



ORIGINAL ARTICLE

Floristic diversity and vegetation analysis of Wadi Arar: A typical desert Wadi of the Northern Border region of Saudi Arabia



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Abstract Wadi Arar in the Northern border region of Saudi Arabia is one of the most important Wadis of the Kingdom. The present study provides an analysis of vegetation types, life forms, as well as floristic categories and species distribution. A total of 196 species representing 31 families of vascular plants were recorded. Compositae, Gramineae and Leguminosae were the most common families. Therophytes and chamaephytes are the most frequent life forms, indicating typical desert spectrum vegetation. The distribution of these species in the different sectors of the Wadi as well as the phytochoria for the recorded species is provided. Ninety-one species (46.5%) are typical bi-regional. Furthermore, about 105 species (53.5%) are mono- or pluriregional taxa. The highest number of species (136 or 69.5%) was recorded for annual plants, while the lowest number of species (60% or 30.5%) was recorded for perennial, short perennial or annual to biennial species.

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1. Introduction

The Kingdom of Saudi Arabia is a huge arid land with an area of about 2,250,000 km² covering the major part of the Arabian Peninsula, characterized by different ecosystems and diversity of plant species (Abdel Khalik et al., 2013).

The topography of Saudi Arabia, as well as that of Arabian Peninsula, is an ancient massif in which geologic structure developed concurrently with the Alps (Country Profile: Saudi Arabia, 2006). The climate in Saudi Arabia differs greatly between the coast and the interior. High humidity coupled with more moderate temperatures is prevalent along the coast,

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whereas aridity and extreme temperatures characterize the interior (Country Profile: Saudi Arabia, 2006).

Saudi Arabia has not permanent rivers or lakes; however “Wadis” are frequent along the country. The word “Wadi” in this article will be used to designate a non permanent river, whose runoff is dependent on rain. It frequently happened, but for decades Wadis have been completely inactive. In the dry lands, Wadis represent one of the most prominent desert landforms, which exhibit physiographic irregularities that lead to parallel variations in plant species distribution (Kassas and Girgis, 1964). Wadi “Arar” is considered one of the most important Wadis in the northern region.

The flora of Saudi Arabia is one of the richest biodiversities in the Arabian Peninsula and comprises very important genetic resources of crops and medicinal plants (Atiqur Rahman et al., 2004). The components of this flora are admixture of Asia, Africa and Mediterranean regions’ plants. According to Colenete (1999), this flora comprises 2250 species belonging to 835 genera and about 142 families. 147 species are classified as “endemic”, 721 species as “endangered” and about 22 species are believed as completely extinct (Colenete, 1999).

The number of wild species occurring in a square kilometer area of Saudi Arabia is less significant, especially in areas such as central, eastern and northern regions. Areas along the northwestern and southwestern regions are densely vegetated and contain the highest number of species. Approximately 70% of the country’s floristic species are reported in these areas. Endemism in Saudi Arabia is relatively insignificant in comparison with some of the neighboring countries such as Yemen and Oman.

Saudi Arabia contains 97 trees, 564 shrubs and about 1620 herbs, which cover, respectively, 4.25%, 24.73% and 71.02% of higher plant diversity of the country (<http://www.plantdiversityofsaudiarabia.info/index.htm>).

Wild plants of Saudi Arabia were studied by many authors (Chaudhary, 1999–2001; Chaudhary and Al-Jowaid, 1999; Colenete, 1999; Migahid, 1996; Miller and Cope, 1996) as general floral studies. Furthermore, many authors have studied more limited areas in the course of floral and taxonomical revision of some genera (Aleem, 1979; Batanouny and Ismail, 1985; Fayed and Zayed, 1989; El Karemy and Zayed, 1992; Hajar et al., 1998; Hegazy et al., 1998; Al Wadie, 2002; Al-Turki and Al-Qlayan, 2003; Atiqur Rahman et al., 2004; Alfarhan et al., 2005; Mosallam, 2007; Alshammari and Sharawy, 2010; El-Ghanem et al., 2010; Al-Sodany et al., 2011; Alatar et al., 2012; Alsherif et al., 2012; Farrag, 2012; Gomaa, 2012; Ihsanullah, 2012; Waly et al., 2012 and Abdel Khalik et al., 2013).

The distribution of life form is closely related to topography and landform (Kassas and Girgis, 1965; Zohary, 1973; Orshan, 1986; Fakhireh et al., 2012). In Wadis, the composition of life forms expresses a typical desert flora, the majority of species being therophytes and chamaephytes. Vegetation of Wadis in general is not constant; it varies from year to year, depending upon the moisture level (Siddiqui and Al-Harbi, 1995). The establishment, growth, regeneration and distribution of the plant communities in the Wadis are controlled by many factors, such as geographical position, physiographic features and human impacts (Shaltout and El-Sheikh, 2003; Kürschner and Neef, 2011; Alatar et al., 2012; Korkmaz and Ozelik, 2013).

The current study includes survey and identification of the wild plants growing in the Wadi Arar and the surrounding sites in the Northern border region of Saudi Arabia. More-

over, the vegetation types, life forms and floristic categories of the collected species were taken into consideration. For future reference, voucher herbarium specimens of different plant samples were pressed and deposited in the herbarium of College of Sciences in Arar (Northern Border University).

2. The study area

The area of the present study is located in the Northern region of Saudi Arabia (30° 55' 13" N, 41° 0' 3" E). Wadi Arar (Wadi of the Anizah tribe) is one of the main Wadis which existed in the northeast of Saudi Arabia (Fig. 1). It covers an area of about 9500 km square and extends next to Arar city. According to the Worldwide Bioclimatic Classification System (<http://www.globalbioclimatics.org>), this region falls within the Mediterranean desertic continental climate. This area is dry zone, characterized by hot, arid, desert climate and an average annual temperature of 21.5 °C (Fig. 2). Precipitation is scanty, with an average annual of 20.2 mm, which usually falls during the winter months, the extreme rainfall occurring in January and May with more than 90 mm (<http://www.globalbioclimatics.org>).

3. Materials and methods

This study was performed in Wadi Arar from November 2011 to April 2013 during active plant growth period, when most species were expected to be present. The wild vegetations were sampled in 25 localities including the different Wadi tributaries; in each locality, the present species were recorded. .

The collected plant specimens were identified and named according to Colenete (1999), Cope (1985), Migahid (1996), and Chaudhary (1999–2001). They are deposited in the Herbarium of Biology Department, College of Sciences, Northern Border University.

Life forms of species were determined depending upon the location of the regenerative buds and the shed parts during the unfavorable season (Raunkier, 1934). The floristic categories of the investigated species were made to assign the registered species to world geographical groups according to Wickens (1978) and Zohary (1973).

4. Results

Table 1 shows the plant species recorded in different surveyed sectors of Wadi Arar. The list includes 196 species belonging to 31 families of phanerogams. Their generic representation is quite variable. However, one family is represented by more than 29 genera (Compositae), another by 19 genera (Gramineae); the third, most represented family carries about 14 genera (Cruciferae). Five families are represented by four to eight genera (Caryophyllaceae and Leguminosae with 8 genera; Umbelliferae with 7 genera; and Zygophyllaceae with 4 genera). Furthermore, eight families showed less number of genera (2 to 3 genera) and 15 families are represented by a single genus (Table 1).

From the standpoint of species richness within the described families of the region, only one family exceeded 30 species (Compositae: 48), one family was represented by 26 species (Gramineae), the third family contained 22 species (Leguminosae), two families had more than 10 species (Caryophyllaceae: 12 and Cruciferae: 17). Moreover, seven families showed eight

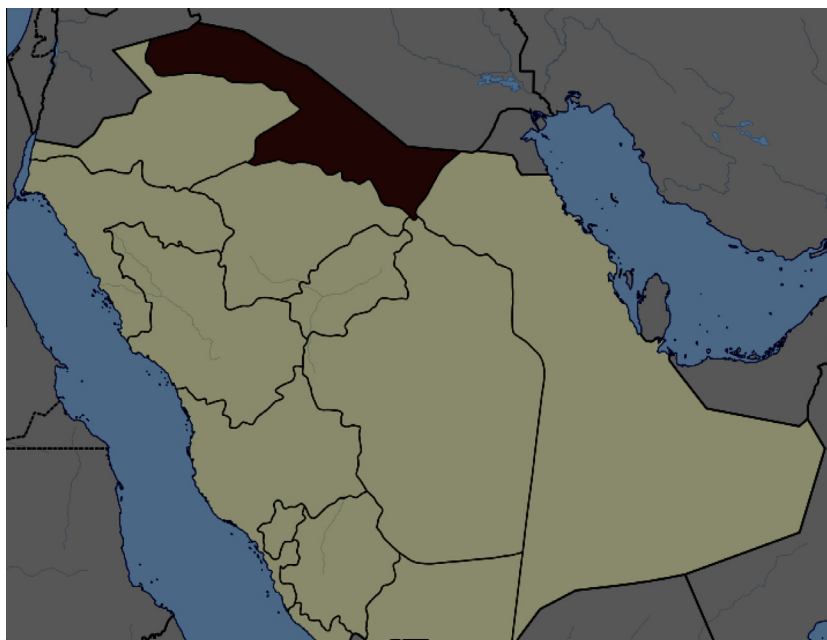


Figure 1 Location map of Saudi Arabia showing the Northern border region.

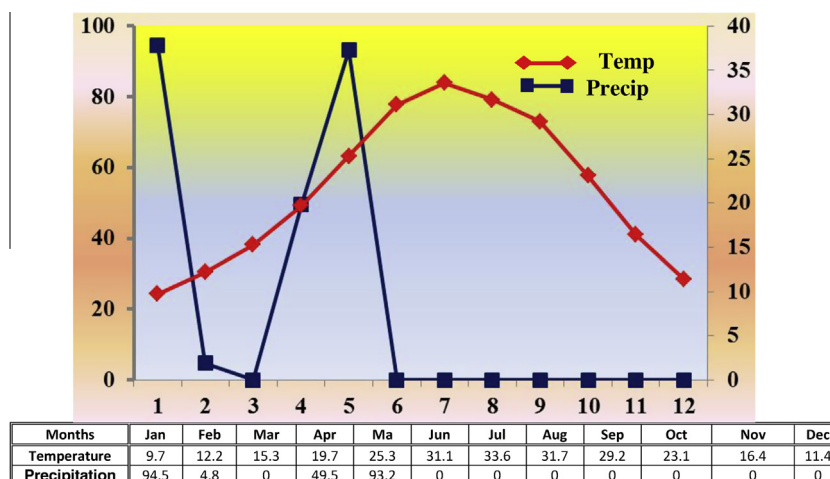


Figure 2 Climate diagram for Arar, Northern border region, Saudi Arabia.

to five species (Boraginaceae: 5, Labiatae and Zygophyllaceae: 6, Plantaginaceae: 7, Umbelliferae and Chenopodiaceae: 8 genera). As well, two families were represented by three species, six possessed two species only. Finally 12 families were represented by a single species (Table 1).

With regard to the growth type, the majority of the recorded species in this study were annual plants (136 species or 69.5% of the total recorded species). The second most recorded growth type was the perennials, which were represented by 53 species (27.0% of the total species). Biennial, annual or short-perennial growth types in the investigated area do not exceeded two species and ultimately only one species was recorded as a short-perennial (*Launaea mucronata* sp. *mucronata*) (Table 2, Fig. 3).

Table 2 showed the life form spectra of the recorded species according to the classification of Raunkiaer (1937). Thero-

phytes were the most frequent life form plants constituted by 140 species, followed by chamaephytes with 33 species and hemicryptophytes with 16 species, with a percentage of 71.5%, 16.8% and 8.2% of the total registered species respectively. Parasite plants were represented by three species from three different genera (*Cuscuta campestris*, *Cistanche phelypaea* and *Orobanche tinctoria*). Two species were geophytes (*Cynodon dactylon* and *Polypogon maritimus*) and both cryptophytes and phanerophytes were represented only by single species (*Reichardia tingitana* and *Calotropis procera* respectively) (Table 2, Fig. 4).

From a phytogeographical point of view, the recorded species in the different sectors of Wadi Arar may be classified as monoregional, biregional or pluriregional taxa. A total of 46 species representing 23.5% of the total number of recorded species were monoregional taxa of different affinities. The

Table 1 A list of the species recorded in the study area with their families, vegetation type, life form and floristic categories.

Family	Species	Vegetation type	Life form	Floristic categories	
Aizoaceae	<i>Aizoon canariense</i> L.	Perennial	H	SA-SI + S-Z	
Amaranthaceae	<i>Aerva javonica</i> (Burm. f.) Juss. ex Scult.	Perennial	Ch	SA-SI + S-Z	
	<i>Amaranthus graecizans</i> L.	Annual	Th	PAL	
	<i>Amaranthus viridis</i> L.	Annual	Th	COSM	
Asclepiadaceae	<i>Calotropis procera</i> (Aiton) W. T. Aiton	Perennial	Ph	SA + S-Z	
	<i>Perennialgularia tomentosa</i> L.	Perennial	Ch	SA-SI + S-Z	
Boraginaceae	<i>Arnebia decumbens</i> (Vent.) Coss. & Kralik var. <i>decumbens</i>	Annual	Th	SA-SI + S-Z	
	<i>Arnebia decumbens</i> (Vent.) Coss. & Kralik var. <i>macrocalyx</i> Coss. & Kralik	Annual	Th	SA-SI + S-Z	
	<i>Arnebia linearifolia</i> A. DC.	Annual	Th	SA-SI + S-Z	
	<i>Heliotropium bacciferum</i> Forssk. subsp. <i>bacciferum</i> var. <i>bacciferum</i>	Perennial	Ch	SA-SI + S-Z	
Capparaceae	<i>Cleome amblyocarpa</i> Barratte & Murb.	Annual	Th	SA-SI + S-Z	
Caryophyllaceae	<i>Gypsophila capillaries</i> (Forssk.) C. Chr.	Annual	Th	SA	
	<i>Gypsophila linearifolia</i> (Fisch. & C. A. Mey.) Boiss.	Annual	Th	IR-TR	
	<i>Gypsophila viscosa</i> Murray	Annual	Th	IR-TR	
	<i>Herniaria hemistemon</i> J. Gay	Perennial	Th	ME + SA-SI	
	<i>Herniaria hirsuta</i> L.	Annual	Th	ME + SA-SI	
	<i>Paronychia arabica</i> (L.) DC.	Annual	Th	ME + SA-SI + IR-TR	
	<i>Polycarpea robbairea</i> (Kuntze) Greuter & Burdet	Perennial	H	SA-SI + S-Z	
	<i>Polycarpon tetraphyllum</i> (L.) L.	Annual	Th	ME + SA-SI + IR-TR	
	<i>Pteranthus dichotomus</i> Forssk.	Annual	Th	ME + SA + IR-TR	
	<i>Silene arabica</i> Boiss.	Annual	Th	SA-SI	
	<i>Sperennialgularia diandra</i> (Guss.) Boiss.	Annual	Th	ME + SA + IR-TR	
	<i>Sperennialgularia marina</i> (L.) Bessler.	Annual	Th	ME + IR-TR	
	Chenopodiaceae	<i>Atriplex leucoclada</i> Boiss. var. <i>turcomania</i> (Moq.) Zohary.	Perennial	Ch	ME + SA-SI
		<i>Bassia eriophora</i> (Schrad.) Asch.	Annual	Th	SA + IR-TR
		<i>Chenopodium ambrosioides</i> L.	Biennial	Th	COSM
		<i>Chenopodium murale</i> L.	Annual	Th	COSM
<i>Haloxyton salicornicum</i> (Moq.) Bunge ex Boiss.		Perennial	Ch	S-Z	
<i>Salsola villosa</i> Schult.		Perennial	Ch	ME + SA-SI + IR-TR	
<i>Salsola volkensis</i> Schweinf. & Asch.		Perennial	Ch	COSM	
<i>Suaeda pruïnosa</i> Lange		Perennial	Ch	ME + SA	
<i>Helianthemum lippi</i> (L.) Dom.		Perennial	Ch	SA-SI + S-Z	
<i>Helianthemum vesicarium</i> Boiss.		Perennial	Ch	SA	
Cistaceae	<i>Cleome amblyocarpa</i> Barrtte & Murb.	Annual	Th	SA-SI + S-Z	
Compositae	<i>Anthemis arvensis</i> L.	Annual	Th	SA	
	<i>Anthemis cotula</i> L.	Annual	Th	SA	
	<i>Anthemis deserti</i> (Boiss.) Eig.	Annual	Th	ME + SA	
	<i>Anthemis melampodina</i> Delile.	Annual	Th	ME + SA	
	<i>Anthemis pseudocotula</i> Boiss.	Annual	Th	ME + SA	
	<i>Anthemis scrobicularis</i> Yavin.	Annual	Th	ME + SA-SI + IR-TR	
	<i>Artemisia judaica</i> L.	Perennial	Ch	SA	

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Table 1 continued

Family	Species	Vegetation type	Life form	Floristic categories
	<i>Artemisia monosperennialma</i> Delile.	Perennial	Ch	ME + SA
	<i>Artemisia scoparia</i> Waldst. & Kit.	Perennial	Ch	IR-TR + EU-SI
	<i>Atractylis carduus</i> (Forssk.) C. Christ. var. <i>angustifolia</i> Täckh. & Boulos.	Perennial	Th	ME
	<i>Calendula arvensis</i> L.	Annual	Th	ME + SA-SI + IR-TR
	<i>Calendula tripterocarpa</i> Rupr.	Annual	Th	PAN
	<i>Carthamus nitidus</i> Boiss.	Annual	Th	SA + IR-TR
	<i>Carthamus oxycantha</i> M. Bieb.	Annual	Th	ME + IR-TR
	<i>Centaurea pseudosinaica</i> Czerep.	Annual	Th	IR-TR
	<i>Centaurea sinaica</i> DC.	Annual	Th	IR-TR + EU-SI
	<i>Chamaemelum mixtum</i> (L.) All.	Annual	Th	ME + SA
	<i>Cotula anthemoides</i> L.	Annual	Th	SA
	<i>Cotula cinerea</i> Delile.	Annual	Th	SA- SI
	<i>Crepis nigricans</i> Viv.	Annual	Th	SA
	<i>Filago desertorum</i> Pomel	Annual	Th	SA-SI + IR-TR
	<i>Garhadiolus angulosus</i> Jaub. & Spach.	Annual	Th	ME + IR-TR
	<i>Glebionis coronaria</i> (L.) Tzvelv. (= <i>Chrysanthemum coronarium</i> L.)	Annual	H	ME + SA-SI
	<i>Gymnarrhena micrantha</i> Desf.	Annual	Th	ME + SA-SI
	<i>Helichrysum conglobatum</i> (Viv.) Steud.	Perennial	Th	ME
	<i>Homognaphalium pulvinatum</i> (Delile.) Fayed & Zareh.	Annual	Th	SA-SI + IR-TR
	<i>Iftoga spicata</i> (Forssk.) Sch. Bip. subsp. <i>albescens</i> Chrtek.	Annual	Th	ME + SA-SI
	<i>Koelpinia linearis</i> Pall.	Annual	Th	ME + SA + IR-TR
	<i>Lactuca serriola</i> L.	Annual or biennial	Th	IR-TR
	<i>Lasiopogon muscoides</i> (Desf.) DC.	Annual	Th	ME + SA-SI
	<i>Launaea capitata</i> (Spreng.) Dandy	Annual	Th	ME + SA-SI
	<i>Launaea fragilis</i> (Asso) Pau subsp. <i>fragilis</i> (= <i>L. tenuiloba</i> (Boiss.) Kuntze)	Annual	Th	ME + SA-SI
	<i>Launaea mucronata</i> (Forssk.) Muschl. subsp. <i>mucronata</i>	Short-Perennial	Th	SA-SI + IR-TR
	<i>Launaea nudicaulis</i> (L.) Hook. fil.	Perennial	Th	SA-SI + IR-TR + S-Z
	<i>Leontodon hispidulus</i> (Delile.) Boiss.	Annual	Th	ME + SA-SI
	<i>Leontodon laciniatus</i> (Bertol.) Widder.	Annual	Th	ME + SA-SI
	<i>Matricaria aurea</i> (Loefl.) Sch. Bip.	Annual	Th	SA-SI
	<i>Nauplius graveolens</i> (Forssk.) Wiklund. (= <i>Asteriscus graveolens</i> (Forssk.) Less.)	Perennial	Ch	ME + SA-SI
	<i>Picris altissima</i> Delile.	Annual	Th	ME + SA
	<i>Picris asplenioides</i> L.	Annual	Th	ME + IR-TR
	<i>Picris cyanocarpa</i> Boiss.	Annual	Th	SA
	<i>Pseudognaphalium luteoalbum</i> (L.) Hilliard & B. L. Burt.	Annual	Th	ME + SA + IR-TR
	<i>Reichardia tingitana</i> (L.) Roth	Perennial	Cr	ME + SA-SI + IR-TR
	<i>Senecio belbeysius</i> Delile.	Annual	Th	ME + IR-TR + EU-SI
	<i>Senecio glaucus</i> L. subsp. <i>coronopifolius</i> (Maire) C. Alexander (= <i>S. desfontainei</i> Druce)	Annual	Ch	SA-SI + IR-TR
	<i>Sonchus oleraceus</i> L.	Annual	Th	COSM
	<i>Sonchus tenerrimus</i> L.	Annual	Th	COSM
	<i>Urosperennialmum picroides</i> (L.) F.W. Schmidt	Annual	Th	ME + IR-TR
Convolvulaceae	<i>Convolvulus arvensis</i> L.	Perennial	H	PAL
	<i>Cuscuta campestris</i> Yunck.	Perennial	P	SA-SI + S-Z
Cruciferae	<i>Arabidopsis kneuckeri</i> (Bornm.) O. E. Schulz	Annual	Th	SA-SI
	<i>Carrichtera annualua</i> (L.) DC.	Annual	Th	ME + SA-SI
	<i>Coronopus didymus</i> (L.) Sm.	Annual or biennial	Th	SA
	<i>Diplotaxis acris</i> (Forssk.) Boiss.	Annual	Th	ME + IR-TR

	<i>Enarthrocarpus strangulatus</i> Boiss.	Annual	Th	SA-SI
	<i>Eruca sativa</i> Mill.	Annual	Th	ME + SA + IR-TR + EU-SI
	<i>Erucaria crassifolia</i> (Forssk.) Delile	Annual	Th	ME + SA-SI
	<i>Erucaria hispanica</i> (L.) Druce	Annual	Th	ME + SA-SI
	<i>Farsetia aegyptia</i> Turra	Perennial	Ch	SA-SI + S-Z
	<i>Farsetia stylosa</i> R. Br.	Annual or short-Perennial	Th	SA-SI
	<i>Horwoodia dicksoniae</i> (Viv.) Turrill	Annual	Th	SA-SI
	<i>Matthiola arabica</i> Boiss.	Annual	Th	SA
	<i>Matthiola longipetala</i> (Vent.) DC.	Annual	Th	ME + IR-TR
	<i>Savignya parviflora</i> (Delile) Web.	Annual	Th	SA-SI + IR-TR
	<i>Schimperenniala arabica</i> Hochst. & Steud. Ex Endl	Annual	Th	SA-SI
	<i>Sisymbrium irio</i> L.	Annual	Th	ME + SA-SI + IR-TR + EU-SI
	<i>Zilla spinosa</i> (L.) Prantl subsp. <i>spinosa</i>	Perennial	Ch	ME + SA-SI + IR-TR + EU-SI
Cucurbitaceae	<i>Citrullus colocynthis</i> (L.) Schrad.	Perennial	H	ME + SA-SI + IR-TR + S-Z
Euphorbiaceae	<i>Euphorbia peplus</i> L.	Annual	Th	COSM
	<i>Euphorbia prostrata</i> Aiton, Hort.	Annual	Th	ME + SA-SI + IR-TR
	<i>Euphorbia serpens</i> Kunth.	Annual	Th	SA-SI + IR-TR
Fumariaceae	<i>Hypecoum pendulum</i> L.	Annual	Th	ME + IR-TR
Geraniaceae	<i>Erodium crassifolium</i> L' Hér. (= <i>E. hirtum</i> (Forssk.) Willd.)	Perennial	Th	SA-SI
Gramineae	<i>Agropyron cristatum</i> (L.) Gaertn.	Perennial	H	IR-TR
	<i>Bromus scoparius</i> L.	Annual	Th	ME + SA-SI + IR-TR
	<i>Bromus tectorum</i> L.	Annual	Th	COSM
	<i>Cutandia memphitica</i> (Spreng.) Benth.	Annual	Th	ME + IR-TR
	<i>Cynodon dactylon</i> (L.) Perennials.	Perennial	G	PAN
	<i>Enneapogon lophotrichus</i> Chiov. Ex H. Scholz & P. Kõng	Annual	Th	IR-TR
	<i>Eragrostis aegyptiaca</i> (Willd) Delile.	Annual	Th	S-Z
	<i>Eremopyrum bonaepartis</i> (Spreng.) Nevski	Annual	Th	IR-TR
	<i>Eremopyrum confusum</i> Melderis	Annual	Th	IR-TR
	<i>Hordeum murinum</i> L. subsp. <i>glaucum</i> (Steud.) Tzvelv	Annual	Th	ME + IR-TR
	<i>Hordeum murinum</i> L. subsp. <i>leporinum</i> (Link.) Arcang.	Annual	Th	ME + IR-TR
	<i>Lamarckia aurea</i> (L.) Moench	Annual	Th	ME + IR-TR + S-Z
	<i>Lolium multiflorum</i> Lam.	Annual	Th	ME + IR-TR + EU-SI
	<i>Lolium perenniale</i> L.	Annual	Th	COSM
	<i>Lolium rigidum</i> Gaudin	Annual	Th	ME + IR -TR
	<i>Parapholis incurva</i> (L.) C. E.	Annual	Th	ME + IR-TR + EU-SI
	<i>Phalaris paradoxa</i> L.	Annual	Th	ME + IR-TR
	<i>Poa annualua</i> L.	Annual or short-Perennial	Th	ME + IR-TR + EU-SI
	<i>Polypogon maritimus</i> Willd.	Annual	G	COSM
	<i>Polypogon monspeliensis</i> (L.) Desf.	Annual	Th	ME + SA-SI + IR-TR
	<i>Rostraria pumila</i> (Desf.) Tzvelev.	Annual	Th	ME + SA-SI
	<i>Schismus arabicus</i> Nees.	Annual	Th	ME + SA + IR-TR
	<i>Schismus barbatus</i> (L.) Thell.	Annual	Th	ME + SA-SI + IR-TR
	<i>Setaria pumila</i> (Poir.) Roem. & Schutt.	Annual	Th	ME + IR-TR + S-Z
	<i>Stipagrostis ciliata</i> (Desf.) De Winter	Perennial	H	SA + IR-TR + SU
	<i>Triticum aestivum</i> L.	Annual	Th	SA + IR-TR + SU

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Table 1 continued

Family	Species	Vegetation type	Life form	Floristic categories
Labiatae	<i>Phlomis brachyodon</i> (Boiss.) Zoh.	Perennial	H	IR-TR
	<i>Salvia aegyptiaca</i> L.	Perennial	Ch	SA-SI + S-Z
	<i>Salvia lanigera</i> Poir.	Perennial	Ch	ME + SA-SI
	<i>Salvia spinosa</i> L.	Perennial	H	ME + IR-TR
	<i>Teucrium oliverianum</i> Ging. ex. Benth.	Perennial	Ch	COSM
	<i>Teucrium polium</i> L.	Perennial	Ch	ME + IR-TR
Leguminosae	<i>Alhagi graecorum</i> Boiss.	Perennial	Ch	ME + SA + IR-TR + SU
	<i>Astragalus bombycinus</i> Boiss.	Annual	H	SA-SI + IR-TR
	<i>Astragalus corrugatus</i> Bertol. subsp. <i>corrugatus</i>	Annual	Th	IR-TR
	<i>Astragalus hauarensis</i> Boiss.	Annual	H	IR-TR
	<i>Astragalus schemperenniali</i> Boiss. var. <i>subsessilis</i>	Annual	Th	ME
	<i>Astragalus sieberi</i> DC.	Perennial	Ch	SA + IR-TR
	<i>Astragalus spinosus</i> (Forssk.) Muschl.	Perennial	Ch	SA-SI + IR-TR
	<i>Astragalus tribuloides</i> Delile var. <i>tribuloides</i>	Annual	Th	SA-SI + IR-TR
	<i>Hippocrepis areolata</i> Desv.	Annual	Th	ME + S-Z
	<i>Hippocrepis cyclocarpa</i> Murb.	Annual	Th	ME
	<i>Hippocrepis multisiliquosa</i> L.	Annual	Th	IR-TR
	<i>Medicago laciniata</i> (L.) Mill. var. <i>brachyacantha</i> Boiss.	Annual	Th	SA-SI
	<i>Medicago laciniata</i> (L.) Mill. var. <i>laciniata</i>	Annual	Th	SA-SI
	<i>Medicago monospeliaca</i> (L.) Trautv.	Annual	Th	ME + IR-TR
	<i>Medicago polymorpha</i> L.	Annual	Th	ME + IR-TR + EU-SI
	<i>Melilotus albus</i> Medik.	Annual	Th	ME + SA + IR-TR
	<i>Melilotus indicus</i> (L.) All.	Annual	Th	PAL
	<i>Onobrychis ptolemaica</i> (Delile.) DC.	Perennial	H	IR-TR
	<i>Tephrosia purpurea</i> (L.) Perennials. subsp. <i>Leptostachya</i> (DC.) Brummitt, Bol.	Perennial	Ch	SA-SI + S-Z
	<i>Trigonella hamosa</i> L.	Annual	Th	ME + SA-SI
	<i>Trigonella laciniata</i> L.	Annual	Th	ME + SA-SI + IR-TR
	<i>Trigonella stellata</i> Forssk.	Annual	Th	SA-SI + IR-TR
	Malvaceae	<i>Malva parviflora</i> L.	Annual	Th
Orobanchaceae	<i>Cistanche phelypaea</i> (L.) Cout.	Perennial	P	ME + SA-SI + IR-TR + S-Z
	<i>Orobanche tinctoria</i> Forssk	Perennial	P	SA-SI + IR-TR
Plantaginaceae	<i>Plantago amplexicaulis</i> Cav. subsp. <i>Bauphula</i> (Edgew.) Rech. f.	Annual	Th	SA-SI + IR-TR
	<i>Plantago ciliata</i> Desf.	Annual	Th	ME + SA-SI + IR-TR
	<i>Plantago crassifolia</i> Forssk.	Annual	H	ME
	<i>Plantago lagopus</i> L.	Annual	Th	ME + IR-TR
	<i>Plantago lanceolata</i> L.	Annual	Th	ME + SA-SI + IR-TR
	<i>Plantago ovata</i> Forssk.	Annual	Th	SA + IR-TR
	<i>Plantago psammophila</i> Agnew & Chalibi-Ka, bi.	Annual	Th	SA-SI + IR-TR
	Polygonaceae	<i>Emex spinosa</i> (L.) Campd.	Annual	Th
	<i>Polygonum equisetiforme</i> Sm.	Annual	Ch	M + IR-TR
	<i>Rumex vesicarius</i> L.	Perennial	Th	ME + SA-SI + S-Z
Portulacaceae	<i>Portulaca oleracea</i> L.	Annual	Th	ME + SA-SI
Primulaceae	<i>Anagallis arvensis</i> L. var. <i>arvensis</i>	Annual	Th	ME + IR-TR + EU-SI
Resedaceae	<i>Oligomeris linifolia</i> (Vahl ex Hornem.) J. F. Macbr. (= <i>Reseda linifolia</i> Vahl ex Hornem.)	Annual	Th	ME + SA + S-Z
	<i>Reseda muricata</i> C. Presl.	Annual	Th	SA-SI + IR-TR
Scrophulariaceae	<i>Veronica polita</i> Fr. (= <i>V. didyma</i> sensu auct)	Annual	Th	M + IR-TR

Solanaceae	<i>Hyoscyamus muticus</i> L.	Perennial	Ch	SA-SI + IR-TR
	<i>Solanum nigrum</i> L.	Perennial	Ch	COSM
Umbelliferae	<i>Ammi majus</i> L.	Annual	Th	ME
	<i>Anisoscadium isociadum</i> Borrm	Annual	Th	SA + IR-TR
	<i>Anisoscadium lanatum</i> Boiss.	Annual	Th	SA + IR-TR
	<i>Deverra tortuosa</i> (Desf.) DC.	Perennial	Ch	SA-SI
	<i>Ducrosia anethifolia</i>	Perennial	Th	IR-TR
	<i>Ferula ovina</i>	Perennial	Ch	IR-TR
	<i>Pteroxelinum crispum</i> (Mill.) A. W. Hill. = <i>P. Saivum</i> (L.) P. Hoffm.	Biennial	Th	PAL
	<i>Tordylium aegyptiacum</i> (L.) Poir.	Annual	Th	ME + SA
Urticaceae	<i>Forsskaolea tenacissima</i> L.	Annual	H	SA-SI + S-Z
Zygophyllaceae	<i>Fagonia bruguieri</i> DC.	Perennial	H	SA-SI + IR-TR
	<i>Fagonia glutinosa</i> Delile.	Perennial	H	SA-SI
	<i>Peganum harmala</i> L.	Perennial	H	ME + SA-SI + IR-TR
	<i>Tribulus macropterus</i> Boiss.	Annual	Ch	SA-SI + IR-TR
	<i>Tribulus megistopterus</i> Kralik.	Annual	Ch	SA-SI + IR-TR
	<i>Zygophyllum simplex</i> L.	Annual	Th	SA-SI + S-Z

Vegetation type: Annual = annual; Bi = biennial; Perennial = perennial; s-Perennial = short perennial; Life form: Ch = chamaephytes; Cr = cryptophytes; G = geophytes; H = hemicryptophytes; P = parasites; Ph = phanerophytes; Th = therophytes. Floristic categories (the Chorotypes): COSM = Cosmopolitan; EU-SI = Euro-Siberian; IR-TR = Irano-Turanian; ME = Mediterranean; PAL = Palaeotropical; PAN = Pantropical; S-Z = Sudano-Zambezian; SA = SaharoArabian; SA-SI = Saharo-Sindian; SU = Sudanian; TR = Tropical.

recorded monoregional species fall under three main phytochoria: Irano-Turanian taxa (15 species forming 7.7% of recorded species), Saharo-Sindian taxa (13 species forming 6.6% of recorded species) and Saharo-Arabian taxa (10 species forming 5.1% of recorded species). Among these, six species were typical Mediterranean species (*Atractylis carduus*, *Helichrysum conglobatum*, *Astragalus schemperenniali*, *Hippocrepis cyclocarpa*, *Plantago crassifolia* and *Ammi majus*). Mediterranean species were rarely represented in different sectors of the Wadi. The last phytochoria (Sudano-Zambezian) was rarely represented in the different sectors of the Wadi with only two species (*Haloxylon salicornicum* and *Eragrostis aegyptiaca*) forming 1.0% of the total number of recorded species (see Table 3, Figs. 5 and 6).

The other 91 species (46.5%) were biregional taxa. Both Mediterranean-Saharo-Sindian and Mediterranean-Irano-Turanian phytochorial regions were represented by 19 species (9.7%). Saharo-Sindian-Irano-Turanian region was represented by 18 species (9.2%). Saharo-Sindian-Irano-Turanian region was represented by 17 species (8.7%). Both Mediterranean-Saharo-Arabian and Saharo-Arabian-Irano-Turanian regions were represented by eight species (4.1%) and six species (3.1%) respectively. Irano-Turanian-Euro-Siberian region was represented by two species (*Artemisia scoparia* and *Centaurea sinaica*). Only one species was registered in both Saharo-Arabian-Sudano-Zambezian region (*Calotropis procera*) and Mediterranean-Sudano-Zambezian region (*Hippocrepis areolata*) (Table 3, Figs. 5 and 6).

39 species representing 19.8% of the recorded species were pluriregional taxa of different affinities. The recorded pluriregional species fell also under three main phytochoria: Mediterranean-Saharo-Sindian-Irano-Turanian phytochorion (14 species forming 7.1% of recorded species) and both Mediterranean-Saharo-Arabian-Irano-Turanian and Mediterranean-Irano-Turanian-Euro-Siberian phytochoria (six species for each phytochorion forming 3.1% of recorded species). Mediterranean-Irano-Turanian-Sudano-Zambezian, Mediterranean-Saharo-Sindian-Irano-Turanian-Euro-Siberian, Mediterranean-Saharo-Sindian-Irano-Turanian-Sudano-Zambezian and SaharoArabian-Irano-Turanian-Sudanian regions were represented by two species (1.0%) which were *Lamarekia aurea*, *Setaria pumila*, *Sisymbrium irio*, *Zilla spinosa*; *Citrullus colocynthis*, *Cistanche phelypaea* and *Stipagrostis ciliata*, *Triticum aestivum* respectively. Only one species (or 0.5% of the registered species) occurred in the following regions: Mediterranean-Saharo-Arabian-Irano-Turanian-Euro-Siberian (*Eruca sativa*), Mediterranean-SaharoArabian-Irano-Turanian-Sudanian (*Alhagi graecorum*), Mediterranean-SaharoArabian-Sudano-Zambezian (*Oligomeris linifolia*), Mediterranean-Saharo-Sindian-Sudano-Zambezian (*Rumex vesicarius*) and Saharo-Sindian-Irano-Turanian-Sudano-Zambezian (*Launaea nudicaulis*). The remaining twenty species were distributed as follows: 12 species are cosmopolitan, followed by four palaeotropical species and four pantropical species (Table 3, Figs. 5 and 6).

5. Discussion and conclusions

By the end of the present study, which focused on flora of Wadi Arar area, five of collected families (Compositae, Gramineae, Leguminosae, Caryophyllaceae and Cruciferae) contributed nearly to two thirds of the total flora. The most representative families of this region were corresponded to a

Table 2 Tubular summary showing the total number of families, genera and species, growth types and life forms of collected plants.

Total number of			Growth type			Life forms		
Families	Genera	Species	Type	Number of species	Percentage (%)	Form	Number of species	Percentage (%)
31	130	196	Annual	136	69.5	H	16	8.2
			Perennial	53	27	Ch	33	16.8
			Biennial	2	1	Ph	1	0.5
			Annual or short-Perennial	2	1	Th	140	71.5
						P	3	1.5
			Annual or Biennial	2	1	G	2	1
						Cr	1	0.5
			Short-Perennial	1	0.5			
			Total Number	196	100%	Total Number	196	100%

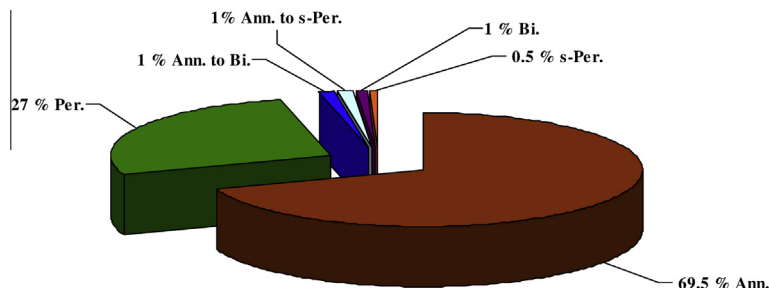


Figure 3 Vegetation type relative spectrum of Wadi Arar vegetarian: Ann = annual; Bi = biennial; perennial; s-per = short perennial.

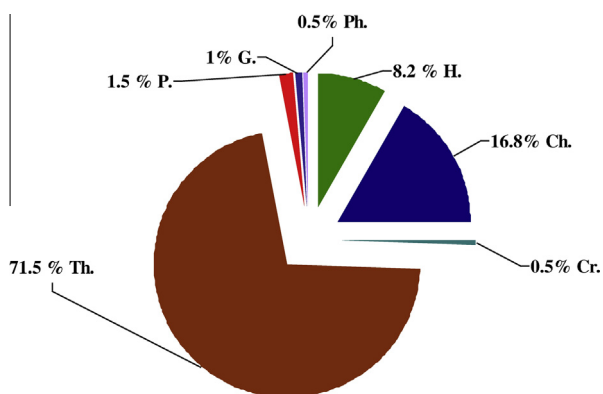


Figure 4 Life form relative spectrum of Wadi Arar vegetarian: Ch = Chamaephytes; Cr = Crptophytes; G = geophytes; H = hemicryptophytes; P = Parasites; Ph = phanerophytes; Th = therophytes.

typical Mediterranean-North African floristic structure and this agrees with the results of [Quézel \(1978\)](#) study.

According to [Al-Hassan \(2006\)](#), about 458 species which belong to these floristic structures were represented in the northern sector of the Kingdom of Saudi Arabia. In Wadi Arar area, the present survey recorded 196 species, and this represented over one third of the checklist recorded before in the whole northern region of the Kingdom. The total number of identified genera was 130, indicating a high generic index of 1.5 (196/130). These results were conforming to those of [Pielou \(1975\)](#) and [Magurran \(1988\)](#) studies, where the taxonomic diversity is higher in an area in which the species were divided between many genera. Taxonomic diversity in Wadi Arar is 1.5 for species/genera ratio and 6.3 for genera/families. This indicates a higher taxonomic diversity in the studied region than in other areas ([Tables 1 and 2](#)). This high diversity was due to the abundance of water sources, soil fertility and the diversity of relief (open shallow valleys, mountains and sand dunes) as mentioned by [Al-Shammeri \(2010\)](#) and [Al-Shammari and Sharawy \(2010\)](#).

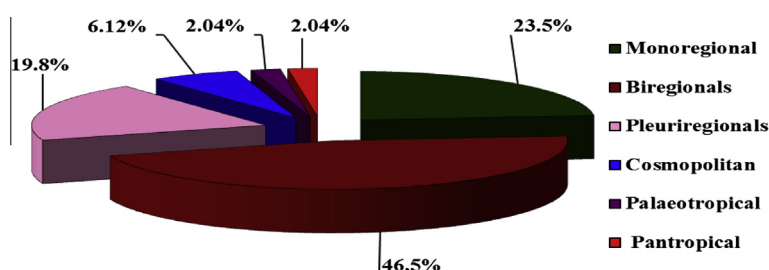


Figure 5 Floristic category spectrum of Wady Arar according to number of vegetarian regions.

Table 3 The number of recorded species belonging to the main floristic categories and their relevant percent (%) abbreviations.

Phytochoria	Number of species	Percentage (%)
<i>Monoregional</i>		
ME	06	3.1
SA-SI	13	6.6
IR-TR	15	7.7
SA	10	5.1
S-Z	02	1.0
Total	46	23.5
<i>Biregionals</i>		
SA-SI + S-Z	17	8.7
SA + S-Z	01	0.5
ME + SA-SI	19	9.7
ME + IR-TR	19	9.7
SA + IR-TR	06	3.1
ME + SA	08	4.1
IR-TR + EU-SI	02	1.0
SA-SI + IR-TR	18	9.2
ME + S-Z	01	0.5
Total	91	46.5
<i>Pleuriregionals</i>		
ME + SA-SI + IR-TR	14	7.1
ME + SA + IR-TR	06	3.1
ME + IR-TR + EU-SI	06	3.1
ME + IR-TR + S-Z	02	1.0
ME + SA-SI + IR-TR + EU-SI	02	1.0
ME + SA-SI + IR-TR + S-Z	02	1.0
ME + SA + IR-TR + EU-SI	01	0.5
ME + SA + IR-TR + SU	01	0.5
ME + SA + S-Z	01	0.5
ME + SA-SI + S-Z	01	0.5
SA-SI + IR-TR + S-Z	01	0.5
SA + IR-TR + SU	02	1.0
Total	39	19.8
Cosm	12	6.12
Pal	04	2.04
Pan	04	2.04
Total	20	10.2

The wild vegetation in this studied area comprised 196 plant species, including 136 annuals (69.5%) and 53 perennials (27.0%). The high contribution of annuals can be attributed to their short life cycle that enables them to resist the instability of the ecosystem (Gomaa, 2012). Moreover, they were generally characterized by a high allocation of resources to the reproductive organs (Harper, 1977) and the production of flowers early in their lifespan to ensure some seed production even in a year when the growing season is cut short (Sans and Masalles, 1995). These results corroborated previous studies focusing on Hail province (Al-Turki and Al-Qlayan, 2003; Sharawy and Alshammari, 2009 and Al-Shammari and Sharawy, 2010). Moreover, members of the family Compositae dominated the wild plants of Wadi Arar region (48 species), followed by Gramineae (26 species), Leguminosae (22 species), Cruciferae (17 species) and Caryophyllaceae (17 species), (Table 2, Fig. 3).

The vegetation of northern region does not had appreciable contribution to the flora of Saudi Arabia with regard to other parts of the country (Al-Turki and Al-Qlayan, 2003). Vegetation of the northern part of the country is also dominated by annual species. However, perennial components such as

Salsola sp., *Haloxylon salicornicum*, *Artemisia* sp., *Zilla spinosa*, *Hyoscyamus muticus*, *Fagonia glutinosa* etc. are forming large communities in all range lands. (<http://www.plantdiversityofsaudi-arabia.info/biodiversity-saudi-arabia/flora/Flora.htm>). The studied area was widely regarded as a transition zone between the floristic regions of Mediterranean, Irano-Turanian and Saharo-Sindian, Saharo-Arabian or Sudano-Zambeian regions. The influences of these phytogeographical zones were very much reflected in the flora of Northern region. The other floristic elements such as cosmopolitan, pantropical, palaeotropical, Euro-Siberian and Sudanian elements were represented by a varying number of species reflecting their differential capability to penetrate the region.

Among the recorded species from this region, some were extremely rare and poorly known and their results reveal that some of these plants had been collected from a single locality (*Calotropis procera*, *Gypsophila* sp., *Cistanche phelypaea* and *Orobancha tinctoria*), while others have been collected in the studied area only once or twice (*Aerva javanica*, *Anthemis* sp., *Koelpinia linearis*, *Solanum nigrum* and *Anagallis arvensis*), (Al-Turki and Al-Qlayan, 2003).

Regarding the life form spectra, therophytes had the highest contribution, followed by chamaephytes, hemicryptophytes, parasites, geophytes and finally both phanerophytes and cryptophytes (Tables 1 and 2 and Fig. 4). The life form of desert plants is closely linked with rainfall, topography and land form (Kassas and Girgis, 1965; Zohary, 1973; Orshan, 1986). Therophytes (which had a lifespan as short as few weeks) are characteristic of desert regions (Gomaa, 2012).

Considering the floristic categories, in the studied area, 46.5% of the recorded species were belonging to the biregional category: (Mediterranean-Saharo-Sindian and Mediterranean-Irano-Turanian phytochoria had 19 species, Saharo-Sindian-Irano-Turanian phytochoria possessed 18 species, Saharo-Sindian-Sudano-Zambeian phytochoria include 17 species, Mediterranean-Saharo-arabian phytochoria contained eight species, Saharo-arabian-Irano-Turanian phytochoria comprised six species, Irano-Turanian-Euro-Siberian phytochoria had two species (*Artemisia scoparia* and *Centaurea sinaica*) and only one species is present in both Saharo-arabian-Sudano-Zambeian phytochoria (*Calotropis procera*) and Mediterranean-Sudano-Zambeian phytochoria (*Hippocrepis areolata*).

A monoregional category was the second one with 23.5% of the total recorded species: (15 species in Irano-Turanian region, 13 species in Saharo-Sindian region, 10 species in Saharo-arabian region, six species in Mediterranean region and two species in Sudano-Zambeian region (*Haloxylon salicornicum* and *Eragrostis aegyptiaca*). Pluriregional category was the third one with 19.8% of the total recorded species in this area (14 species in Mediterranean-Saharo-Sindian-Irano-Turanian region, six species in both Mediterranean-Saharo-arabian-Irano-Turanian and Mediterranean-Irano-Turanian-Euro-Siberian regions, two species in Mediterranean-Irano-Turanian-Sudano-Zambeian region (*Lamarckia aurea* and *Setaria pumila*), Mediterranean-Saharo-Sindian-Irano-Turanian-Euro-Siberian region (*Sisymbrium irio* and *Zilla spinosa*), Mediterranean-Saharo-Sindian-Irano-Turanian-Sudano-Zambeian region (*Citrullus colocynthis* and *Cistanche phelypaea*) and Saharo-arabian-Irano-Turanian-Sudanian region (*Stipagrostis ciliata* and *Triticum aestivum*) and only one species in Mediterranean-Saharo-arabian-Irano-Turanian-Euro-Siberian region

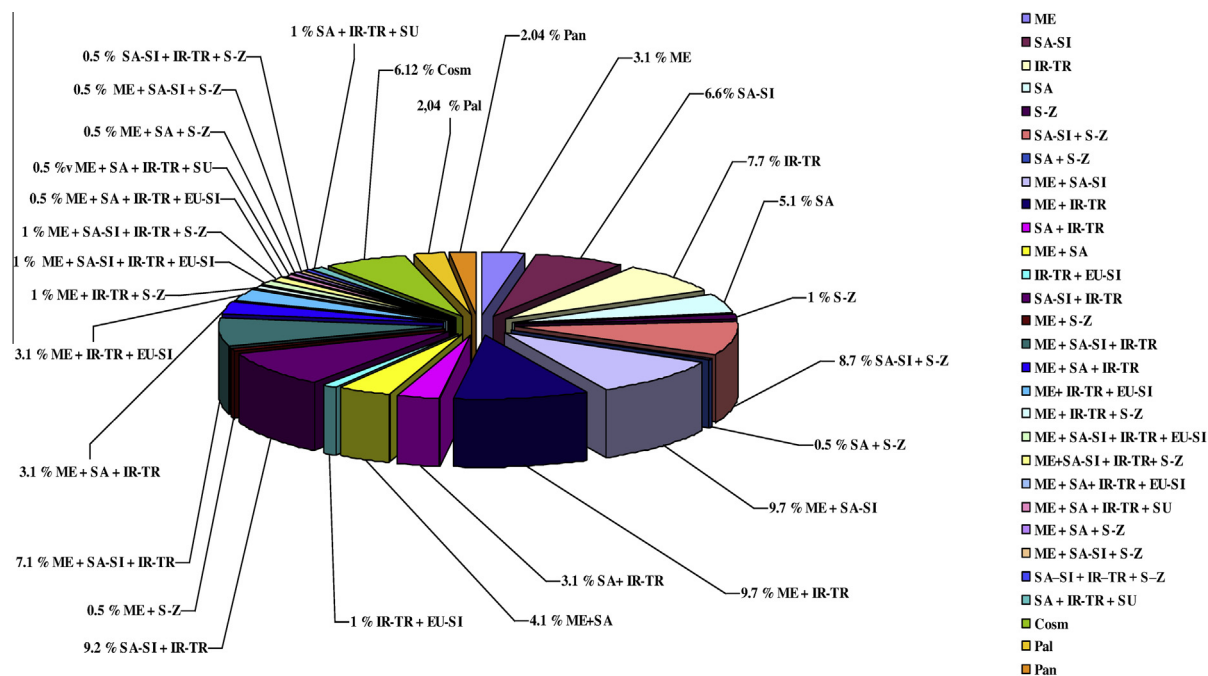


Figure 6 Floristic category of Wadi Arar: COSM = Cosmopolitan; EU-SI = Euro-Siberian; IR-TR = Irano-Turanian; SA-SI = Saharo-Sindian; SU = Sudanian; TR = Tropical.

(*Eruca sativa*), Mediterranean-Saharo-arabian-Irano-Turanian-Sudanian region (*Alhagi graecorum*), Mediterranean-Saharo-arabian-Sudano-Zambezian region (*Oligomeris linifolia*), Mediterranean-Saharo-Sindian-Sudano-Zambezian region (*Rumex vesicarius*) and Saharo-Sindian-Irano-Turanian-Sudano-Zambezian region (*Launaea nudicaulis*). Cosmopolitan category has 6.12% and eventually both Palaeotropical and Pantropical categories had 2.04%, (Table 3 and Figs. 5 and 6).

The results indicate that Irano-Turanian elements predominate the studied area (97 species, 49.5%), and were represented as mono-regional (15 species, 7.7%), bi-regional under the influence of Mediterranean, SaharoArabian, Euro-Siberian and Saharo-Sindian regions (45 species, 23%) and Pleuriregionals under the influence of Mediterranean, Saharo-Sindian, SaharoArabian, Euro-Siberian, Sudano-Zambezian and Sudanian regions (37 species, 18.8%). Mediterranean region was represented by 89 species (or 45.4%), followed by Saharo-Sindian region (87 species, 44.4%), followed by Sudano-Zambezian region (45 species, 23%) and at last Saharo-Arabian region (36 species, 18.4%). Taxa of wide geographical range, like Cosmopolitan (12 species, 6.12%), Palaeotropical (4 species, 2.04%) and Pantropical (4 species, 2.04%), have apparently lower presence value (Table 3).

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