EFFECT OF HABITAT TYPE ON FLORISTIC DIVERSITY ON SAUDI UNIVERSITY CAMPUSES AS URBAN HABITATS

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Abstract. Urban biodiversity has become more important due to the increasing impacts of urbanization on natural ecological systems. Campuses of universities are urban places with a high concentration of people and a variety of habitat types. This study, which is the first of its kind in Saudi Arabia, sought to investigate how various ecosystems affect plant diversity on university campuses. We selected Princess Nourah bint Abdulrahman University (NC) and Taif University (TC), two universities situated in two distinct regions. Six distinct habitats were identified on university campuses, and their floristic compositions were examined. On both campuses, the data showed that there were 159 species, representing 118 genera and 38 families. The number of species, genera, and families in the TC was 3.3%, 15.7%, and 40% greater than that of the NC, respectively. Twenty families were represented by a single species, but 33.3% of the documented species belonged to the Poaceae and Asteraceae groups. Plant diversity is greatly influenced by habitat type; in the TC, the humid, fertile soil environment had the highest species count (52 species), whereas in NC, the habitat is sandy, arid surroundings had the highest species count (42 species). The life forms and chorotypes of the recorded species and their distribution in the different habitats on the two campuses are presented. The current results show the great plant diversity of Saudi university compounds, which highlights the importance of the role of these habitats in preserving biodiversity.
Keywords: *urbanization, biodiversity, chorotype, life form, campuses, Saudi Arabia*

Introduction

Urban areas include unique habitats such as gardens, parks, roadsides and university campuses that are characterized by a high degree of human population and traffic may result in novel ecosystems (McKinney, 2002; Schmidt et al., 2014). Urban ecosystems and their biodiversity are likely to be drastically affected by human activities with predicted increases in human population in the future (Schmidt et al., 2014; Lososová et al., 2018). In addition, these ecosystems are treated by two major drivers of biodiversity loss: habitat disturbance and biological invasions. In recent decades, urban biodiversity has become more important due to the increasing impacts of urbanization on natural ecological systems. Although they face strong anthropogenic pressure (McKinney, 2002), urban areas can contain rather high levels of biodiversity (Luck, 2007). Biodiversity in urban areas may

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be enhanced by factors such as small-scale habitat heterogeneity (Pyšek, 2010), geological diversity (Kühn et al., 2004), representing early successional stages and "average" habitat conditions (McKinney, 2008). Previously, it was documented that the increasing biodiversity of urban ecosystems may have positive effects on the quality of life of inhabitants (Hanski et al., 2012), as well as promoting ecosystem functioning, such as carbon storage and sequestration, ecological value as grassland habitats (Rudolph et al., 2017), and decreases in temperature (Susca et al., 2011).

Urbanization affects biodiversity in many ways: it alters the abiotic environmental factors, such as temperature, soil characteristics and water availability (Csorba and Szabó, 2012). In addition, it leads to considerable loss and isolation of natural habitats. Urban ecosystems are characterized by a fine-scale pattern of various habitat types, which are usually heavily disturbed and enriched in nutrients (Lososová et al., 2012). Several anthropogenic disturbance regimes are associated with urban habitats, such as trampling, soil disturbance and pollution (Al-Sherif et al., 2013; Vince et al., 2014). This differentiation of disturbance levels on urban habitat types plays an important role in species richness/diversity and composition (Deák et al., 2016). Furthermore, urban green infrastructures will likely face substantial changes in future global conditions (Lososová et al., 2018). In many cities, urban green spaces preserve the remnants of the semi-natural habitats such as grasslands or forests, and they also have an important role in preserving at least a part of the regional species pool of semi-natural habitats. Species composition of urban habitats depends on their environmental characteristics, spatiotemporal dynamics, management, and size (Cervelli et al., 2013) and contain suitable habitats for numerous native plant species (Mckinney, 2006). Furthermore, urban habitats provide important ecosystem services for society such as purification of air and water, temperature regulation and water storage (Cervelli et al., 2013).

To better understand the effects of urbanization on biodiversity, university campuses are powerful systems for various reasons: they have relatively homogenous conditions compared to cities, which makes them suitable for comparisons across large environmental scales; and they often have reliable plant surveys since they are home to many botanists (Liu et al., 2017). Currently, there are government and foundation universities in Saudi Arabia, with more than 29 universities, which offers a unique research opportunity. Even though urban habitats play an important role in biodiversity conservation, there is no study in Saudi Arabia about the floristic composition of university campus habitats. Our aim was to explore the link between plant diversity and habitat types across university campuses in Saudi Arabia, providing the first comprehensive study in Saudi Arabia. We addressed the following questions: (1) How do species richness patterns vary across campuses? (2) How habitats affect plant species diversity and how important are these variables?

Materials and methods

The study area

We chose two universities located in two different geographical regions, Princess Nourah bint Abdulrahman University, NC, (24°50'46.19"N 46°43'19.07"E) which located in Riyadh city and Taif University, TC, (21°25'57.34"N 40°29'39.74"E), which located in Taif city, as the study areas (*Fig. 1*). *Table 1* shows that the average temperature in the TC is between 15.1°C and 28.2°C, whereas in the NC it is between 14°C and 36.1°C. Every month, TC receives 2–37 mL of precipitation, while NC

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experiences 4 months without rain and the remaining 4 months between 0 and 14 mL of precipitation. TC had a maximum humidity of 58%, whereas NC had a maximum humidity of 44% (*Table 1*).

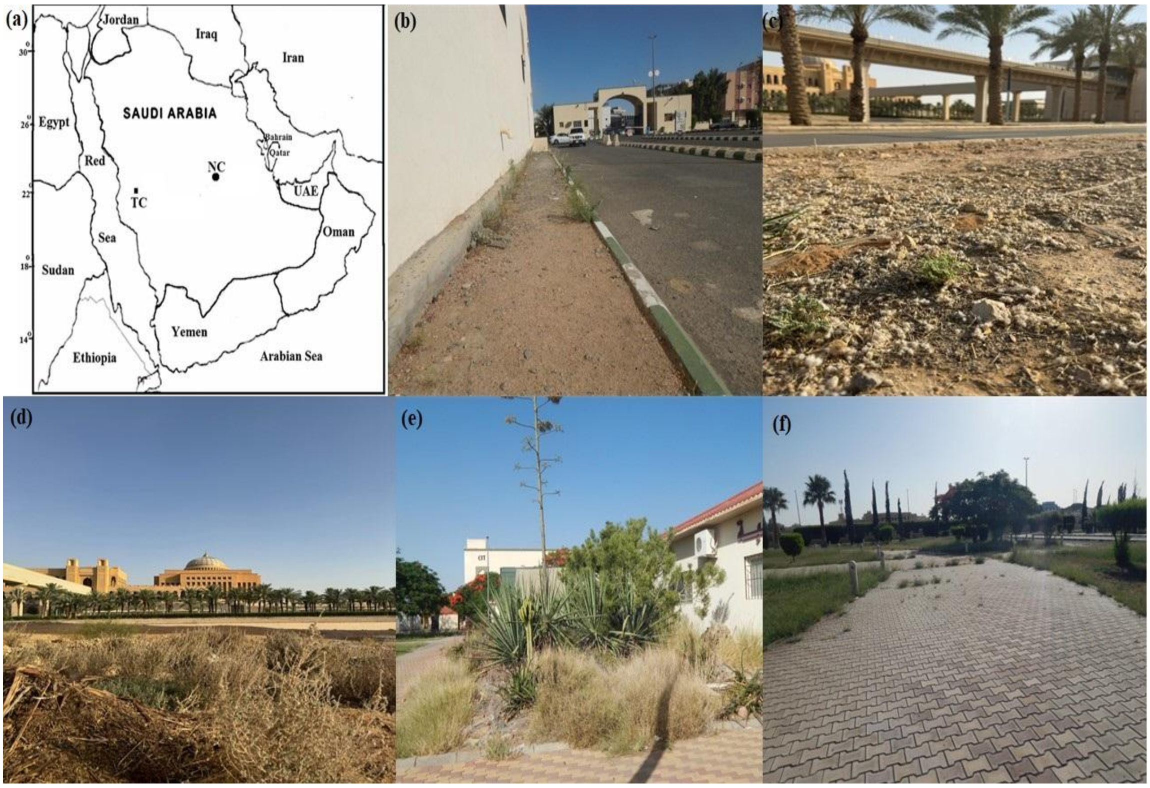

Figure 1. *Map showing the location of the studied campuses (a) and their different studied habitats: sandy dry habitats around buildings, H1 (b), fallow land of fine sandy soil, H2 (c), abandoned cultivated quadrates H3 (d), stone structures for aloe cultivation H4 (e) both humid fertile squares H5 and court footway habitat H6 (f)*

Sample collection

Each campus was divided into six different habitats as follows: sandy dry habitats around buildings (H1), fallow land of fine sandy soil (H2), abandoned cultivated quadrates (H3), stone structures for aloe cultivation (H4), stands of humid fertile squares (H5), and court footway habitat (H6). A comprehensive survey was conducted between March 2021 and March 2022. Four visits to each campus, one visit per season, were done during the study period. Plant samples were collected from 60 stands, five stands in each habitat in each campus. During the sampling, all vascular plants that spontaneously occurred in each urban habitat were collected. The frequencies of each species in the different habitats were recorded. With the assistance of many Floras (Chaudhary, 2001), the collected specimens were identified. The voucher specimens were placed at Taif University and Nourah bint Abdulrahman University. The placement of the regenerative buds and the components shed during the unfavorable season were used to determine the life forms of the identified species. The investigated species' biogeographic affinities were ascertained at each habitat in accordance with Wickens (1976).

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Soil analysis

Five soil samples were taken from a profile ranging in depth from 0 to 25 cm for every habitat in each campus. These five soil samples were combined to create a single composite sample, which was then properly mixed and allowed to air dry. The hydrometer method, which yielded quantitative information on the amount of sand, silt, and clay, was used to determine the texture of the soil. Using pH and conductivity meters, respectively, the pH and conductivity of the soil were measured in a saturated soil paste extract. Total nitrogen and organic matter (Bremmer, 1965) were measured. Moisture content was determined by the oven-drying method.

Table 1. *Temperature, precipitation and humidity of the two campuses during study. Climatic data were obtained from the meteorological stations in Taif (for TC) and Riyadh (for NC)*

		Avg. temperature °C	**Min. temperature °C**	**Max. temperature °C**	**Precipitation (mm)**	**Humidity (%)**
January	TC	15.1	10.4	20.4	37	58%
	NC	14	7.3	20.3	11	41%
February	TC	17.1	11.7	23	10	48%
	NC	17.1	9.7	23.6	6	30%
March	TC	19.3	13.7	25.3	22	40%
	NC	21.5	13.8	28	12	24%
April	TC	22.1	16.9	27.8	37	39%
	NC	26.9	19.1	33.4	14	20%
May	TC	25.8	20.8	31.4	26	26%
	NC	32.5	24.2	38.9	2	14%
June	TC	28.2	22.9	33.9	2	17%
	NC	34.8	26	41.6	0	10%
July	TC	27.5	22.3	33	3	23%
	NC	36.1	27.5	42.8	0	11%
August	TC	27.4	22.4	32.9	16	30%
	NC	36.1	27.5	42.7	0	12%
September	TC	26.7	21.9	32.2	14	29%
	NC	32.7	24.4	39.5	0	14%
October	TC	22.9	17.5	28.6	10	34%
	NC	27.7	20.1	34.1	1	18%
November	TC	18.8	13.9	24.1	15	49%
	NC	20.3	13.9	26.2	11	35%
December	TC	16.2	11.4	21.5	20	56%
	NC	15.1	8.5	21.3	9	44%

Statistical analysis

For cluster analysis, dendrograms were generated by the similarity matrices using “R” software for Windows version 3.5.1. ß-diversity/similarity of stands, which is

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dependent on the presence or lack of species, was assessed using Jaccard's similarity index (Castro and Jaksic, 2008). To determine significant differences among means for soil parameters, One-way Anova and the Tukey's Honestly Significant Difference (HSD) tests were used.

Results

Soil characters of the different habitats

Table 2. shows some characters of the soils of the studied habitats. The pH values ranged between 7.25 and 8.02, while organic carbon exhibited the highest value. In N5 habitats in both campuses, while the lowest value was recorded in H4. The moisture contents showed the most variable factors, where it exhibited its highest values in H 5 in each campus.

Table 2. *Soil characters of the different habitats*

	H1		H2		H3		H4		H5		H6	
	TC	NC	TC	NC	TC	NC	TC	NC	TC	NC	TC	NC
pH value	8.02 ± 0.25a	7.89 ± 0.36a	7.5 ± 0.25a	7.8 ± 0.11a	7.25 ± 0.25b	7.26 ± 0.22b	7.85 ± 0.25a	7.91 ± 0.11a	7.5 ± 0.25b	7.63 ± 0.23b	7.5 ± 0.25b	7.42 ± 0.33b
Organic carbon (%)	1.3 ± 0.05a	1.36 ± 0.06a	1.5 ± 0.05b	1.12 ± 0.01b	1.6 ± 0.05b	1.03 ± 0.02a	0.7 ± 0.05c	0.69 ± 0.01c	2.1 ± 0.09d	1.90 ± 0.02d	0.8 ± 0.05e	0.84 ± 0.01e
EC (mmhos/cm)	2.1 ± 0.35a	1.89 ± 0.41a	2.4 ± 0.34b	2.6 ± 0.02b	2.3 ± 0.33b	2.2 ± 0.03b	1.9 ± 0.32a	2.1 ± 0.02a	1.8 ± 0.33a	1.6 ± 0.01a	1.11 ± 0.31c	1.09 ± 0.01c
Cl^- (%)	0.07 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.91 ± 0.01	0.06 ± 0.01	0.08 ± 0.01	0.05 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01
Soluble CO_3^{--} (%)	0.06 ± 0.005	0.06 ± 0.01	0.04 ± 0.005	0.02 ± 0.01	0.04 ± 0.005	0.05 ± 0.01	0.05 ± 0.005	0.05 ± 0.01	0.04 ± 0.005	0.03 ± 0.01	0.04 ± 0.005	0.4 ± 0.01
Moisture content (%)	0.4 ± 0.05a	3.2 ± 0.1e	0.9 ± 0.05	0.8 ± 0.01b	1.4 ± 0.1c	1.10 ± 0.3c	0.5 ± 0.05a	0.45 ± 0.01a	15.4 ± 0.5d	8.96 ± 1.2f	1.1 ± 0.1	0.98 ± 0.1c
Coarse sand (%)	63.6 ± 0.3a	61.9 ± 1.6a	33.5 ± 0.3b	26.8 ± 1.3a	3.7 ± 0.1c	2.8 ± 0.03c	23.5 ± 0.1d	23.8 ± 2.4d	3.7 ± 0.1c	0.9 ± 0.03d	0.5 ± 0.1d	1 ± 0.01c
Fine sand (%)	26.4 ± 0.3a	27.3 ± 0.6a	58.5 ± 0.4b	63.7 ± 2.4b	56.3 ± 0.5c	56.6 ± 2.3c	46.5 ± 0.5c	46.6 ± 2.8c	36.3 ± 0.5e	42 ± 2.7c	56.5 ± 0.5c	63.8 ± 2.3c
Silt (%)	6.4 ± 0.2a	6.7 ± 0.2a	5.4 ± 0.2b	6.6 ± 0.7a	30.4 ± 0.2d	29.9 ± 1.4d	20.3 ± 0.2c	19.5 ± 1.2c	40.5 ± 0.5e	39.8 ± 1.6e	30.3 ± 0.2e	28.5 ± 1.2e
Clay (%)	4.6 ± 0.3	4.1 ± 0.03	2.6 ± 0.3	2.9 ± 0.02	9.6 ± 0.3	10.7 ± 0.65	9.7 ± 0.3	10.1 ± 0.6	19.5 ± 0.3	17.3 ± 1.03	12.7 ± 0.3	6.7 ± 0.5
Soil texture	Sandy	sandy	Sandy	sandy	Sandy loam	sandy loamy	Sandy loam	Sandy loam	Loamy	Sandy loam	Sandy loam	Sandy loam

Values are mean of three replicates (n = 3) ± SE. Values with similar letters, within the same row, are non-significantly different at $p \leq 0.005$ as determined by Duncan test

Floristic compositions and their distributions in the campuses' habitats

The total floristic composition for the studied two campuses was 159 species belonging to 118 genera and 37 families (*Table A1* in the *Appendix*). Taxa`s numbers on the Taif university campus (TC) were higher than those recorded on the Nourah campus (NC), where the number of species, genera and families at TC were higher than those in NC by 3.3%, 15.7%, and 40%, respectively. Sixty-nine species were recorded in the TC; however, they were not recorded on the NC. On the other hand, 57 species that were not listed on the TC were recorded there. With six species, the genus *Euphorbia* has the most diversity, followed by *Fagonia* and *Launaea* (five species each). Eleven

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genera were represented by two species and ninety-eight genera were represented by only one species for each. The total number of plant species for each habitat in both campuses showed that H1 had the highest species number followed by H5, while H4 exhibited the lowest species number (*Fig 2a*). The humid fertile soil habitat (H5) exhibited the largest species number on the Taif University campus, while the stony soil habitat (H4) showed the lowest species number (*Fig. 2b*). The sandy drought surrounding habitat (H1) recorded the highest species at NC, in contrast, fallow land habitat (H2) and stony soil habitat (H4) were completely devoid of plant species. Not only Poaceae exhibited the highest rich family with 29 species followed by Asteraceae with 24 species but also, they represented 33.3% of the recorded species, while 20 families were represented by only one species (*Fig. 3*).

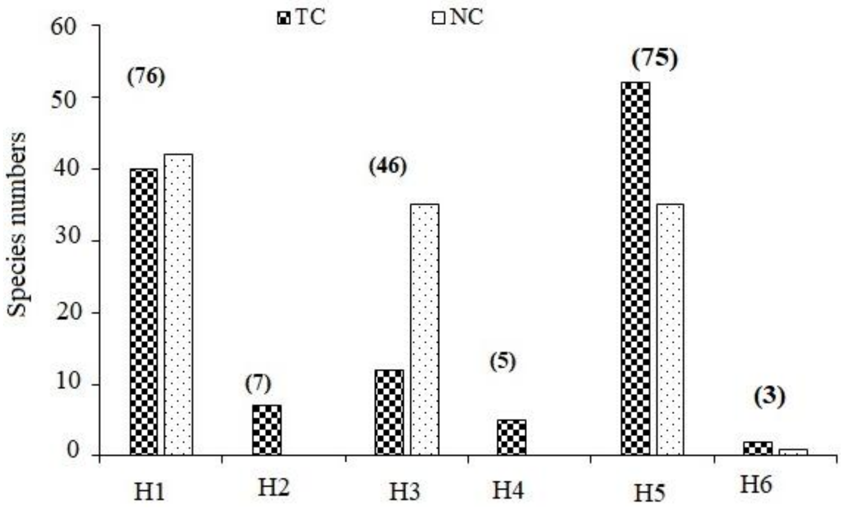

Figure 2. *Species number in the different habitats. H1: Sandy dry habitats around buildings, H2: fallow land of fine sandy soil, H3: abandoned cultivated quadrates, H4: stone structures for aloe cultivation, H5: stands of humid fertile squares, and H6: court footway habitat. The number in parentheses indicates the total number for each environment*

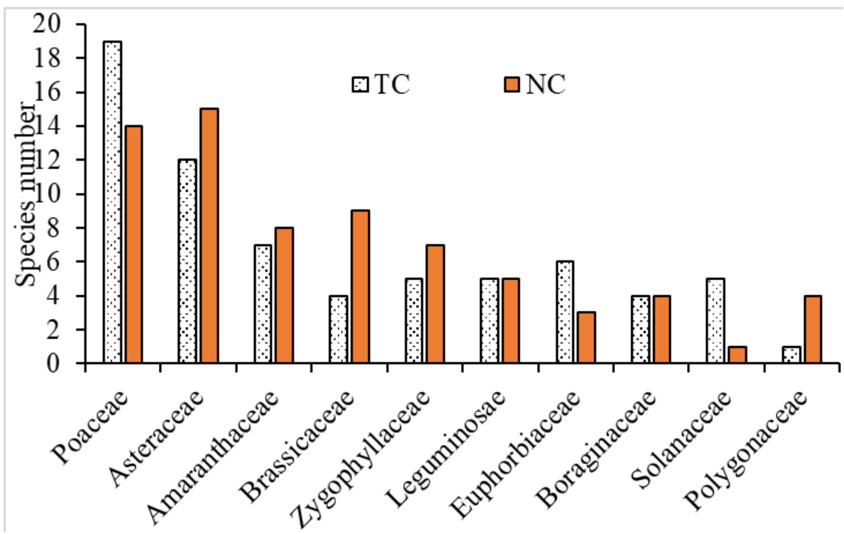

Figure 3. *The most representative families. TC: Taif university campus and NC: Nourah bint Abdulrahman university campus*

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H1 and H3 habitats included more species in NC than those in TC, opposite the other three habitats which recorded more species in TC than those in NC (*Fig. 2b*). *Figure 4* shows that the number of species gradually declines as the number of habitats they exist in increases (an inverse J-shaped relationship), where the number of taxa that occur in one habitat was 104 taxa, in two habitats (38 taxa), but the species number was ten species in three habitats, on the other hand only seven species (*Tribulus terrestris* L., *Forsskaolea tenacissima* L., *Setaria viridis* (L.) P. Beauv., *Cynodon dactylon* (L.) Pers., *Euphorbia prostrata* Aiton, *Convolvulus arvensis* L. and *Sonchus oleraceus* L.) were recorded in four habitats. While it has not been recorded that plant species exist in six different habitats, or even in five different habitats.

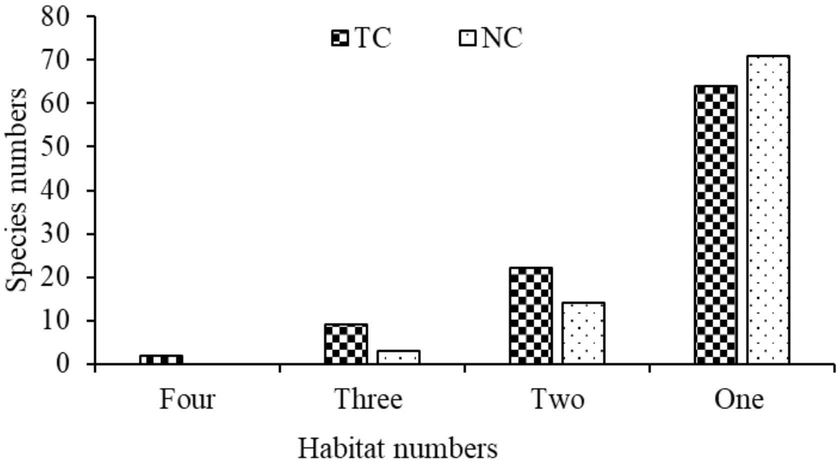

Figure 4. *The numbers of species that are found in different habitats*

The floristic relationship of the studied habitats was constructed using COR function of R program (*Fig. 5*). The cluster analysis of the floristic composition of the studied habitats using heat map analysis produced three clusters. The first one included four habitats H2, H3, H4 and H6. While each of the 2nd and the third were comprised of only one habitat, H1 and H5 respectively. Different habitats of NC showed similarities between each other more than those recorded between habitats of TC. Jaccard similarity exhibited the highest value (19%) between humid fertile soil and court footway habitats of TC (*Table 3*). Sandy dry habitats around buildings in TC showed higher similarities with each of stands of humid fertile squares and Court footway habitat in the same campus. More than 32% of Jaccard similarities values were zero.

Table 3. *Jaccard similarities between different habitats based on the floristic composition*

	TC 1	NC 1	TC 2	NC 2	TC 3	NC 3	TC 4	NC 4	TC 5	NC 5	TC 6	NC 6
TC 1	1.00											
NC 1	0.08	1.00										
TC 2	0.04	0.02	1.00									
NC 2	0.00	0.00	0.00	1.00								
TC 3	0.12	0.09	0.05	0.00	1.00							
NC 3	0.07	0.12	0.03	0.03	0.02	1.00						
TC 4	0.02	0.07	0.00	0.00	0.05	0.03	1.00					
NC 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00				

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TC 5	0.15	0.11	0.03	0.00	0.08	0.07	0.09	0.00	1.00			
NC 5	0.07	0.15	0.03	0.00	0.09	0.10	0.08	0.00	0.16	1.00		
TC 6	0.15	0.09	0.06	0.00	0.05	0.07	0.13	0.00	0.19	0.13	1.00	
NC 6	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	1.00

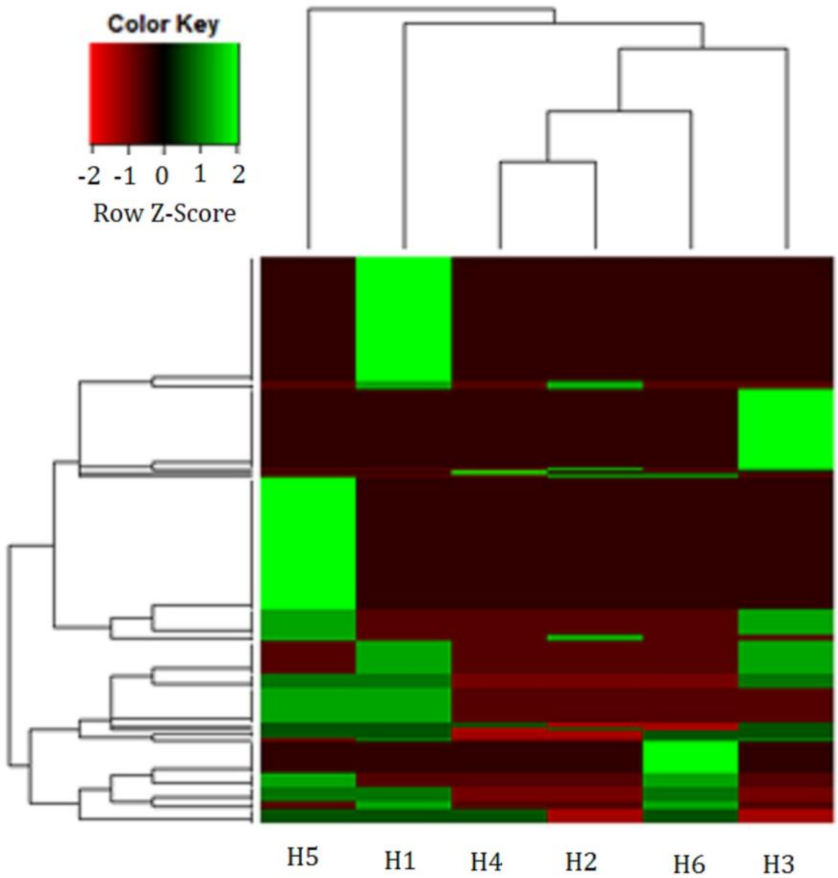

Figure 5. *Heat map with hierarchical clustering of studied five habitats (X-axis) and the floristic characters (Y-axis). Green indicates a high level of expression; Red represents a low level of expression; increasing color intensity is directly proportional to the value of the studied characters. H1: Sandy dry habitats around buildings, H2: fallow land of fine sandy soil, H3: abandoned cultivated quadrates, H4: stone structures for aloe cultivation, H5: stands of humid fertile squares, and H6: court footway habitat.*

Life forms and their distributions in the campuses' habitats

The species recorded in the current study belong to five life forms as follows: Therophytes which dominated the other life forms by 63.5%, followed by hemicryptophytes (13.2%), chamaephytes (11.3%), phanerophytes (5.6%), and geophytes (6.2%). The therophytes ` percentage on the NC was much greater than that thise recorded on the TC (by 12%); in contrast, the proportions of phanerophytes and geophytes were higher on the TC than on NC by 5% for each. In addition, the percentage of hemicryptophytes and chamaephytes was slightly higher on the TC than on the NC (*Fig. 6*).

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Chorotype of the recorded species and their distribution

Figure 7 shows that the chorotype of the recorded species showed that the Saharo-Sindian elements not only recorded the highest monoregional elements (10.6%) but also exhibited the most frequent elements included in the biregional elements (30.8%) and in the pluriregional elements (18.8%). There were 50 species (10.7% biregional and 20.6% pluriregional) that represented the Irano-Turanian element. The Mediterranean element represented 28.3%, where 1.3% of them monoregional, 11.9% biregional, and 15.7% pluriregional. Thirty-eight species were found to represent the Sudano-Zambezian element; 26.4% of them comprised only one monoregional species, 16.4% were biregional, and 9.4% were pluriregional. There were 21 species (14.5%) in the Neotropical components and 14 species (12%) in the Cosmopolitan elements. Palaeotropical elements are represented by the lowest number of species (7 species, 4.4%), as shown in *Table 3*. Each of the biregional elements Sa-Si + S-Z, Sa-Si + I-T, and M + I-T were represented in TC with more species than in NC.

Invasive species and their distribution

Five invasive species were found in the current study, despite the fact that no endemic species were found on either campus. *Salicornia europaea* and *Lepidium ruderale* were found only in NC, while *Leucaena leucocephala* and *Argymone ochroleuca* were found only in TC. Furthermore, records *of Euphorbia prostrata* were made on both campuses.

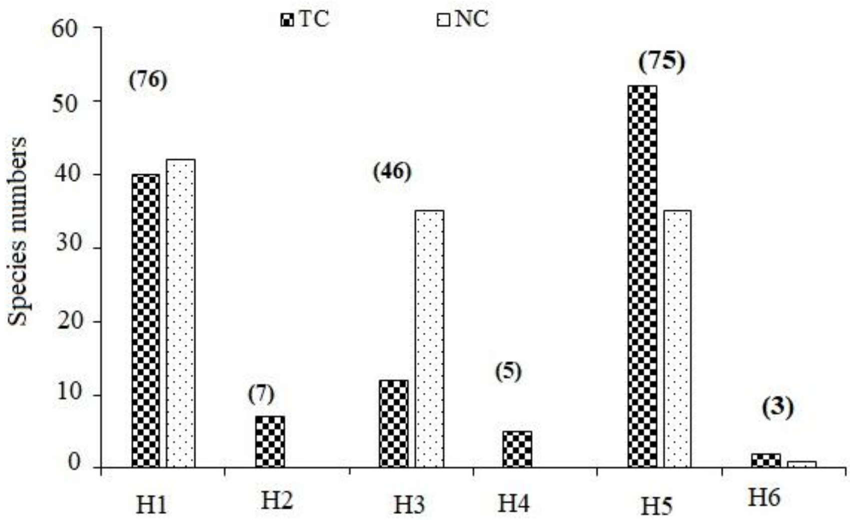

Figure 6. *Plant life forms in different habitats. Th: therophytes, Ch: chamaephyte, Ph: phanerophytes, Ge: geophytes and He: hemi-cryptophytes. The number in parentheses indicates the total number for each environment*

Discussion

The high species numbers in both studied campuses, in relation to their area, indicate the high biodiversity of these studied urban habitats. Previously it was reported that urban habitats may preserve and maintain relatively high levels of biodiversity (Salinitro et al., 2018). Despite the huge area difference between the NC and the valley, 111 plant species were identified in a recent study conducted in Wadi Hargan, one of

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the valleys with the most diverse flora, which is close to NC (Abd-ElGawad et al., 2021). This shows how important urban habitats are for species conversation in arid regions. Species composition of these habitats is subjected to their management types, intensity, patch size and shape, patch connectivity, temporal dynamics with biotic and abiotic compounds (Cervelli et al., 2013). However, particularly in hyper-arid drylands, urbanized areas are the ones that can offer enough water and room for plants in addition to their inhabitants. According to estimates, urban irrigated regions in dryland North American cities use between 59 and 67 percent of their household water (Milesi et al., 2009). As arguably the largest urban green spaces, forest parks and public gardens offer a significant amount of space, water, and other resources for plants, preserve a distinctive mix of native and planted species, and typically maintain higher levels of biodiversity than their nearby urban areas and even unspoiled dryland areas. 162 native and exotic plant species, belonging to 130 genera and 43 families, may be found at Tehran, Iran's Chitgar Forest Park (Arabzadeh et al., 2014). at contrast, a relatively nearby natural area of Kalak is home to about 153 species. Other examples of the species' richness of urban green spaces include the public gardens in Mexico City, Mexico, which have an overall biodiversity of roughly 750 species (Smith et al., 2006), and the impressive biodiversity of six large public gardens in Cairo, Egypt, which are home to about 962 native and exotic plant species (Hamdy et al., 2007). The great difference between the plant species recorded at the two universities is due to the difference in geography and climate between them.

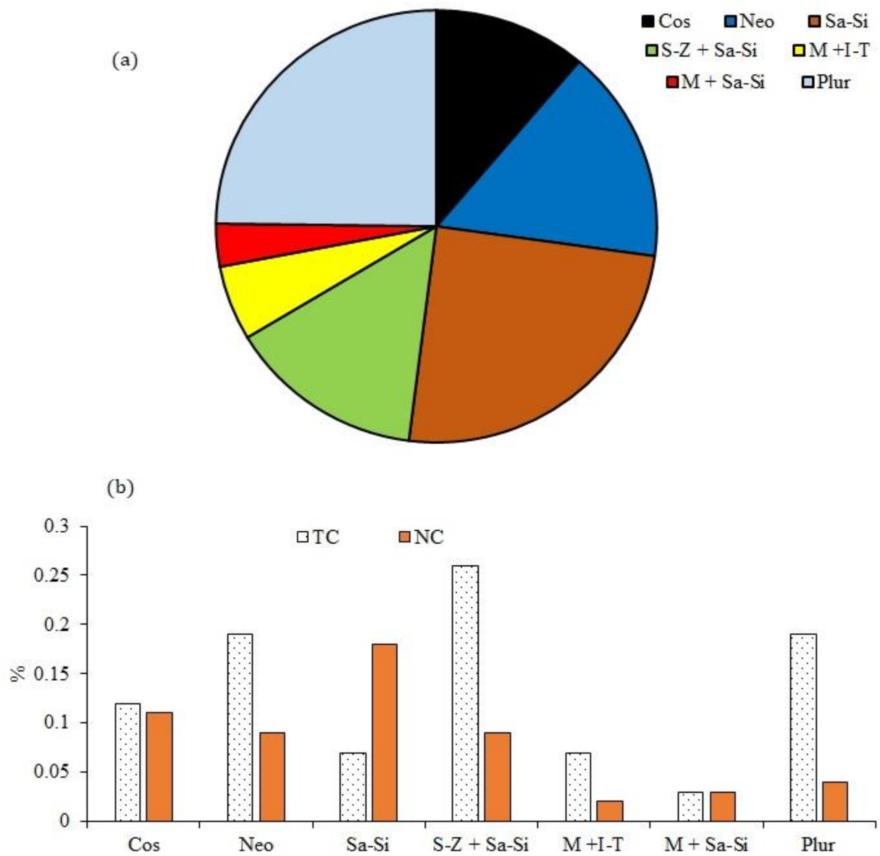

Figure 7. *The chorotype percentages of the recorded species (a) total chorotype at both campuses and (b) chorotype for each campus. M: Mediterenean, S-Z: Sudano-Zambezian, Sa-Si: Saharo-Sindian, I-T; Irano-Turanian, Eur-Sib: Euro-Siberian, Cosm.: Cosmopolitan*

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The possible role of irrigated patches in metropolitan regions to sustain native species is indicated by the biodiversity of green spaces in cities. There is a significant difference between natural non-irrigated dryland areas and urban irrigated sites. While the latter could not withstand prolonged droughts without losing many of its floral features, the former may possibly preserve and even grow its biodiversity with a stable condition of humidity provided by artificial irrigation. Thus, it stands to reason that urban green spaces might shield native plants in arid regions from the damaging impacts of progressive drought and global warming. However, urban environments have certain advantages over rural and natural landscapes in drylands when it comes to water since they have a comparatively high percentage of sealed soil surface and sewer systems, which may lower water evaporation and boost groundwater reserves (Safriel, 2006). Furthermore, urban areas can afford to receive water through alternative methods like desalination and wastewater recycling, but rural and natural areas mostly depend on wells and ground freshwater (Jain and Jain, 2020). Additionally, cities have more technological advantages and better infrastructure to increase water usage efficiency (Mahjabin et al., 2018). Urban settlements in many arid and semi-arid countries may become decertified due to long-term droughts and global warming. Cities are the last and greatest option for preserving the native species under such circumstances. In order to maintain this opportunity, both citizens and decision-makers need to understand that cities should no longer be used just for human habitation and that green areas should not be viewed as resources for inhabitants' entertainment and well-being. The added responsibility of protecting plants, particularly those endangered species that have lost their natural home, must be accepted by those areas. The significance of urban vegetation for the preservation of native species, particularly those that are endangered, was reported by earlier research on urban vegetation in arid regions (Ghahremaninejad et al., 2021; Neyns and Canters, 2022; Abuayyash et al., 2023; Gafarova et al., 2024).

The high species number recorded in the H5 on both campuses could be attributed to their high moisture content. It was recorded that moisture conditions are also variable, ranging from arid soils with no irrigation to over-irrigated soils that can host even marshy species (Magura et al., 2013). It was reported that species diversity of urban habitats is considerably influenced by the various disturbance levels, which affect both the magnitude of the inter- and intra-specific competition, and the ratio of disturbance adapted species (Magura et al., 2013). Therophytes (annuals and biennials) not surprisingly account for 58% in TC and 70% in NC of the total species of the region and agree with the life form spectra in other parts of Saudi Arabia (Alsherif et al., 2013; Fadl et al., 2021). Life-form spectrum in the present study is characteristic of an arid desert region that dry climate, tend to increase the percentage of therophytes through the introduction and spread of weedy grasses and forbs of this life form. Moreover, the high proportion of therophytes is also attributed to human activities (Barbero et al., 1990). Most plant species recorded on one university campus were therophytes, representing 74% of the species that were not documented in TC and 55% of the species that were not recorded in NC. The higher proportion of therophytes in NC than those recorded in the TC could be attributed to the more aridity of NC. The low percentage of the recorded Phanerophytes is due to removing wild trees and planting ornamental trees. In addition, horticultural activity can considerably modify the natural flora by intensive management (such as mowing, fertilizing, removal of woody vegetation, preferring grasses and herbs instead of woody species). Recently, it was reported that therophytes

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typically contribute approximately 30% to 55% of the species in semideserts (Heneidy et al., 2021; Nurah, 2022; Hofland et al., 2024). Previous studies reported that the increasing percentage of hemicryptophytes at TC indicated a relatively cold, arid climate in the study campus.

Saharo-Arabian elements showed the highest species number may be due to plant species in this region show the usual ways of adaptation to aridity and very high temperature in such a harsh environment. Many early studies state that the flora and vegetation of Saudi Arabia is comprised by elements from two main phytogeographical regions that cover much of North Africa and the Middle East, the Saharo-Arabian-Sindian region and the Sudano-Zambezian region (White and Leonard, 1991), In addition, it was reported that the studied area is primarily influenced by the Saharo-Sindian element. These influences explain why the highest values for monoregional, biregional and pluriregional species were recorded for the Saharo-Sindian elements, followed by those of the Sudano-Zambesia. It was reported that endemism in Saudi Arabia in general is relatively insignificant in comparison with some of the adjoining nations, such as Yemen and Oman (Al-Nafie, 2008), which explain no endemic species were recorded in the present results. 22% of the species that were not documented in the TC belonged to the S-Z + Sa-Si, while 25% of the species that were not recorded in the NC belonged to the Sa-Si, and 17% were Neotropical elements. The recording of invasive species in the current study indicates the significant importance of urban habitats in biological conservation. Previous studies recorded these invasive species in different locations in Saudi Arabia (Abbas et al., 2023; Alharthi et al., 2023). Previously it was documented that about 19–45% of the urban flora in the Eastern United States and 20–56% of the urban flora in Central European cities are alien species (Clemants and Moore, 2003).

Conclusion

To maintain the original flora of the cities and their habitats, the undisturbed patches in the urban regions should be kept intact. To boost the genetic variety among the populations of cultivated species, the artificial green spaces should be positioned and designated in a way that allows plants to effectively breed. It is crucial to do a thorough investigation of the dryland flora. It is necessary to identify the threatened and endangered species in the regions under study, conserve and preserve their natural habitats if at all possible or relocate them to urban areas where they can breed and be preserved for future redistribution. To deal with the likely scarcity of water in the upcoming years, irrigation efficiency should be raised.

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APPENDIX

Table A1. *List of plant species recorded in the studied campuses with their families, life forms and chorotypes*

Family	Species name	Taif Campus	Nourah Campus	Life form	Chorology
Aizoaceae	*Aizoon canarense* L.	1	0	Th	Sa-Si + S-Z
	Zalyea pentandra (L.) Jeffrey	1	0	He	Sa-Si+M+I-T+S-Z
Amaranthaceae	*Aerva javanica* (Burm.f.) Juss. ex Schultes	1	0	Ch	Sa-Si + S-Z
	Alternanthera sessilis (L.) DC.	1	0	He	Paleo + Neo
	Amaranthus blitum ssp. *oleraceus* (L.) Costea	0	1	Th	Neo
	Amaranthus hybridus L.	1	0	Th	Neo
	Amaranthus viridis L.	1	1	Th	Neo
	Atriplex halimus L.	0	1	Ph	M + Sa-Si
	Bassia eriophora (Schrader) Asch.	0	1	Th	Sa-Si+ I-T
	Bassia muricata (L.) Asch.	0	1	Th	Sa-Si+M+I-T
	Chenopodium murale L.	1	1	Th	Cos
	Chenopodium opulifolium Schrader ex Koch & Ziz	1	0	Th	Cos
	Dysphania ambrosioides (L.) Mosyakin & Clemants	1	0	Th	Neo
	Halocnemum strobilaceum (Pallas) M.	0	1	Ch	M+I-T+Sa-Si+Eur-Sib
	Salicornia europaea L.	0	1	Th	M+I-T+Eur-Sib
Apiaceae	*Ammi majus* L.	1	0	Th	M+Sa-Si
	Foeniculum vulgare Mill.	1	0	He	M
Arecaceae	*Phoenix dactylifera* L.	1	1	Ph	Sa-Si
Asclepiadaceae	*Calotropis procera* (Ait.) Ait.f.	1	0	Ch	Sa-Si + S-Z
Asteraceae	*Aaronsohnia factorovskyi* Warb. & Eig.	0	1	Th	M+Sa-Si
	Bidens aurea (Ait.) Sherff	1	0	Th	Neo
	Calendula arvensis L.	0	1	Th	Sa-Si +I-T+M
	Cichorium bottae Defl.	1	0	Th	Sa-Si
	Erigeron sumatrensis Retz.	1	0	Th	Neo
	Conyza bonarensis (S.Moore) Cufod.	0	1	Th	Neo
	Echinops hystrichoides Kit-Tan	1	0	Th	Sa-Si

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	Flaveria trinervea (Spreng.) Mohr	1	0	Th	Neo
	Ifloga spicata (Forssk.) Sch.- Bip.	0	1	Th	Sa-Si+I-T+M
	Lactuca saligna L.	0	1	Th	M+Sa-Si+I-T
	Lactuca serriola L.	1	0	Th	M+I-T
	Launaea angustifolia (Desf.) Kuntze	0	1	Th	Sa-Si
	Launaea capitata (Spreng.) Dandy	0	1	Th	Sa-Si+I-T+S-Z
	Launaea massauensis (Fresen.) Sch.-Bip.	1	0	Th	Sa-Si + S-Z
	Launaea mucronata (Forssk.) Muschl.	0	1	Th	Sa-Si
	Launaea procumbens Roxb.	0	1	Th	Sa-Si
	Picris cyanocarpa Boiss.	0	1	Th	Sa-Si
	Pluchea dioscroides (L.) DC.	1	0	Ch	Sa-Si + S-Z
	Pulicaria undulata May	1	1	Ch	S-Z + Sa-Si
	Reichardia tingitana	0	S1	Th	Sa-Si+M+I-T+S-Z
	Sonchus oleraceus L.	1	1	Th	Cos
	Sonchus tenerrimus L.	1	0	Th	M+Sa-Si
	Tripleurospermum auriculatum (Boiss.) Rech. f.	0	1	Th	M+Sa-Si
	Urospermum picroides (L.) Scop.	1	1	Th	M+I-T + Sa-Si
Boraginaceae	*Arnebia hispidissima* (Lehm.) DC.	1	0	Th	Sa-Si
	Heliotropium arbainense Fresen.	1	0	Ch	S-Z + Sa-Si
	Heliotropium crispum Desf	1	1	Ch	Sa-Si+I-T+S-Z
	Heliotropium curassavicum L.	1	1	Th	Neo
	Maltkiopsis ciliata (Forssk.) I.M. Johnston	0	1	Ch	Sa-Si+M
	Trichodesma africanum (L.) Sm.	0	1	Ch	S-Z +Sa-Si
Brassicaceae	*Brassica nigra* (L.) K.Koch	1	0	Th	Paleo + M
	Brassica tournefortii Guan.	0	1	Th	M+I-T + Sa-Si
	Capsella bursa-pastoris (L.) Medikus	0	1	Th	Cos
	Diplotaxis harra (Forssk.) Boiss.	0	1	Th	Sa-Si
	Farsetia aegyptia Turra	0	1	Ch	S-Z + Sa-Si
	Farsetia longisiliqua Decne.	1	0	Ch	S-Z + Sa-Si
	Farsetia stylosa R.Br.	0	1	Ch	S-Z + Sa-Si
	Lepidium didymus L.	0	1	Th	Cos
	Lepidium ruderale L.	0	1	Th	M+I-T+ Eur-Sib
	Savignya parviflora (Del.) Webb	0	1	Th	Sa-Si
	Sisymbrium irio L.	1	1	Th	M+I-T + Sa-Si
	Sisymbrium orientale L.	1	0	Th	M + Sa-Si
Capparaceae	*Dipterygium glaucum* Decne.	0	1	He	Sa-Si+ I-T
Carophyllaceae	*Hernaria hirsuta* L.	0	1	Th	M + Sa-Si
	Paronychia arabica (L.) DC.	0	1	Th	Sa-Si+I-T
	Spergula fallax (Lowe) Krause	1	1	Th	M + Sa-Si
Cistaceae	*Helianthemum lippi* (L.) Doum.- Cours.	0	1	Ch	Sa-Si
Convolvulaceae	*Convolvulus arvensis* L.	1	1	Ge	Cos
	Convolvulus prostratus Forssk.	0	1	Ge	Sa-Si
Cyperaceae	*Cyperus rotundus* L.	1	1	Ge	Paleo + Neo
Euphorbiaceae	*Euphorbia arabica* Hochst. & Wteyd.	1	0	He	Sa-Si +M+S-Z
	Euphorbia hirta L.	1	0	Th	Neo
	Euphorbia hypericifolia L.	1	1	Th	Neo
	Euphorbia indica Lam.	1	1	Th	Neo
	Euphorbia peplus L.	1	0	Th	M+I-T+ Eur-Sib
	Euphorbia prostrata Aiton	1	1	Th	Neo
	Ricinus communis L.	1	0	Ph	Sa-Si
Geraniaceae	*Erodium laciniatum* (Cav.) Willd.	0	1	Th	M+I-T + Sa-Si
	Monsonia nivea (Decne.) Decne. ex Webb.	1	0	He	Sa-Si + S-Z
Lamiaceae	*Mentha longifolia* (L.) Huds.	1	0	Ge	M+I-T

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Leguminosae	*Acacia ehrenbergiana* Hayne	1	0	Ph	Sa-Si + S-Z
	Astragalus schimperi Boiss.	0	1	Th	Sa-Si
	Leucaena leucocephala Lam.) de Wit	1	0	Ph	Neo
	Lotus corniculatus L.	0	1	He	Cos
	Medicago laciniata (L.) Mill.	0	1	Th	Sa-Si +M
	Medicago sativa L.	1	0	He	M+I-T
	Melilotus indicus (L.) All.	1	1	Th	Sa-Si+ I-T+M
	Senna italic Miller	1	0	Ch	S-Z
	Trigonella hamosa L.	0	1	Th	Sa-Si
Liliaceae	*Tulipa biflora* Pall.	1	0	Ge	Sa-Si+I-T
Lophiocarpaceae	*Corbichonia decumbens* (Forssk.) Exell	1	0	Th	Sa-Si + S-Z
Malvaceae	*Malva parviflora* L.	1	1	Th	M+I-T
	Sida ovata L.	1	0	Ch	Sa-Si
Molluginaceae	*Mollugo cerviana* (L.) Seringe	1	0	Th	Paleo+M+I-T
Moraceae	*Ficus palmata* Forssk.	1	0	Ph	Sa-Si + S-Z
Nitrariaceae	*Peganum harmala* L.	1	0	He	Sa-Si + I-T
Nyctaginaceae	*Commicarpus mistus* Thulin	1	0	Ch	Sa-Si + S-Z
Orobanchaceae	*Cistanche violacea* (Desf.) G. Beck.	0	1	He, parasite	Sa-Si
Oxalidaceae	*Oxalis corniculata* L.	1	1	Th	Cos
Papaveraceae	*Argymone ochroleuca* L.	1	0	Th	Neo
Phyllanthaceae	*Phyllanthus rotundifolius* Klein ex Willd.	0	1	Th	M+I-T
Plantaginaceae	*Plantago amplexicaulis* Cav.	0	1	Th	Sa-Si+ M
	Veronica anagallis-aquatica L.	1	0	He	Cos
Poaceae	*Bromus catharticus* Vahl	1	0	Th	Neo
	Cenchrus ciliaris L.	0	1	Th	Paleo
	Cenchrus echinatus L.	1	1	Th	Neo
	Cenchrus pennisetiformis Hochst. & Stedudel ex Steudel	1	0	Th	Sa-Si + S-Z+ I-T
	Chloris barbata Swartz.	0	1	Th	Paleo
	Cynodon dactylon (L.) Pers.	1	1	Ge	Sa-Si + S-Z+ I-T
	Dactyloctenium aegyptium (L.) Willd.	1	0	Th	Paleo
	Dichanthium annulatum (Forssk.) Stapf	1	0	Th	Neo
	Digitaria sanguinalis (L.) Scop.	0	1	Th	Sa-Si + S-Z+ I-T
	Dinebra retroflexa (Vahl) Panzer	1	0	Th	Paleo
	Echinochloa colona (L.) Link	1	0	Th	Paleo
	Eleusine indica (L.) Gaertn.	1	0	Th	Paleo + Neo
	Eragrostis barrelieri Dav.	0	1	Th	Sa-Si
	Eragrostis minor Host	0	1	Th	Paleo
	Eragrostis pilosa (L.) P. Beauv.	1	0	Th	Paleo + Neo
	Leptochloa fusca (L.) Kunth.	0	1	He	Paleo + Neo
	Panicum coloratum L.	1	0	He	Paleo
	Pennisetum setaceum (Forssk.) Chiov.	1	0	Ge	Sa-Si+S-Z+I-T+M
	Phragmites australis (Cav.) Trin. & Steudel.	0	1	Th	Paleo + Neo
	Poa annua L.	1	1	Th	Cos
	Polypogon monspeliensis (L.) Desf.	1	1	Th	Sa-Si+M+I-T
	Polypogon viridis (Gouan) Breistr.	1	0	Th	M+I-T
	Rostraria pumila (Desf.) Tzvelev	0	1	Th	Sa-Si+M+I-T
	Schismus barbatus (L.) Thell.	0	1	Th	Sa-Si+M+I-T+ S-Z
	Setaria verticillata (L.) P. Beauv.	0	1	Th	Sa-Si+M+I-T
	Setaria viridis (L.) P. Beauv.	1	0	Th	M+I-T
	Stipa parviflora Desf.	1	0	He	Sa-Si+M+I-T
	Tetrapogon villosus Desf.	1	0	Ge	Sa-Si+M+I-T+ S-Z
	Tricholaena teneriffae (L.f.) Link.	1	0	Ge	Sa-Si+M+I-T+ S-Z

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Polygonaceae	*Emex spinosus* (L.) Campd.	0	1	Th	Sa-Si+M+I-T
	Polygonum argyrocoleum Steudel ex Kunze	0	1	Th	Sa-Si
	Polygonum palaestinum Zoh.	0	1	He	M
	Rumex vesicarius L.	1	1	Th	Sa-Si+I-T
	Portulaca oleracea L.	1	1	Th	Cos
Primulaceae	*Anagallis arvensis* var. *arvensis* L.	1	0	Th	Cos
	Anagallis arvensis var. caerulea (L.) Gouan	1	0	Th	Cos
Resedaceae	*Ochradenus baccatus* Del.	1	1	Ph	Sa-Si + S-Z
	Oligomeris linifolia (Vahl) J.F. Macbr.	0	1	Th	Sa-Si + S-Z
Rhamnaceae	*Ziziphus spina-christi* (L.) Willd.	1	0	Ph	Sa-Si + S-Z
Solanaceae	*Datura innoxia* Mill.	1	0	Th	Neo
	Datura stramonium L.	1	0	Th.	Neo
	Solanum nigrum L.	1	1	Th	Cos
	Solanum villosum Mill.	1	0	Th	Sa-Si+M
	Withania somnifera (L.) Dun.	1	0	Ch	Sa-Si+M+I-T+ S-Z
Tamaricaceae	*Tamaris senegalensis* DC.	1	1	Ph	Sa-Si + S-Z
Typhaceae	*Typha domengensis* (Pers.) Poir	1	0	Ge	Palaeo + Neo
Urticaceae	*Forsskaolea tenacissima* L.	1	1	He	Sa-Si + S-Z
Zygophyllaceae	*Fagonia arabica* L.	0	1	He	Sa-Si
	Fagonia bruguieri DC.	1	0	He	Sa-Si + I-T
	Fagonia glutinosa Del.	0	1	He	Sa-Si
	Fagonia indica Burm. f.	1	1	He	Sa-Si + I-T
	Fagonia oliveri DC.	0	1	He	Sa-Si + I-T
	Tetraena coccinea (L.) Beier & Thulin	0	1	Ch	Sa-Si+ I-T
	Tetraena simplex (L.) Beier & Thulin	1	0	Th	Sa-Si + S-Z
	Tribulus macropetrus Boiss.	1	0	Th	Sa-Si + S-Z
	Tribulus pentandrus Forssk.	0	1	Th	Sa-Si + S-Z
	Tribulus terrestris L.	1	1	Th	Sa-Si+ I-T+ S-Z

1: present, 0: absent, the life forms are: Ph, phanerophytes; Ch, chamaephytes; Ge, geophytes; He, hemi-cryptophytes and Th, therophytes. The chorotypes are: Cosm, cosmopolitan AM, American; I-T, Irano-Turanian; M, Mediterranean; Sa-Si, Saharo-Sindian; S-Z, Sudano-Zambezian and TR, Tropical; Paleo: Plaeotropical, Neo: Neotropic

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