VEGETATION ANALYSIS OF SOME WETLAND HABITATS IN CENTRAL REGION OF SAUDI ARABIA

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Abstract. In this study, the vegetation of 63 sabkha and sewage canals in central region of Saudi Arabia was analyzed. A total of 109 plant species belonging to 83 different genera and 34 different plant families were collected. The most common plant families were *Chenopodiaceae* (18 species), *Poaceae* (16 species) and *Asteraceae* (10 species). Vegetation in the study area was classified into 6 groups; two of them were found in sabkhas only, one was found in sewage canals only and the other three were found in both habitats. The main factors controlling the plant presence and vigour in the studied wetlands were soil salinity, pH, EC, soil texture and content of organic matter.
Keywords: *wetlands, vegetation, DECORANA, TWINSPAN*

Introduction

Wetlands are defined as the areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions (LePage, 2011). They include, for example, salt marshes (sabkhas), shallow ponds and sewage canals. Wetlands are identified by unique soils (hydric soils), plants adapted to life in wet environments (hydrophytes) and the presence of water (hydrology) during the growing season. From an ecological perspective, wetlands are simply a particular slice of the continuum between the wettest ecosystem types (rivers, lakes, estuaries, and the marine environment) and the driest environments within a physiographic (broad-scale subdivisions of the Earth's surface based on terrain texture, rock type, geologic structure, and history) region (Brinson, 2011).

Wetlands in the central region of Saudi Arabia are considered among the main diverse habitats. However, there have been no studies of their vegetation diversity until now. In Saudi Arabia, wetlands are located in a hot and dry region that is experiencing major climate changes. They are generally characterized by high biodiversity in terms of both animals and plants. With their hydrologic characteristics, wetlands have a great ecological importance. They have plants with high productivity and provide habitats for many wild fishes and birds (LePage, 2011). Saudi Arabia has several natural and industrial wetlands including lakes, sabkhas and wadis. Beside their importance to various animals especially amphibians, wetland habitats have a great potential to conserve biodiversity of plants (Flinn et al., 2008). Al-Obaid et al. (2017) stated that wetlands are also of great economic importance in agriculture and grazing. Nevertheless, the plant communities of different wetlands in Saudi Arabia has not been fully described. The aim of this study was to characterize the vegetation of different wetlands in central region of Saudi Arabia.

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Materials and methods

Study area

The central "Najd" region is the large central plateau in Saudi Arabia; it is divided into two parts: the higher Najd in the west (located on the Arabian Shield region) and the lower Najd in the east. The altitude in this area ranges from 500 - 1000 m above sea level. The higher Najd is characterized by an extensive system of large wadis. Wadis in general flow from west to east, following the slope of the land, from the higher mountains in the west to the lower plains of Najd.

Qassim is located in the northern central region of Saudi Arabia with an area of 80.000 km^2. It has two different geological regions; one is located on the Arabian Shield region and the other is located in the sedimentary sector (the Arabian Shelf). Qassim has many sabkhas and wadis in addition to several mountains. Riyadh is located at 24° 38' N lat. and 46° 43' E long. in the central region of Saudi Arabia occupying a large area of Najd plateau with an average altitude of 600 m above sea level. Riyadh is characterized by several mountains (e.g. the Tuwaiq Mountains) and sand dunes. Similar to Qassim, Riyadh is divided into two geological sectors; the western part is the Arabian Shield sector and the eastern is the sedimentary sector (*Fig. 1*).

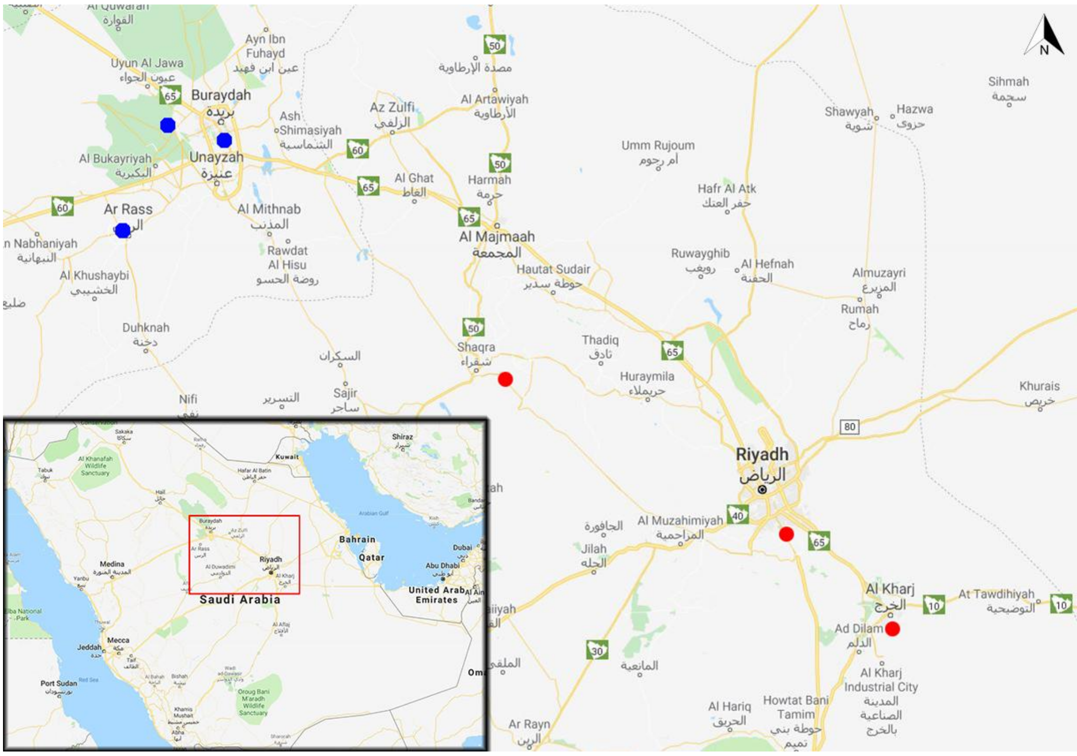

Figure 1. *A map showing the different studied sites*

The study area is characterized by high temperatures especially from June to August when the temperature can exceed 45 °C. The general climate in the study area is hot summer and mild to cold winter. The rainfall is very low with an average of less than 200 mm/ month, and most of the rain falls during spring with almost no rain in the summer. The wind is usually laden with dust from upwind desert areas. *Table 1* summarizes the climate characteristics of the two studied areas; Riyadh and Qassim.

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***Table 1.** Average of climate records for 10 years (2005 – 2014) in Riyadh and Qassim areas (Source: Saudi General Authority of Meteorology and Environmental Protection)*

Climate variable	Riyadh		Qassim	
	Range	**Mean**	**Range**	**Mean**
Max air temperature (°C)	20.95 – 43.93	32.44	20.43 – 44.72	32.58
Min air temperature (°C)	7.48 – 27.66	17.57	6.74 – 27.33	17.00
Rainfall (mm/ month)	0.00 – 320.91	160.46	0.00 – 320.00	160.00
Relative humidity (%)	8.30 – 94.30	51.30	4.20 – 99.80	52.00
Wind speed (km/ h)	4.10 – 7.10	5.6	4.90 – 7.40	6.15

Sample stands

In the present study, 63 different stands were selected to represent the two main studied habitats (sabkhas and sewage canals) that exist in different wetlands in the central region of Saudi Arabia. GPS coordinates for all the studied stands were recorded (*Appendix 1*) and in every stand, an area of 50 m × 50 m was sampled. Sampling was carried out during the spring season 2016 in order to ascertain the maximum presence of the different plant species. Plant samples collected from each stand were identified according to Collenette (1999) and Chaudhary (2001) and presented at the herbarium of King Saud University, Riyadh, Saudi Arabia. Plants were classified into annual herbs, annual grasses, perennial herbs, perennial grasses and shrubs (*Appendix 2*). The pattern of geographical distribution (chorotype) of each species were studied following Chaudhary (2001). The total and mean cover and presence of each species were calculated for each stand following the method described by Kent (2012).

Soil analysis

Three soil samples were collected from each stand at a depth of 50 cm and mixed together to form a composite sample. Soil physical and chemical characteristics were assessed. The hydrometer method was used to determine the soil texture (Day, 1965). The “Loss on Ignition” method (combustion at 550 °C) was used to calculate the total organic matter present in the soil samples. Soil pH and electrical conductivity (EC) was calculated in soil suspension 1: 5 w: v. Nitrogen content in soil samples was determined using the micro Kjeldahl method (AOAC, 1990). Phosphorus content was determined following the method of APHA (2005). Concentrations of various nutrients (Ca, K, Mg, Fe, Na) were measured following the methods described by Allen (1989).

Water analysis

One water sample from each stand was collected (where applicable) and chemical analyses were performed. Samples were collected at a depth of 1 m above surface that is around the middle of each water body. Water pH and EC were examined according to Allen (1989). Phosphorus content was determined following the method of APHA (2005). In addition, levels of Ca, K, Mg, Fe and Na in the water samples were investigated (Allen, 1989).

Statistical analysis

Canonical correspondence analysis (CCA) and detrended correspondence analysis (DCA) using DECORANA software (Hill, 1979a) and multivariate analysis using

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TWINSPAN software (Hill, 1979b) were performed to calculate the estimates of cover for 109 plant species collected from the 63 stands. Species richness (α-diversity) was defined as the average number of species present in each individual stand. Gamma diversity (γ-diversity) was determined based on the total number of species for each stand. The relative cover (p_i) of each stand was used to calculate the relative evenness using the Shannon-Wiener index $\hat{H} = -\sum_{i=1}^{s} p_i \log p_i$ and the relative dominance concentration using the Simpson index $C = \sum_{i=1}^{s} p_i^2$ where s is the total number of species collected (Pielou, 1975; Magurran, 1988).

Results

The total number of plants collected from the different wetlands studied in the Riyadh and Qassim areas was 109 plant species belonging to 83 different genera and 34 different plant families, with a species richness factor of 1.31 (109 species / 83 genera). The most abundant plant families were Chenopodiaceae with 18 different plant species (16.5%), Poaceae represented by 16 different plant species (14.7%), Asteraceae with 10 different plant species (9.2%) and Fabaceae with 7 different plant species (6.4%). The least abundant families were Aizoaceae, Amaranthaceae, Apocynaceae, Asphodelaceae, Cistaceae, Cucurbitaceae, Ephedraceae, Frankeniaceae, Juncaceae, Lamiaceae, Malvaceae, Molluginaceae, Neuradaceae, Orobanchaceae, Portulacaceae and Ruppiaceae, with each family being represented by only one plant species (*Fig. 2a*, bar chart). *Fig. 2b* (pie chart) shows that the predominant life forms were annual herbs with 40 different plant species (36.7%) and perennial herbs with 34 different plant species (31.2%). The total number of different annual species was 45 (41.3%), while the perennial species were represented by 64 different species (58.7%). In terms of the global geographical distribution of the plants collected, the most represented regions were the Saharo-Arabian region with 39 (35.10%) different plant species followed by the bi-regional Saharo Arabian-Somalia Masai with 10 (9.2) different plant species and the Tropical and Saharo Arabian-Irano Turanian regions with 8 (7.3%) different plant species for each. Generally, the most abundant species were those typically found in a single region (52 species, 46.9%) and the bi-regional species (30 species, 28.4%) while the multi-regional and cosmopolitan species were the least abundant with 12 species (11.0%) and 1 species (0.9%), respectively. The most abundant plant species in all the habitats studied were *Phragmites australis* (with a relative presence 'P' = 41.3%, a relative coverage 'C' = 15.4%), *Tamarix nilotica* (P = 39.4%, C = 5.71%), *Salosola imbricate* (P = 34.9%, C = 1.32%), *Zygophyllum propinquum* ssp. *migahidii* (P = 25.4%, C = 16.0%) and *Tamarix aucheriana* (P = 25.4%, C = 16.0%). In contrast, the rarest plants (≤ 1) in the habitats studied included (for example) *Aizoon canariense*, *Chenopodium album*, *Plantago amplexicaulis* and *Salvia spinosa*.

In the present study, two forms of wetlands in Saudi Arabia were studied, namely sabkhas (natural) and sewage canals (industrial). Seventy-nine different plant species belonging to 69 genera and 28 families were found in sabkhal habitats. Chenopodiaceae, Poaceae and Asteraceae were the most highly represented plant families with 14, 14 and 7 plant species, respectively. Most of the plant species in sabkhas were annual herbs (34 species, 43%) and perennial herbs (20 species, 25.3%). The most abundant plant species were *Tamarix aucheriana* (P = 39.47%, C = 13.16%) and *Zygophyllum propinquumm* ssp.*migahidii* (P = 34.21%, C=4.03%), while the rarest plant species were *Chenopodium album* and *Salvia spinosa*. In contrast, in sewage canal habitats, 58 different plant

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species belonging to 50 genera and 26 families were found. The most abundant families there were members of the Poaceae (9 species, 15.5%) and Chenopodiaceae (8 species, 13.8%). Perennial herbs twenty different species (34.5%) were the most represented group followed by annual herbs with 16 species (27.6%). *Phragmites australis* was the most abundant plant species (P=57.69%, C=24.04%) followed by *Tamarix nilotica* (P=50.00%, C=8.85%), *Calotropis procera* (P=38.46%, C=8.31%) and *Pulicaria undulata* (P=38.46%, C=6.92%). In contrast, *Aeluropus lagopoides* and *Amaranthus viridis* were the rarest plants (*Appendix 1*).

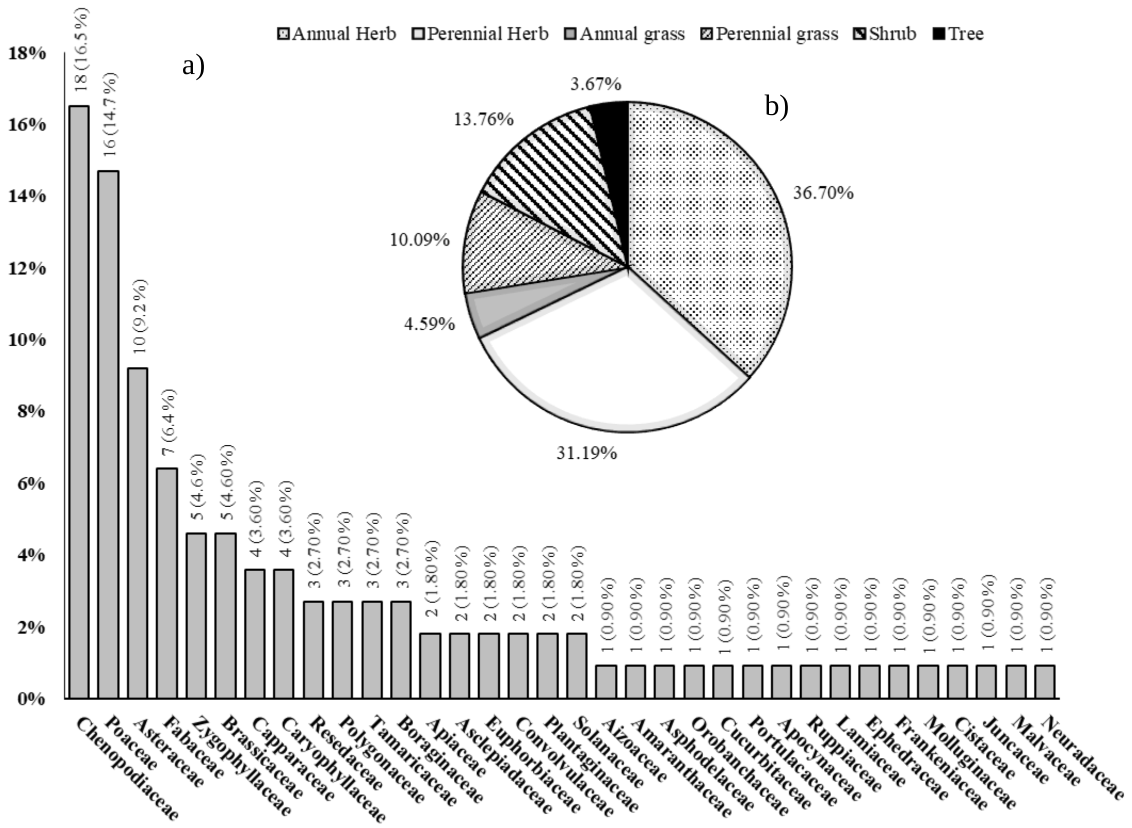

Figure 2. *(a) Number and percentages of different represented families (bar chart) and (b) lifeforms (pie chart) in the studied stands.*

Cover estimates for 109 plants collected from 63 different stands using TWINSPAN software generated 6 different vegetation groups at the third level of classification (*Fig. 3a*, *Table 2*). Of these groups, only two groups only occupied sabkhas habitats; a) that characterized by *Tamarix aucheriana – Phragmites australis* and b) that characterized by *Centropodium forsskalii – Emex spinosa*. One group occupied sewage canals only (*Calotropis procera – Citrullus colocynthis*), two groups mainly occupied sabkhas; a) *Suaeda vermiculata – Seidletzia rosmarinus – Zygophyllum propinquum* ssp. *Migahidii* and b) *Haloxylon salicornicum – Suaeda aegyptiaca*. One group mainly occupied sewage canals (*Tamarix nilotica – Salsola imbricata*). Further analysis of the same data set using DECORANA software showed a reasonable segregation between the groups that had been generated (*Fig. 3b*).

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Table 2. *Characteristics of different vegetation groups produced by TWINSPAN*

VG	Stands	Stands (%)	Species	Habitats		First dominant species	P%	C%	Second dominant species	P%	C%
				Sabkhas	Sewage						
1	7	11.00	35	71.4	28.6	*Haloxylon salicornicum*	57	18.86	*Suaeda aegyptiaca*	43	6.43
2	10	15.87	31	80	20	*Suaeda vermiculata*	43	10.9	*Seidletzia Rosmarinus* *Zygophyllum propinquum ssp. migahidii.*	50 50	10 8.2
3	16	25.40	70	100	0	*Tamarix aucheriana*	56	25	*Phragmites australis*	56	16.31
4	19	30.16	59	36.8	63.2	*Tamarix nilotica*	63	16.84	*Salsola imbricata*	47	3.58
5	9	14.29	41	0	100	*Calotropis procera*	44	15.78	*Citrullus colocynthis*	33	2.0
6	2	3.17	6	100	0	*Centropodium forsskalii*	50	3.89	*Emex spinosa.*	50	1.0

P: presence of species, C: relative cover of species

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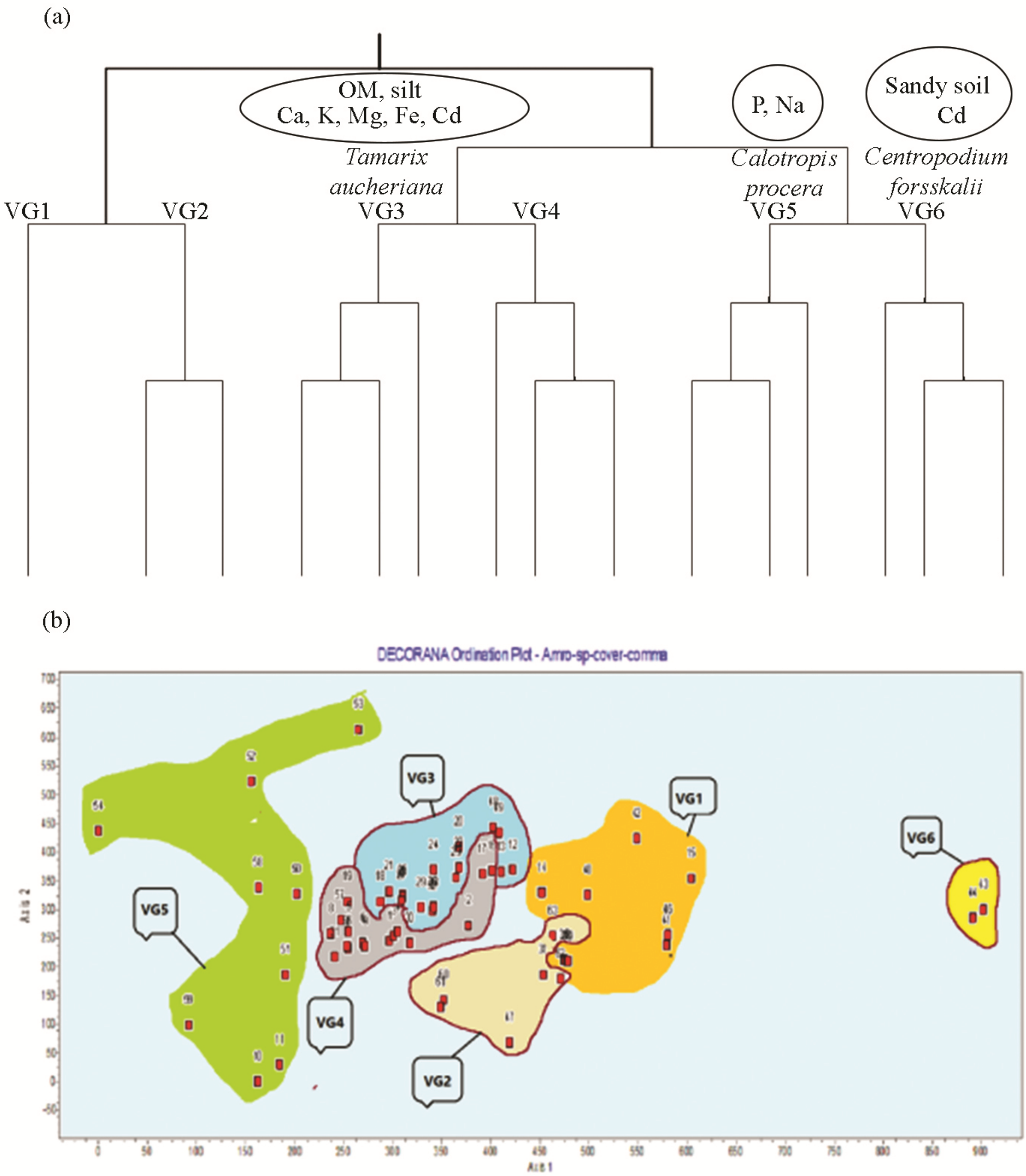

Figure 3. *(a) Dendogram showing the relationship between 6 different vegetation groups generated by TWINSPAN and (b) Segregation of different vegetation groups after applying DECORANA analysis.*

CCA analysis showed that different environmental factors related to soil affect the species distribution on the two axes. There was a positive correlation between the Simpson index value and the first axis and a negative correlation between the same axis and EC, Ca, Mg, Cr and Cd. Meantime, the second axis correlated negatively with silt percentage in soil, organic matter, Ca, K, Mg, and Cd (*Fig. 4a*). Plant species recognized as psammophytic (associated with sandy soils) occupied the positive upper left and right sides of the CCA plot (*Fig. 4b*) and showed a positive correlation with the

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Shannon-Wiener index, evenness, species richness, sand percentage in soil, Zn and Na. Psammophytic plants included, for example, *Bassia eriophora*, *Pennisetum divisum*, *Cynodon dactylon* and *Asphoedelus tenuifolius*. Shrubs such as *Calotropis procera*, *Tamarix aucheriana* and *Heliotropium digynum* were found on the lower side of the first axis and showed a strong correlation with the Simpson index and P content. Halophytes mainly occupied the negative lower side of the first axis and showed strong correlation with increasing pH, EC, Cr, Pb, Mg and organic matter. This group of plants included, for example, *Aeluropus lagopoides*, *Salicornia europaea* and *Juncus rigidus*.

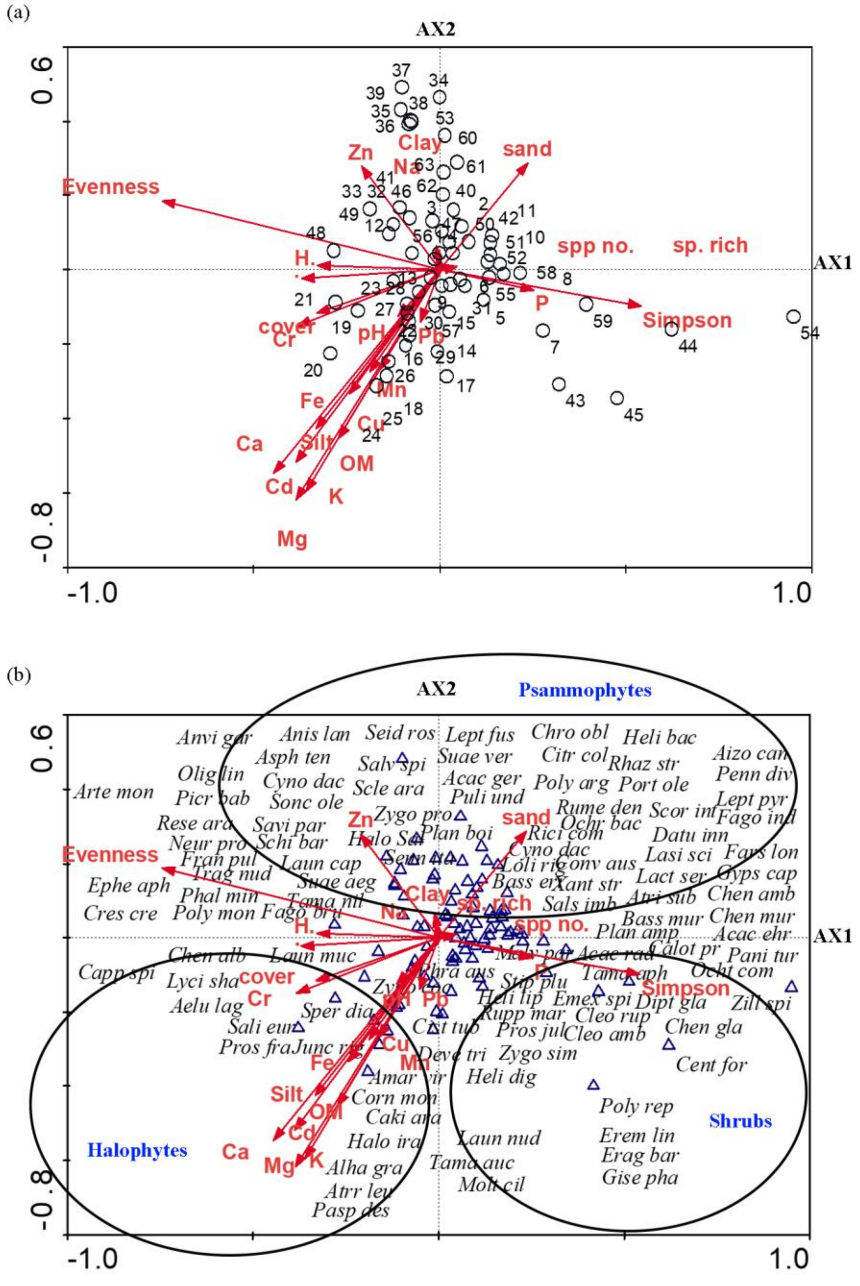

Figure 4. *(a) The CCA plot shows the relationships between the stands studied and the soil characteristics and biological indices (the Simpson index and measures of evenness). (b) The same plot showing the abundant species represented by the first four letters of genus and first three letters of species.*

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Discussion

Wetlands are considered a very significant habitat for diverse group of animals, plants and even microbes. In addition to their important role in the water cycle, and in removing excess nutrients and other contaminants from polluted water, they are one of the most biodiverse sites around the world. Wetlands contribute significantly in keeping the ecological balance between different plant species. In Saudi Arabia, wetlands are the richest habitats from the point of view of plant diversity because of the availability of moisture, in contrast to the many dry places around the kingdom. In this study of the vegetation of 63 different sites, it was found that perennial plants were the most abundant life forms. Our earlier (unpublished) studied on wetlands in Saudi Arabia have also shown that perennial plants are more abundant than annual plants in valley habitats in the Riyadh area. In contrast, we found that annual plants were more abundant in Sabkha habitat in the Qassim area (unpublished data). Levels of species richness (1.31) in this study indicated the high plant diversity at the region. Members of the Chenopodiaceae family were the most abundant family in the stands studied. This may be due to the high tolerance of drought and salinity typical of the members of this family. Stebbins (1974) pointed out that the Chenopodiaceae plants were typically able to grow in saline sandy soils such as sabkhas. It could, also, be due to the fact that members of the Chenopodiaceae disperse readily due to their lightweight seeds (El-Sheikh, 2013). In the present study, where the Chenopodiaceae were most abundant, they were followed by Poaceae and Asteraceae. In contrast, at the level of Saudi Arabia as a whole, Chaudhary (2001) found that the most abundant families were first, the Poaceae followed by the Chenopodiaceae and the Zygophyllaceae.

In the present study, perennial plants were more represented than annuals. Wetlands habitats such as sabkhas and sewage treatment areas are very different from the dryland areas, in that they provide the moisture required by plants, and do so year-round. In addition, soils in wetlands have higher concentrations of various nutrients that promote the growth of various perennial species. The dominant plants in wetlands are trees as they can tolerate drought stress for longer periods, and they can draw water from surface and deep soil via their extensive root systems (Al-Rowaily et al., 2012). Chorotype analysis showed that mono-regional plants were the most abundant and were represented by the Saharo Arabian, Tropical and Irano-Turanian groups, respectively. The study stands are located, mainly, in the Arab Sahara Region located between the Tropical and Irano-Turanian regions (Alatar et al., 2012). The central region of Saudi Arabia is a part of the Arab Sahara Region and their plants are mainly mono-regional belonging to the Saharo Arabian group (Al-Nafie, 2008). The presence of plants normally associated with Saharo Arabian-Somalia Masai, Saharo Arabian-Irano Turanian and Mediterranean-Irano Turanian floras indicate that the central region of Saudi Arabia is a transitional area with some of the characteristics of surrounding regions. This supports earlier vegetation studies of the central region (Alatar et al., 2012; Alatar et al., 2015) and studies of Kuwait (El-Sheikh et al., 2012).

TWINSPAN analysis showed that there were 6 different vegetation groups in the study sites. Shaltout et al. (1997) studied the vegetation of coastal lowland of eastern Saudi Arabia. In their analysis, they found 12 different vegetation groups include *Tamarix aucheriana* and *Phragmites australis* communities. In addition, *Phragmites australis* was found in the Hail region in northern Saudi Arabia (El-Ghanim et al., 2010). In the present study, it was found that salinity, soil texture and nutrient levels were the main environmental factors affecting the distribution of plants in each stand.

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Our results are supported by other studies of similar habitats (Alatar et al., 2012; El-Sheikh et al., 2012). The Shannon index showed a positive correlation with sand content in soil because soils with more sandy texture provide soil aeration in wetlands such as sabkhas and sewage canals. Furthermore, percentage of cover was positively correlated with organic matter content and potassium levels. Shrubs and trees benefit from the presence of high organic matter which as it decomposes provides nutrients for growth, allowing development of significant biomass (Alatar et al., 2015). Other macronutrients especially K, Mg and Ca also play a critical role in maintaining plant osmotic pressure in a saline environment, adjusting the pH of the plant cell, protecting cells from toxicity and serving as co-factors for several enzymes (Shiel, 2001).

Psammophytic plants were the most abundant lifeform in the stands studied followed by halophytes and shrubs. This pattern reflects characteristics of the whole flora of Saudi Arabia (Chaudhary, 2001). Psammophytic plants were correlated with Shannon index, species evenness, species richness and number of species in each stand. Increased plant cover may promote higher chlorophyll content in plants as a result of competition and shading. Abou-Sitta and Al-Taisan (1995) found that desert plant growing in shade had higher chlorophyll content than plants growing in sunny areas. Higher chlorophyll content enhancing plant's ability to photosynthesize and produce the carbohydrates essential for growth. There was a clear correlation between halophytes and the EC of the soil. Clearly, we could expect halophytic plants to be the most abundant group of plants under high salinity conditions (Alatar et al., 2012; El-Sheikh et al., 2012). In the present study, the third and sixth vegetation groups which dominated by *Tamarix aucheriana* and *Centropodium forsskalii*, respectively, were found only in sabkha habitats. This could be attributed to the high salinity levels in these habitats. Halophytes are, also, able to hyperaccumulate some of the heavy metals including Cr, Pb, Fe, Mn, Cu and Cd. Heavy metals hyperaccumulators can remediate contaminated soil by sorting such metals in inert forms in their vacuoles using a mechanism similar to the one that halophytes use to cope with salinity (Van Oosten and Maggio, 2015). In the present investigation, the fifth vegetation group dominated by *Calotropis procera* was found only in sewage canals habitats. These habitats were characterized by high levels of heavy metals. This could be an explanation for the high presence of *Calotropis procera* in these habitats because its high ability to accumulate heavy metals (Galal et al., 2016).

The vegetation of the sabkhas and sewage canals in this study fell into 6 different vegetation groups. The third vegetation group, dominated by *Tamarix aucheriana* and *Phragmites australis*, showed high values of percentage of cover and a high Shannon index associated with high soil organic matter, silt percentage in the soil and concentrations of Ca, K, Mg, Fe and Cd. In contrast, the fifth vegetation group, dominated by *Calotropis procera* and *Citrullus colocynthis*, was associated with high soil concentrations of Na and P. This could be due to the role of Na in maintaining pH and ionic balance in plant cells and tissues, and the essential role of P as a macronutrient required for the biosynthesis of amino acids and nuclear proteins (Shiel, 2001). The sixth vegetation group, dominated by *Centropodium forsskalii* and *Emex spinosa*, was associated with high values of species richness and a high Simpson index. This vegetation group was mainly found in sand habitats with good soil conditions. Sandy soils are particularly suitable for growth of various annual herbs and grasses. The distribution of such plants is related to salinity.

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REFERENCES

[1] Abou-Sitta, Y. M., Al-Taisan, W. A. (1995): Variations in mineral ion composition of some succulent halophytes in the Eastern coastal province of Saudi Arabia. – Desert Institute Bulletin, Egypt 45(1): 99-110.
[2] Al-Nafie, A. H. (2008): Phytogeography of Saudi Arabia. – Saudi J. Biol. Sci. 15: 159-176.
[3] Al-Obaid, S., Samraoui, B., Thomas, J., El-Serehy, H. A., Alfarhan, A. H., Schneider, W., O'Connell, M. (2017): An overview of wetlands of Saudi Arabia: Values, threats, and perspectives. – Ambio 46(1): 98-108.
[4] Al-Rowaily, S. L., El-Bana, M. I., Al-Dujain, F. A. R. (2012): Changes in vegetation composition and diversity in relation to morphometry, soil and grazing on a hyper-arid watershed in the central Saudi Arabia. – CATENA 97(Supplement C): 41-49.
[5] Alatar, A. A., El-Sheikh, M. A., Thomas, J. (2012): Vegetation analysis of Wadi Al-Jufair, a hyper-arid region in Najd, Saudi Arabia. – Saudi J. Biol. Sci. 19(1): 43-54.
[6] Alatar, A. A., El-Sheikh, M. A. R., Thomas, J., Hegazy, A. K., El Adawy, H. A. (2015): Vegetation, Floristic Diversity, and Size-Classes of Acacia gerrardii in an Arid Wadi Ecosystem. – Arid Land Res. Manage. 29(3): 335-359.
[7] Allen, S. E. (1989): Chemical analysis of ecological materials. (2nd ed.) – Oxford: Blackwell Scientific.
[8] AOAC (1990). Official methods of analysis of AOAC International.
[9] APHA (2005). Standard Methods for the Examination of Water and Wastewater. (21st ed.) – Washington, DC: American Public Health Association.
[10] Brinson, M. M. (2011): Classification of Wetlands. – In: LePage, B.A. (ed.) Wetlands: Integrating Multidisciplinary Concepts. Dordrecht: Springer Netherlands: 95-113.
[11] Chaudhary, S. A. (2001): Flora of the Kingdom of Saudi Arabia. Vol. 2. – Riyadh: Ministry of Agriculture and Water.
[12] Collenette, S. (1999): Wildflowers of Saudi Arabia. – Riyadh: National Commission for Wildlife Conservation and Development (NCWCD).
[13] Day, P. R. (1965): Particle Fractionation and Particle-Size Analysis. – In: Black, C.A. (ed.) Methods of Soil Analysis. Madison: American Society of Agronomy Inc.: 545-567.
[14] El-Ghanim, W. M., Hassan, L. M., Galal, T. M., Badr, A. (2010): Floristic composition and vegetation analysis in Hail region north of central Saudi Arabia. – Saudi J. Biol. Sci. 17(2): 119-128.
[15] El-Sheikh, M. A. (2013): Population structure of woody plants in the arid cloud forests of Dhofar, southern Oman. – Acta Bot. Croat. 72(1): 97-111.
[16] El-Sheikh, M. A., Abbadi, G. A., Alatar, A. A. (2012): Phytosociological behavior & mineral allocation in Panicum turgidum Forssk. along the coast of the Arabian Gulf, Kuwait. – Feddes Repert. 3: 177-192.
[17] Flinn, K. M., Lechowicz, M. J., Waterway, M. J. (2008): Plant species diversity and composition of wetlands within an upland forest. – Am. J. Bot. 95(10): 1216-1224.
[18] Galal, T. M., Farahat, E. A., El-Midany, M. M., Hassan, L. M. (2016): Nutrients and heavy metals accumulation by the giant milkweed Calotropis procera (Aiton) W.T. Aiton in urbanized areas, Egypt. – Rendiconti Lincei. 27(2): 241-250.
[19] Hill, M. O. (1979a): DECORANA: A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging. – NY: Section of Ecology and Systematics, Cornell University.
[20] Hill, M. O. (1979b): TWINSPAN: A FORTRAN Program for Arranging Multivariate Data in an Ordered Two-way Table by Classification of the Individuals and Attributes. – NY: Section of Ecology and Systematics, Cornell University.
[21] Kent, M. (2012): Vegetation Description and Data Analysis: A Practical Approach. (2nd ed.) – Chichester: John Wiley & Sons.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_32553269

[22] LePage, B. A. (2011): Wetlands: A Multidisciplinary Perspective. – In: LePage, B.A. (ed.) Wetlands: Integrating Multidisciplinary Concepts. Dordrecht: Springer Netherlands: 3-25.
[23] Magurran, A. E. (1988): Diversity indices and species abundance models. – In: Magurran, A. E. (ed.) Ecological Diversity and Its Measurement. Dordrecht: Springer Netherlands: 7-45.
[24] Pielou, E. C. (1975): Ecological diversity. – NY: Wiley.
[25] Shaltout, K. H., El-Halawany, E. F., El-Garawany, M. M. (1997): Coastal lowland vegetation of eastern Saudi Arabia. – Biodivers. Conserv. 6(7): 1027-1040.
[26] Shiel, R. S. (2001): Nutrient Elements in Grassland: Soil–Plant–Animal Relationships. – Eur. J. Soil Sci. 52(3): 523-524.
[27] Stebbins, G. L. (1974): Flowering plants, Evolution Above the Species Level. – Cambridge: M. A. the Belknap Press of Harvard University.
[28] Van Oosten, M. J., Maggio, A. (2015): Functional biology of halophytes in the phytoremediation of heavy metal contaminated soils. – Environ. Exp. Bot. 111(Supplement C): 135-146.

APPENDIX

Appendix 1. *GPS coordinates of the studied stands in Riyadh and Qassim regions*

Stand No.	Habitat	Coordinates	Altitude (m)	Stand No.	Habitat	Coordinates	Altitude (m)
1	Sewage, Riyadh	N 24° 06' 05.5" E 47° 23' 21.4"	421	33	Sabkha, Qassim	N 26° 01' 20.57" E 44° 10' 33.07"	608
2	Sewage, Riyadh	N 24° 06' 01.9" E 47° 23' 14.9"	420	34	Sabkha, Qassim	N 26° 23' 09.1" E 43° 48' 14.5"	629
3	Sewage, Riyadh	N 24° 05' 58.7" E 47° 23' 08.5"	420	35	Sabkha, Qassim	N 26° 23' 23.3" E 43° 47' 42.5"	629
4	Sewage, Riyadh	N 24° 06' 07.9" E 47° 23' 32.3"	421	36	Sabkha, Qassim	N 26° 23' 39.13" E 43° 47' 21.48"	629
5	Sewage, Riyadh	N 24° 06' 15.7" E 47° 23' 22.4"	421	37	Sabkha, Qassim	N 26° 23' 44.8" E 43° 47' 54.3"	634
6	Sewage, Riyadh	N 24° 06' 38.7" E 47° 23' 34.4"	420	38	Sabkha, Qassim	N 26° 23' 48.5" E 43° 48' 39.7"	635
7	Sewage, Riyadh	N 24° 05' 50.9" E 47° 22' 42.7"	417	39	Sabkha, Qassim	N 26° 23' 26.26" E 43° 48' 58.21"	625
8	Sewage, Riyadh	N 24° 04' 47.2" E 47° 22' 14.2"	431	40	Sabkha, Riyadh	N 25° 14' 28.2" E 45° 32' 33.5"	645
9	Sewage, Riyadh	N 24° 04' 28.0" E 47° 22' 11.3"	434	41	Sabkha, Riyadh	N 25° 14' 00.7" E 45° 32' 59.8"	646
10	Sewage, Riyadh	N 24° 11' 10.0" E 47° 26' 03.3"	410	42	Sabkha, Riyadh	N 25° 13' 50.7" E 45° 33' 07.7"	648
11	Sewage, Riyadh	N 24° 11' 07.98" E 47° 25' 58.41"	410	43	Sabkha, Riyadh	N 25° 13' 03.1" E 45° 33' 13.6"	669
12	Sabkha, Qassim	N 26° 04' 04.6" E 44° 09' 58.5"	621	44	Sabkha, Riyadh	N 25° 21' 09.07" E 45° 19' 58.99"	671
13	Sabkha, Qassim	N 26° 04' 10.1" E 44° 09' 59.9"	621	45	Sabkha, Riyadh	N 25° 14' 02.5" E 45° 33' 30.0"	646
14	Sabkha, Qassim	N 26° 03' 51.9" E 44° 01' 41.2"	619	46	Sabkha, Riyadh	N 25° 14' 10.3" E 45° 31' 32.2"	651
15	Sabkha, Qassim	N 26° 03' 37.6" E 44° 09' 39.0"	613	47	Sabkha, Riyadh	N 25° 16' 07.6" E 45° 31' 54.0"	644
16	Sabkha, Qassim	N 26° 03' 16.9" E 44° 09' 54.3"	609	48	Sabkha, Riyadh	N 25° 20' 31.4" E 45° 22' 22.0"	655
17	Sabkha, Qassim	N 26° 02' 59.80" E 44° 10' 02.86"	610	49	Sabkha, Riyadh	N 25° 20' 13.5" E 45° 22' 13.0"	662

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18	Sabkha, Qassim	N 26° 03' 46.6" E 44° 08' 28.1"	604	50	Sewage, Riyadh	N 24° 20' 58.2" E 046° 55' 49.9"	499
19	Sabkha, Qassim	N 26° 03' 44.3" E 44° 08' 30.0"	605	51	Sewage, Riyadh	N 24° 22' 02.9" E 046° 54' 28.4"	505
20	Sabkha, Qassim	N 26° 03' 49.5" E 44° 08' 13.6"	601	52	Sewage, Riyadh	N 24° 22' 16.5" E 46° 54' 20.8"	506
21	Sabkha, Qassim	N 26° 03' 46.1" E 44° 08' 13.3"	602	53	Sewage, Riyadh	N 24° 21' 58.8" E 46° 54' 15.9"	506
22	Sabkha, Qassim	N 26° 03' 38.6" E 44° 08' 07.8"	604	54	Sewage, Riyadh	N 24° 21' 48.7" E 46° 54' 20.4"	506
23	Sabkha, Qassim	N 26° 03' 33.6" E 44° 08' 18.6"	603	55	Sewage, Riyadh	N 24° 21' 31.9" E 46° 54' 31.1"	502
24	Sabkha, Qassim	N 26° 03' 26.7" E 44° 08' 20.7"	604	56	Sewage, Riyadh	N 24° 18' 36.35" E 46° 58' 40.14"	501
25	Sabkha, Qassim	N 26° 03' 22.3" E 44° 08' 22.3"	604	57	Sewage, Riyadh	N 24° 23' 01.1" E 046° 49' 45.0"	564
26	Sabkha, Qassim	N 26° 02' 51.39" E 44° 08' 42.48"	605	58	Sewage, Riyadh	N 24° 22' 31.8" E 46° 49' 53.3"	566
27	Sabkha, Qassim	N 26° 02' 26.6" E 44° 08' 13.2"	610	59	Sewage, Riyadh	N 24° 22' 11.6" E 046° 50' 23.8"	559
28	Sabkha, Qassim	N 26° 02' 21.8" E 44° 08' 45.8"	599	60	Sewage, Qassim	N 25° 56' 04.4" E 43° 28' 22.3"	650
29	Sabkha, Qassim	N 26° 00' 27.81" E 44° 09' 16.58"	600	61	Sewage, Qassim	N 25° 56' 06.8" E 43° 28' 27.1"	650
30	Sabkha, Qassim	N 25° 58' 48.0" E 44° 10' 14.9"	602	62	Sewage, Qassim	N 25° 54' 33.3" E 43° 26' 26.9"	649
31	Sabkha, Qassim	N 25° 58' 00.7" E 44° 10' 47.7"	604	63	Sewage, Qassim	N 25° 54' 07.8" E 43° 27' 24.2"	647
32	Sabkha, Qassim	N 25° 58' 58.3" E 44° 11' 30.5"	607				

Appendix 2. *Collected plant species and their families, lifeforms and chorotype*

Species	Families	Lifeform	Chorotype*
Acacia ehrenbergiana	Leguminosae	Shrub	SH-SM
Acacia gerrardii	Leguminosae	Tree	SH-SM
Acacia raddiana	Leguminosae	Tree	SH-SM
Aeluropus lagopoides	Gramineae	Perennial grass	Eu. Sib-Med-IT
Aizoon canariense	Aizoaceae	Annual herb	SA-SM
Alhagi graecorum	Leguminosae	Perennial shrub	MED-IT
Amaranthus viridis	Amaranthaceae	Annual herb	TR
Anisosciadium lanatum	Umbelliferae	Annual herb	SA
Anvillea garcinii	Compositae	Perennial shrub	SA
Artemisia monosperma	Chenopodiaceae	Shrub	SA
Asphoedelus tenuifolius	Asphodelaceae	Annual herb	SA-SM
Atriplex suberecta	Chenopodiaceae	Perennial shrub	Am
Atrriplex leucoclada	Chenopodiaceae	Shrub	SA
Bassia eriophora	Chenopodiaceae	Annual herb	SA-IT
Bassia muricata	Chenopodiaceae	Annual herb	SA-IT
Cakile arabica	Cruciferae	Annual herb	SA
Calotropis procera	Asclepiadaceae	Shrub	SM
Capparis spinosa	Capparaceae	Shrub	Med-SA
Centropodium forsskallii	Gramineae	Perennial grass	SA-IT
Chenopodium album	Chenopodiaceae	Annual herb	PALEO
Chenopodium ambrosioides	Chenopodiaceae	Perennial shrub	TR
Chenopodium glaucum	Chenopodiaceae	Annual herb	EU-MED
Chenopodium murale	Chenopodiaceae	Annual herb	PALEO
Chrozophora oblongifolia	Euphorbiaceae	Perennial shrub	IT

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Species	Families	Lifeform	Chorotype*
Cistache tubulosa	Orobanchaceae	Annual herb	SA-IT
Citrullus colocynthis	Cucurbitaceae	Annual herb	SA
Cleome amblyocarpa	Capparaceae	Annual herb	SA-SM
Cleome rupicola	Capparaceae	Annual herb	SH-SM
Convolvulus austro-aegyptiacus	Convolvulaceae	Perennial shrub	SA
Cornulaca monacantha	Chenopodiaceae	Perennial shrub	SA
Cressa cretica	Convolvulaceae	Annual herb	MED-IT
Cynodon dactylon	Gramineae	Perennial grass	TR
Datura innoxia	Solanaceae	Shrub	AM
Devera triradiata	Umbelliferae	Shrub	SA
Dipterygium glaucum	Capparaceae	Perennial shrub	SA
Emex spinosa	Polygonaceae	Annual herb	MED-SA
Ephedra aphylla	Ephedraceae	Shrub	SA
Eragrostis barrelieri	Gramineae	Perennial grass	MED-SA
Eremobium lineare	Cruciferae	Annual herb	SA
Fagonia bruguieri	Zygophyllaceae	Perennial shrub	SA
Fagonia indica	Zygophyllaceae	Perennial shrub	SA
Farsetia longisiliqua	Cruciferae	Perennial shrub	SA
Frankenia pulverulenta	Frankeniaceae	Annual herb	Eu-Sib-Med-IT
Gisekia pharnaceoides	Molluginaceae	Annual herb	TR
Gypsophila capillaris	Caryophyllaceae	Annual herb	IT
Halothamnus iraqensis	Chenopodiaceae	Perennial shrub	SA-IT
Haloxylon salicornicum	Chenopodiaceae	Perennial shrub	SA
Helianthemum lippii	Cistaceae	Perennial shrub	SA-SM
Heliotropium bacciferum	Boraginaceae	Perennial shrub	SA-SH
Heliotropium digynum	Boraginaceae	Perennial shrub	SA
Juncus rigidus	Juncaceae	Perennial shrub	SA-IT
Lactuca serriola	Compositae	Perennial shrub	Med-Eu-Sib-IT
Lasiurus scindicus	Gramineae	Perennial grass	SA-SH-SM
Launaea capitata	Compositae	Annual herb	SA
Launaea mucronata	Compositae	Annual herb	SA
Launaea nudicaulis	Compositae	Annual herb	SA
Leptadenia pyrotechnica	Asclepiadaceae	Shrub	SA-SM
Leptochloa fusca	Poaceae	Perennial grass	TR
Lolium rigidum	Gramineae	Annual grass	MED-IT
Lycium shawii	Solanaceae	Shrub	SA
Malva parviflora	Malvaceae	Annual herb	MED-IT
Moltkiopsis ciliata	Boraginaceae	Perennial shrub	SA
Neurada procumbens	Neuradaceae	Annual herb	SA
Ochthochloa compressa	Gramineae	Perennial grass	SA-SM
Ochradenus baccatus	Resedaceae	Shrub	SH-SM-SA
Oligomeris linifolia	Resedaceae	Annual herb	SH-SM-SA
Panicum turgidum	Gramineae	Perennial grass	SH-SM-SA
Paspalidium desertorum	Gramineae	Annual grass	SH-SM
Pennisetum divisum	Gramineae	Perennial grass	SA
Picris babylonica	Compositae	Annual herb	SA
Phalaris minor	Gramineae	Annual grass	MED-IT
Phragmites australis	Gramineae	Perennial grass	MED-IT-SA
Plantago amplexicaulis	Plantaginaceae	Annual herb	SA
Plantago boissieri	Plantaginaceae	Annual herb	SA
Polycarpaea repens	Caryophyllaceae	Perennial shrub	SA-SM
Polygonum argyrocoleum	Polygonaceae	Annual herb	MED-IT
Polypogon monsepeliensis	Gramineae	Annual grass	Med-IT-SA
Portulaca oleracea	Portulacaceae	Annual herb	COSM
Prosopis fracta	Leguminosae	Perennial shrub	IT

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Species	Families	Lifeform	Chorotype*
Prosopis juliflora	Leguminosae	Tree	AM
Pulicaria undulata	Compositae	Perennial shrub	SA-SM
Reseda arabica	Resedaceae	Annual herb	SA
Rhazya stricta	Apocynaceae	Perennial shrub	SA
Ricinus communis	Euphorbiaceae	Shrub	TR
Rumex dentaus	Polygonaceae	Perennial shrub	Med-Eu-Sib-IT
Ruppia maritima	Ruppiaceae	Perennial shrub	TR
Salicornia europaea	Chenopodiaceae	Annual herb	Med-Eu.Sib
Salsola imbricata	Chenopodiaceae	Perennial shrub	SA-SH
Salvia spinosa	Labiatae	Annual herb	IT
Savignya parviflora	Cruciferae	Annual herb	SA
Schismus barbatus	Gramineae	Annual grass	SA-IT
Sclerocephalus arabicus	Caryophyllaceae	Perennial shrub	SA
Scorzonera intricata	Compositae	Perennial shrub	IT
Seidletzia rosmarinus	Chenopodiaceae	Shrub	SA
Senna italica	Leguminosae	Perennial shrub	SH-SM
Sonchus oleraceus	Compositae	Annual herb	Eu-Sib-Medi-IT
Spergularia diandra	Caryophyllaceae	Annual herb	Med-IT-Eu.sib
Stipagrostis plumosa	Gramineae	Perennial grass	SA-IT
Suaeda aegyptiaca	Chenopodiaceae	Annual herb	SA
Suaeda vermiculata	Chenopodiaceae	Perennial shrub	SA
Tamarix aphylla	Tamaricaceae	Tree	SA-SM
Tamarix aucheriana	Tamaricaceae	Shrub	SA-SM
Tamarix nilotica	Tamaricaceae	Shrub	SA
Traganum nudatum	Chenopodiaceae	Perennial shrub	SA
Xanthium strumarium	Compositae	Perennial shrub	TR
Zilla spinosa	Cruciferae	Annual herb	SA
Zygophyllum coccineum	Zygophyllaceae	Perennial shrub	SA
Zygophyllum propinquum ssp. migahidii	Zygophyllaceae	Perennial shrub	SA
Zygophyllum simplex	Zygophyllaceae	Annual herb	SH-SM

* TR: Tropical, SH-SM: Sahel-Somalia Masai, SA-SM: Saharo Arabian-Somalia Masai, SA-SH-SM: Saharo Arabian-Sahel-Somalia Masai, SA-IT: Saharo Arabian-Irano Turanian, SA: Saharo Arabian, Paleo: Paleotropic, Med-SA: Mediterranean-Saharo Arabian, MED-IT-SA: Mediterranean-Irano Turanian-Saharo Arabian, MED-IT: Mediterranean-Irano Turanian, IT: Irano Turanian, Eu-Sib-Med-IT: Euro Siberian-Mediterranean-Irano Turanian, COSM: Cosmopolitan, Am: American

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