acids showed a dissimilar performance once they were positioned in opposing quadrants according to soil analysis data in the spring and autumn seasons under the two locations (Fig 2 and 3). Each amino acid behaves differently according to environmental conditions, indicating compensatory effects among them [40]. According to biplot analysis in Fig 2, the amino acids glycine (5), methionine (12), cysteine (10), aspartic (1), glutamic (2), alanine (8), phenylalanine (13), tryptophan (17) and proline (18) were located in the first and third quadrants and positively correlated with pH, K^+, Na^+, S^-, Ca^{2+}, Cl^-, EC and Mg^{2+}, while the other amino acids are located in the second quadrant and positively correlated with water content (WC) in the spring season in WAR. On the other hand, positive correlations among the amino acids (aspartic, cysteine, methionine, phenylalanine, lysine, tryptophan and proline) and soil properties (pH, K^+, Na^+, S^-, Ca^{2+}, Cl^-, EC and Mg^{2+}) were found, whilst the other amino acids and WC showed correlation in positive direction at the autumn season under the WAR.

As for WGH as shown in Fig. 3, the pH, K^+, Na^+, WC and EC positively correlated with the amino acids aspartic (1), glutamic (2), histidine (4), arginine (7), methionine (12), isoleucine (14) and lysine (16) in the spring season, and with the amino acids aspartic (1), alanine (8), tyrosine (9), cysteine (10), valine (11), methionine (12), isoleucine (14) and proline (18) in the autumn season. While, the mineral elements S^-, Cl^- and Ca^{2+} were positively correlated with the amino acids glycine (5), valine (11), tryptophan (17) and proline (18) in the spring season, and with the amino acids leucine (15), lysine (16) and tryptophan (17) in the autumn season. However, the other amino acids were showed correlation in positive direction with S^- and Mg^{++} in the spring and autumn seasons.

Generally, there are positive correlation among the amino acids i.e. aspartic, cysteine, methionine, phenylalanine, tryptophan and proline; and the soil properties i.e., pH, K+, Na+, S-, Ca2+, Cl-, EC and Mg2+ in the spring and autumn seasons in WAR. While, positive association among the amino acids (aspartic acid, methionine and isoleucine) and pH, K+, Na+, WC and EC; as well as among the amino acid tryptophan and soil properties (S-, Cl- and Ca2+) in the spring and autumn seasons in WGH. Finally, the amino acids aspartic acid, methionine and tryptophan had positive correlation with most of the soil properties in the spring and autumn season in the two wadis. According to Prommer et al. [41], the gross production rates of amino compounds were strongly correlated with soil physicochemical parameters. As to water availability, Carrera et al. [42] stated that, under water stress conditions in the field, protein had a linear negative correlation with increasing water deficit. Significant linear regressions were detected for amino acid content regarding precipitation minus potential evapotranspiration [40]. Anderson and Bedford [43] suggested that the suppression of amino-acid uptake in the clam Rangia cuneafa at low salinities was not directly due to the reductions in the levels of Na+ or Cl- in the incubation medium but to osmoregulatory factors. Prommer et al. [41] mentioned that the glucosamine exhibited significant negative correlations with soil pH. In contrast, gross production rates of the other four amino compounds, i.e. muramic acid, L-alanine, D-alanine, and mDAP, were all positively related to pH and cation exchange capacity. No significant effect of pH on amino-acid absorption was observed over the pH range 6.2-8.8 [44]. In contrast, the positive relationship between production rates of D-alanine with soil pH [45]. The amino acids were negatively related to soil pH [46].

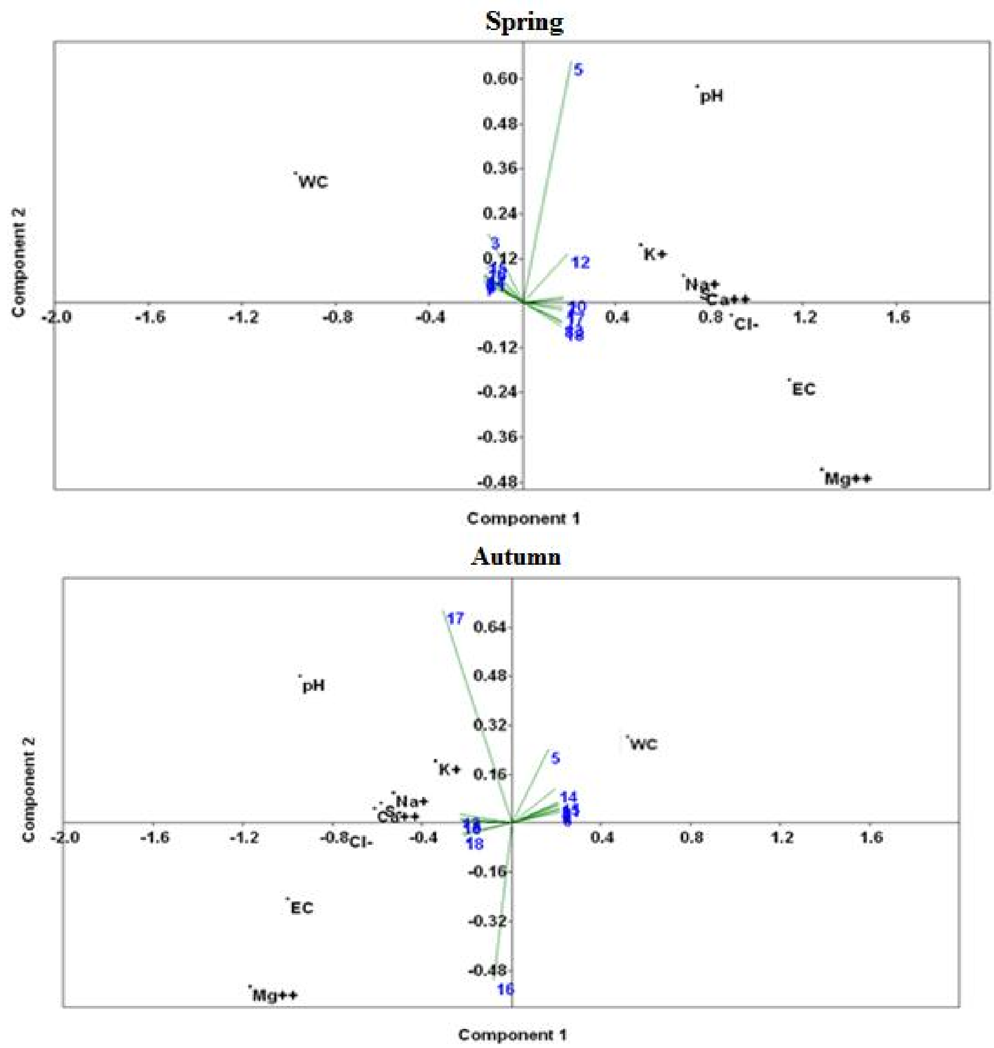

Fig. 2. Biplot diagram based on first two principal component axes of amino acids and soil properties in the spring and autumn seasons under Wadi El-Arbaeen

1: aspartic; 2: glutamic; 3: serine; 4: histidine; 5: glycine; 6: threonine ; 7: arginine; 8: alanine; 9: tyrosine; 10: cysteine; 11: valine; 12: Methionine; 13: phenylalanine; 14: isoleucine; 15: leucine; 16: lysine; 17: tryptophan ; 18: proline

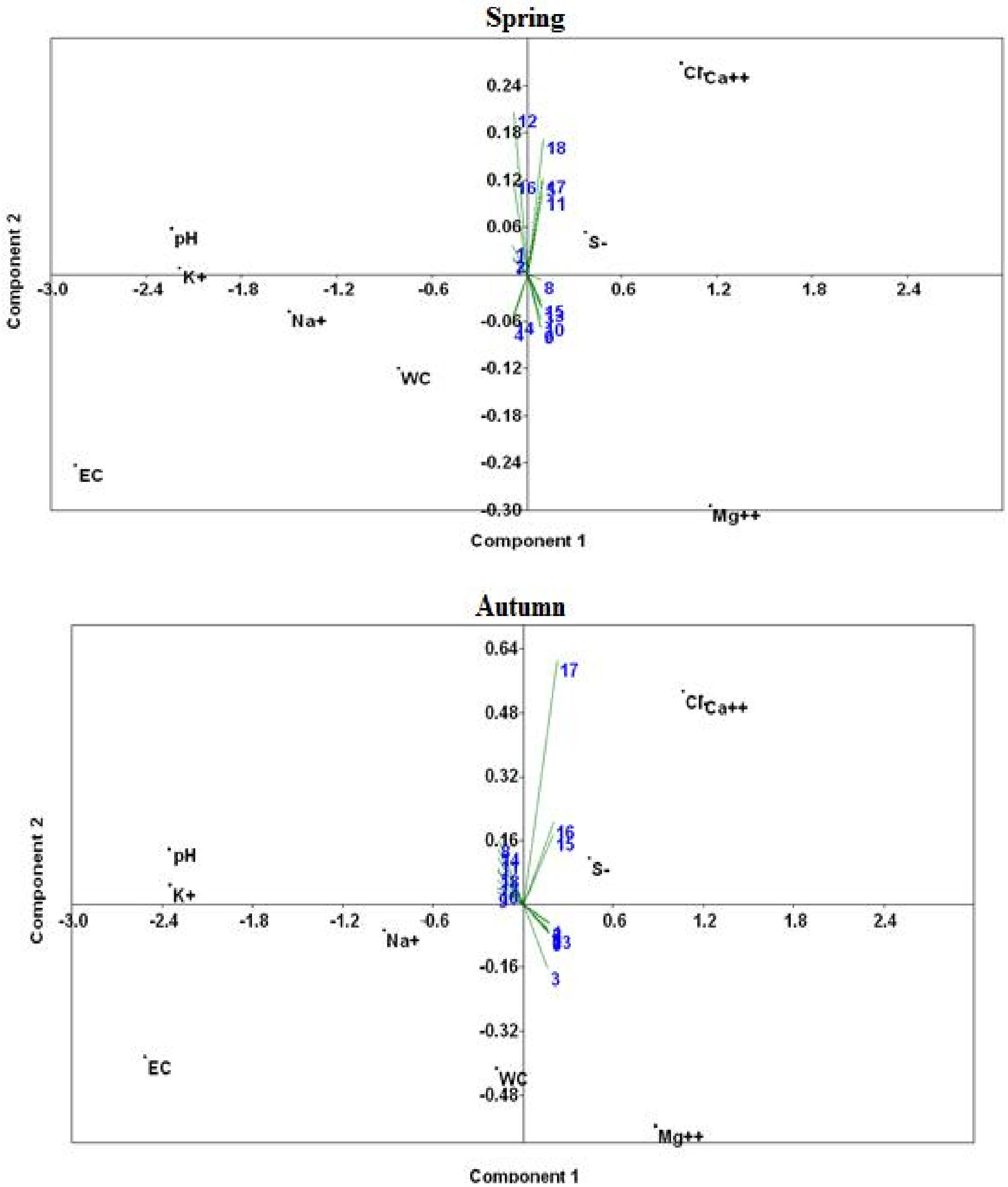

Fig. 3. Biplot diagram based on first two principal component axes of amino acids and soil analysis in the spring and autumn seasons under Wadi Ghrandal

1: aspartic; 2: glutamic; 3: serine; 4: histidine; 5: glycine; 6: threonine ; 7: arginine; 8: alanine; 9: tyrosine; 10: cysteine; 11: valine; 12: methionine; 13: phenylalanine; 14: isoleucine; 15: leucine; 16: lysine; 17: tryptophan ; 18: proline

4. CONCLUSION

The values of S-, Cl-, Ca2+, Mg2+, Na+ and K+ of soil solutions at the up, mid and down streams were higher in Wadi El-Arbaeen (WAR) and Wadi Ghrandal (WGH), compared to those of pH and electric conductivity (EC). Amino acids content in Z. spinosa and P. harmala were different during the spring and autumn seasons in the two locations. According to PCA, the amino acids can be classified into four groups. Based on rank method and PCA, the amino acids proline (Group 1), aspartic acid, glutamic acid, leucine, isoleucine, alanine, arginineand

and phenylalanine (Group 2) recorded the highest content of total amino acids, while, histidine, cysteine and methionine (group 4) were found to contain the lowest values of the total amino acids. Aspartic acid, methionine and tryptophan were positively correlated with most soil properties during the spring and autumn season in the two wadis. It seemed that Z. spinosa and P. harmala were adapted to drought conditions in WAR and WGH.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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