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ORIGINAL ARTICLE

Floristic composition and vegetation analysis in Hail region north of central Saudi Arabia

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Abstract In this study, 19 sites representing different habitats in Hail region were regularly visited for two years, in each site 2–5 stands were selected for investigating floristic composition and vegetation types in the area. A total of 124 species representing 34 families were recorded. The family Asteraceae is represented by the highest number of species (21 species) followed by the Poaceae (17 species) and the Brassicaceae (10 species) whereas, 15 families including Acanthaceae, Convolvulaceae, Moraceae, Nyctaginaceae and Primulaceae, are represented by a single species each. Chronological analysis of the vegetation in the area revealed the domination of Saharo-Sindian elements in the wild vegetations and of weedy species in the cultivated plots. Therophytes and chamaephytes are the dominating life forms of the vegetation spectra; therophytes represent 49.20% and chamaephytes represent 29.00% of the total species in the study area. Application of TWINISPAN and DECORANA classification and ordination techniques to the data produced seven vegetation groups. Ruderal habitats comprised two small groups A and F dominated by *Phragmites australis* and *Imperata cylindrical* (A), *Euphorbia peplus* and *Sisymbrium irio* (F), respectively. Two vegetation groups (B and G) have been recognized in the mountains and slopes dominated by *Launaea mucronata*, *Trigonella stellata* (B) and *Ficus palmate* and *Fagonia bruguieri* (G). Other two groups (C and E) inhabit the desert and mountainous wadies; these are represented by *Gymnocarpos*

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decandrus and *Ochradenus baccatus* (C) and *Senecio glaucus* subsp. *coronopifolius* and *Rumex equisetiforme* (E). On the other hand, one group (D) inhabits the cultivated plots and is represented by *Plantago albicans* and *Rumex vesicarius*, the last group also includes species restricted to the sand dune habitat of the Al-Nafud desert north of Hail city and represented by *Calligonum polygonoides* and *Halyxolon salicornicum*. The vegetation analysis indicated the invasion of Hail Flora by some foreign weeds such as *Solanum nigrum*, *Lactuca serriola* and *Amaranthus lividus*. The presence of these weeds points out the need to monitor the vegetation change in Hail region, and also other regions of Saudi Arabia, in order to elucidate the human impact on the wild plants diversity as human activities change with the fast development in the kingdom.

1. Introduction

Saudi Arabia (Lat. 32° 34′N–16° 83′N, Long. 34° 36′E–56′E) is a vast arid desert with an area of about 2250,000 sq kms covering the major part of the Arabian Peninsula. Accordingly, xerophytic vegetation makes up the prominent features of the plant life in the kingdom (Zahran, 1982). Several reports have been published on the Flora of the country, the most comprehensive are two Floras; the first was written by Mighaid in 1974 and published four times, the last in 1996 (Mighaid, 1996) and the other is the three volume Flora written by Chaudhary (1999, 2000, 2001). Other publications on the Flora of Saudi Arabia include the illustrated flowers of Saudi Arabia by Collenette (1999) and a number of reports on regional on certain parts of the Kingdom. The Middle part of Saudi Arabia, has received attention regarding its floristic survey. Al-Turki (1997) published a check list on the Flora of Al-Qassim region comprising a total of 450 wild and cultivated species of flowering plants belonging to 257 genera and 62 families. Al-Turki and Al-Olayan (2003) published synoptic analysis of the Flora of Hail reveals that 338 wild plants representing 221 genera spread over 61 families in Hail region. Studies on the Al-Aushazia Sabkha vegetation in Al-Qassim region was also described by Al-Huquial and Al-Turki (2006).

A number of ecological studies have been published on the vegetation of Saudi Arabia. Zahran (1982, 1983) wrote an introduction to the plant ecology and vegetation types in the country. Some other reports have dealt with the vegetation types in certain regions of the kingdom particularly in the Hijaz and Aseer regions. Batanouny (1979) described the vegetation types in the Jeddah-Makkah road, Batanouny and Baeshain (1983) described vegetation types in the Al-Madinah-Badr road across the Hijaz Mountains and Fayed and Zayed (1999) reported on the vegetation along Makkah-Taif road. More detailed studies was carried out on the vegetation change in relation to elevation in the Aseer mountains (Abulfatih, 1992) and on vegetation analysis and species diversity in the central Hijaz mountains (Abd-El-Ghani, 1993, 1997) and Wadi El-Ghayl in Aseer mountains (Fahmy and Hassan, 2005). Studies on the vegetation environment relationship in the mountainous Taif area (80–100 km south east of Makkah), indicated that soil water table and salinity cause discontinuities of vegetation in the area (Abdel-Fattah and Ali, 2005). In the central part of Saudi Arabia, the Raudhas vegetation was analyzed by Shaltout and Madi (1996). The floristic account of Raudhat Khuraim in the central province was also reported by Al-Farhan (2001). In addition, comparative ecological studies were also conducted by Al-Ghanim (2002) on the natural vegetation in the Riyadh region. However, few studies have dealt with vegetation analysis and species diversity Saudi Arabia.

Hail region, covers the northern part of the central Najd plateau (Fig. 1), it comprises diverse ecosystems that provide interesting aspects for vegetation and species diversity investigations. The study by Al-Turki and Al-Olayan (2003) represent a comprehensive contribution to the Flora of the region, whereas the recent study by Sharawy and Alshammari (2008) represents a contribution to the poisonous plants in the Aja Mountains, North of Hail. However, to our knowledge no studies have dealt with the vegetation analysis in relation to the florestic composition and habitat variation in the region. The aim of the present work is to study the vegetation in the Hail province in terms of species composition, life form, diversity and vegetation types (groups) in relation to habitat change in the study area. Multivariate techniques and species diversity indices have been used to differentiate vegetation groups and to assess the relation between the vegetation types in the study area.

2. The study area

The Hail region is found in the northern central part of Saudi Arabia and extends between 25° 29′N and 38° 42′E (Fig. 1B). It covers an area of 118,322 sq km and represents 6% of the total area of the kingdom of Saudi Arabia. Hail is bordered to the north by Al-Jouf and the Northern Frontier regions, to the west by Tabouk and Al-Madinah regions, to the south by Al-Qassim and to the east by the Central and Eastern regions. The study area includes the town of Hail and extends to the west, north and south. It covers the major part of the Aja mountain chains that includes Ugdah and Jubbah areas and extends north to Al-Khuttah and further North West to cover part of An-Nafud Al-Kabir sand dune desert and South West to Gazzala. The study area also covers the Wadies in the western parts of Salma mountains to the east of Hail town and also several gardens and orchards in Hail town and Al-Khuttah farms (Fig. 1B).

2.1. Topography and geomorphology

Hail region is characterized by its variation in topography and geomorphology. According to Chapman (1978) the area belongs to the Arabian shield and the great An-Nafud (Nafud Al-Kabir), which is connected by Dahma, to the Rub Al-Khali to the south of Saudi Arabia. The great An-Nafud, which represents a principal part of Hail region, is a very large depression filled up with masses of sand and covers an area of almost 64,000 sq km. One striking aspect of this great body

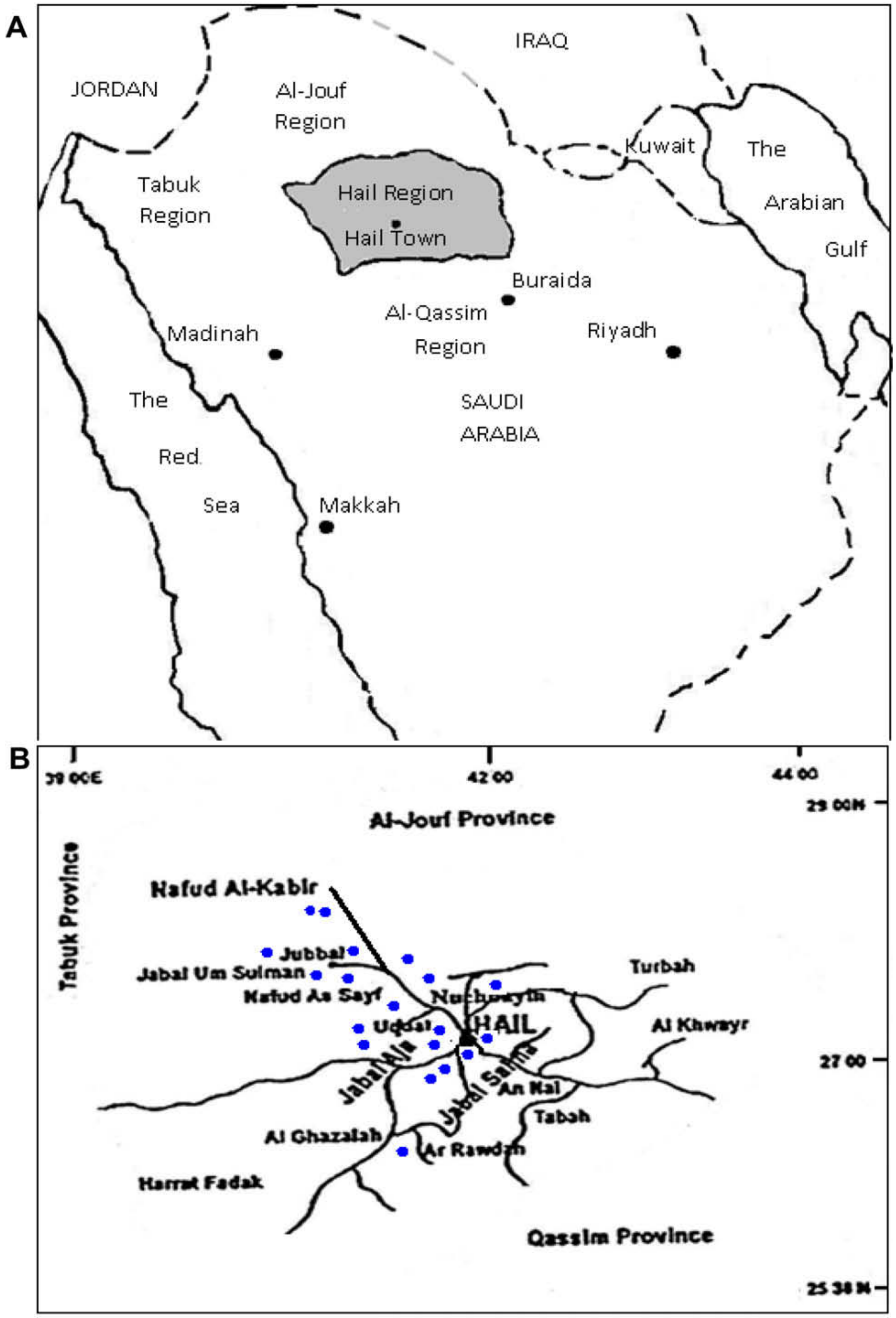

Figure 1 Map of Saudi Arabia showing Hail region (A) and the sampled sites in the study area oh Hail Province (B). Adapted from Al-Turki and Al-Olayan (2003).

of sand is the lack of oases of sand and rivers system. The mountain chains; Jabal Aja (100 km long and 25–30 km wide) to the west of Hail town and Jabal Salma (60 km long and 13 km wide) to the east are granite rocks formation (Fig. 1B). The Arabian shield extends to steep wadies and hills characterized by its limestone sand. The primary source of sand is the large granite mass intrusive igneous rock underlying the Arabian Shield. However, the sand that we see in form of sand sheets and sand dunes appears to be of secondary or more usually tertiary origins from Paleozoic and Mesozoic sand stones. Cultivation is the main activity in the Hail region but the cultivated areas are only about 92,000 hectares, which represents a small fraction of the total area of Hail region.

2.2. Climate

The climate of Saudi Arabia is generally hot and dry. It is affected by two climatic types, namely: Monsoon and Mediterranean. The Monsoon climate affects the southern part while the northern part is affected by Mediterranean climate. The weather

Table 1 The list of 124 species recorded in 57 stands in 19 sites in the study areas and their distribution in seven vegetation groups using the TWINISPAN analysis.

Ser.	Species	A	B	C	D	E	F	G	*P* (%)
01	*Abutilon pannosum* (G. Forst.) Schltdl.		18.2						11.1
02	*Acacia ehrenbergiana* Hayne	14.3				12.5			22.2
03	*Acacia tortilis* subsp. *raddiana* (Savi) Brenan	14.3	36.4	38.5	20.0				44.4
04	*Aerva javanica* (Burm.f.) Juss.			7.7					11.1
05	*Aizoon canariense* L.			7.7		12.5			22.2
06	*Alternanthera sessilis* (L.) DC.					2.5			11.1
07	*Amaranthus lividus* L.					2.5			11.1
08	*Anagallis arvensis* L.					2.5			11.1
09	*Andrachne aspera* Spreng.		18.2	7.7					22.2
10	*Anthemis melampodina* subsp. *deserti* (Boiss.) Eig.	28.6	10.0	7.7	20.0				44.4
11	*Artemisia judaica* L.		42.9	38.5					22.2
12	*Artemisia monosperma* Delile				40.0				11.1
13	*Asclepias fruticosa* L.		18.2	7.7					22.2
14	*Asphodelous fiscidulus* Boiss.			15.4					11.1
15	*Astragalus sieberi* DC.			7.7					11.1
16	*Astragalus spinosus* (Forssk.) Muschl.		45.5	23.8					22.2
17	*Avena barbata* Pott			7.7	20.0				22.2
18	*Avena fatua* L.					2.5			11.1
19	*Bassia eriophora* (Schrad.) Asch.			7.7		2.5			22.2
20	*Bassia muricata* (L.) Asch.			15.4					11.1
21	*Blepharis ciliaris* (L.) B.L. Burtt.		36.4			12.5			22.2
22	*Boerhavia diffusa* L.					15.0			11.1
23	*Brassica tournefortii* Gouan					12.5	2.5		22.2
24	*Calendula arvensis* L.			7.7		12.5			22.2
25	*Calligonum polygonoides* L.			23.8		80.0			22.2
26	*Capsella bursa-pastoris* (L.) Medik.					2.5			11.1
27	*Cenchrus ciliaris* L.					2.5			11.1
28	*Chenopodium murale* L.					5.0			11.1
29	*Citrulus colocynthis* (L.) Schrad.		18.2	46.2	20.0				33.3
30	*Cleome amblyocarpa* Barratte						33.8		11.1
31	*Convolvulus arvensis* L.					2.5			11.1
32	*Conyza bonariensis* (L.) Cronquist.	14.3							11.1
33	*Cynodon dactylon* (L.) Pers.		10.0	15.4		2.5			33.3
34	*Datura innoxia* Mill.			7.7			0.5		22.2
35	*Dichanthium annulatum* (Forssk.) Stapf.		27.3	7.7					22.2
36	*Diplotaxis acris* (Forssk.) Boiss.		10.0						11.1
37	*Diplotaxis harra* (Forssk.) Boiss.			23.8	20.0				22.2
38	*Echinops spinosus* L.		10.0		60.0				22.2
39	*Ephedra alata* Decne.							50.0	11.1
40	*Eragrostis cilianensis* (All.) F.T. Hubb.					0.5			11.1
41	*Erodium cicutarium* (L.) L'Her		10.0	15.4	20.0		1.0		44.4
42	*Erodium glaucophyllum* (L.) L'Her			3.8					11.1
43	*Erodium laciniatum* (Cav.) Willd.					37.5	0.5		22.2
44	*Eruca sativa* Mill.						0.5		11.1
45	*Euphorbia granulata* Forssk.					37.5			11.1
46	*Euphorbia peplus* L.						100		11.1
47	*Euphorbia retusa* Forssk.	28.6	10.0						22.2
48	*Fagonia bruguieri* DC.	14.3						100	22.2
49	*Fagonia cretica* L.		18.2			12.5			22.2
50	*Farsetia aegyptia* Turra		7.7	72.7		37.5	0.5		44.4
51	*Ficus palmata* Forssk.							100	11.1
52	*Flaveria trinervia* (Spreng.) Mohr					37.5			11.1
53	*Forsskaolea tenacissima* L.			38.5		2.5			22.2
54	*Gymnocarpos decandrus* Forssk.			53.8					11.1
55	*Gypsophila capillaris* (Forssk.) C. Chr.			38.5					11.1
56	*Halyxolon salicornicum* (Moq.) Bunge				46.2	80.0			22.2
57	*Helianthemum lippii* (L.) Dum. Cours		18.2				0.5		22.2
58	*Heliotropium arbainense* Frense.			15.4					11.1
59	*Heliotropium bacciferum* Forssk.			15.4					11.1
60	*Heliotropium ramosissimum* (Lehm.) Sieb.		3.8	63.6		12.5			33.3
61	*Hordeum murinum* spp. *leporinum* (Link) Arcang.					37.5			11.1

Table 1 (continued)

Ser.	Species	A	B	C	D	E	F	G	*P* (%)
62	*Iflago spicata* (Forssk.) Sch.Bip.					0.5			11.1
63	*Imperata cylindrica* (L.) Raeusch.	1.0							11.1
64	*Koelpinia linearis* Pall.		27.3	15.4					22.2
65	*Lactuca serriola* L.					0.5			11.1
66	*Launaea mucronata* (Forssk.) Muschl.	85.7	27.3	38.5		2.5			44.4
67	*Launaea nudicaulis* (L.) Hook. F.		38.6						22.2
68	*Lavandula coronopifolia* Poir.		27.3						11.1
69	*Lolium perenne* L.					37.5			11.1
70	*Lycium shawii* Roem. and Schult.	14.3	27.3	7.7					33.3
71	*Malva parviFlora* L.		27.3	46.2		4.0			33.3
72	*Mentha longifolia* (L.) Huds.						33.3		11.1
73	*Mesembryanthemum forsskaolii* Hochst.	28.6	10.0			12.5			33.3
74	*Moltkiopsis ciliata* (Forssk.) I. M. Johnst.		27.3						11.1
75	*Morettia philaeana* (Delile) DC.			38.5		5.0	33.3		33.3
76	*Nauplius graveolens* (Forssk.) Wiklund			23.8					11.1
77	*Nitraria retusa* (Forssk.) Asch.						33.3		11.1
78	*Ochradenus baccatus* Delile		27.3		46.2				22.2
79	*Oligomeris linifolia* (Vahl) J.F. Macbr.					37.5			11.1
80	*Parietaria alsinifolia* Delile			15.4					11.1
81	*Paronychia arabica* (L.) DC.			23.8		37.5	33.3		33.3
82	*Paronychia desortorium* Boiss.		18.2						11.1
83	*Pennisetum divisum* (J.F. Gmel.) Henrard		42.9	7.7					22.2
84	*Pergularia tomentusa* L.	14.3							11.1
85	*Phoenix dactylifera* L.	1.0				12.5			22.2
86	*Phragmites australis* (Cav.) Trin.ex Steud	75.0							11.1
87	*Plantago albicans* L.		10.0			37.5			22.2
88	*Plantago crypsoides* Boiss.		10.0						11.1
89	*Plantago ovata* Forssk.				40.0				11.1
90	*Polygonum equisetiforme* Sm.					2.5	33.8		22.2
91	*Polypogon monspeliensis* (L.) Desf.					37.5			11.1
92	*Portulaca oleracea* L.					37.5			11.1
93	*Pulicaria undulata* (L.) C.A. Mey.		45.5	15.4					22.2
94	*Reichardia tingitana* (L.) Roth	14.3							11.1
95	*Reseda pruinosa* Delile			23.8					11.1
96	*Rhantarum epaposum* Olive	42.9	45.5	15.4					33.3
97	*Rhus tripartita* (Ucria) Grande			15.4				25.0	22.2
98	*Rumex vesicarius* L.		27.3			75.0	33.3		33.3
99	*Salsola imbricata* subsp. *gaetula* (Maire) Boulus			7.7		2.5			22.2
100	*Savignya parvilora* (Delile) Webb		36.4						11.1
101	*Schismus barbatus* (L.) Thell.	28.6							11.1
102	*Senecio flavus* (Decne.) Sch.Bip.						2.5		11.1
103	*Senecio glaucus* subsp. *coronopifolius* (Maire) C. Alexander		10.0				35.8		22.2
104	*Senna italica* Mill.			7.7					11.1
105	*Setaria verticillata* (L.) P.Beauv.					37.5			11.1
106	*Setaria viridis* (L.) P.Beauv.					37.5			11.1
107	*Silene linearis* Decne.					12.5			11.1
108	*Silene villosa* Forssk.						33.3		11.1
109	*Sisymbrium irio* L.					12.5		100	22.2
110	*Solanum nigrum* L.					2.5			11.1
111	*Sonchus oleraceous* L.					2.5			11.1
112	*Spergularia diandra* (Guss.) Boiss.					12.5			11.1
113	*Stipa capensis* Thunb.	42.9	10.0						22.2
114	*Tamarix nilotica* (Ehrenb.) Bunge	1.0							11.1
115	*Telephium sphaerospermum* Boiss.						33.3		11.1
116	*Themedia triandra* Forssk.			7.7	40.0				22.2
117	*Tribulus terrestris* L.			7.7					11.1
118	*Trichodesma africanum* (L.) R. Br.			23.8		12.5			22.2
119	*Trigonella stellata* Forssk.		57.1	15.4					22.2
120	*Tripleurospermum auriculatum* (Boiss.) Rech.f.		10.0						11.1
121	*Withania somnifera* (L.) Dunal					2.5			11.1
122	*Zilla spinosa* (L.) Prantl		10.0	3.8					22.2
123	*Ziziphus spina-christi* (L.) Desf.		18.2						11.1
124	*Zygophyllum simplex* L.					25.0	16.7		22.2

Table 2 Life form spectra of the recorded species in the study area according to Raunkiaer's (1937) classification.

Life form	No. of species	% of collected species
Therophytes	61	49.20
Chamaephytes	36	29.00
Hemicryptophytes	14	11.29
Phanerophytes and Nano-phanerophytes	11	8.87
Hydrophytes and Helophytes	1	0.80
Geophytes	1	0.80

Table 3 The chronological analysis of the collected species according to Wickens (1978) and Zohary (1983).

Floristic categories	Number of species	Percentage
Mono-regional	29	23.4
Sahro-Sindian(SA-SI)	25	20.2
Mediterranean (Med)	2	1.62
Irano-Turanian(IR-Tur)	1	0.81
Sudano-Zambezian (Sud-Zamb)	1	0.81
Bi-regional	48	38.7
SA-SI + Med	4	3.22
SA-SI + IR-Tur	7	5.65
SA-SI + Sud-Zamb	29	23.4
Med + IR-Tur	5	4.23
Palaeotropic	3	2.42
Pantropic	5	4.23
Cosmopolitan	11	8.87
Pluri-regional	28	22.58

system in the Hail regions is general arid to extra arid. It is influenced by two main pressures, namely Siberian high in winter and tropical low in summer months. According to the records of Hail metrological station for the period 1998–2006, the study area is characterized by a mean minimum temperature of 10.8 °C in January and a mean maximum temperature of 34.1 °C in August with an annual mean temperature of 25.6 °C. The rainfall in the region is erratic and irregular; it is mainly winter fall, the high precipitation occurs in November (32.0 mm/day) and the average annual rainfall is 104.4 mm/day, however in the summer months no rain has been detected. The relative humidity is extremely low in summer as it reached 15.0% in July and relatively high January (53.0%); the mean annual average is 31.0%. The average annual wind velocity in the study area is 68.4 km/h and the mean number of stormy days may reach 25 per year, storms are more frequent in the spring from the North East direction. The rate of evaporation in the area is generally low; it ranges between 6.6 mm in January and 8.7 mm in November.

3. Materials and methods

Nineteen sites in the study region, representing different habitats, were regularly visited from October 2005 to May 2007. These sites are in or around Hail town, Ugdah, El-Nafud, Gebel Aja and Jubba (Fig. 1B). In each site, 2–5 stands were randomly selected for this investigation. In each stand; quadrates of 10×10 m^2 in the desert area were used. In the urban and cultivated plots areas quadrates of 5×5 m^2 and 1×1 m^2 were respectively, used. Cover, abundance and presence values of the specie were calculated in the examined quadrates. The collected plant specimens were identified and named according to Collenette (1999), Cope (1985) Mighaid (1996) and Chaudhary

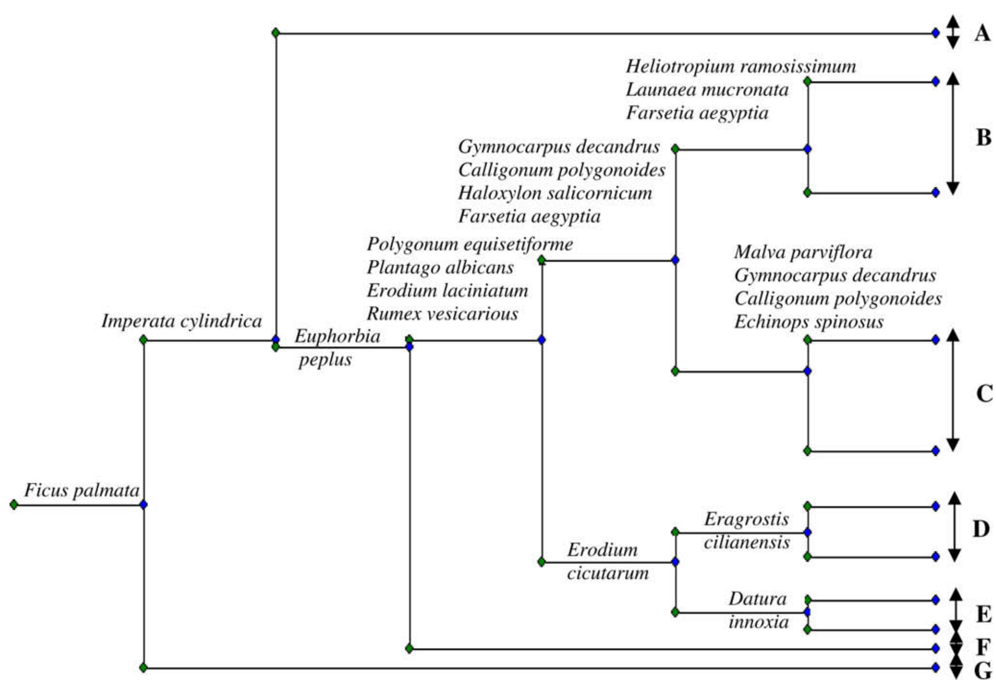

Figure 2 The dendrogram illustrating the presence of seven vegetation groups using TWINSPAN analysis of 57 sampled stands in the study area.

(1999, 2000, 2001). Voucher specimens are deposited in the Science Department, Faculty of Science, Hail University.

A floristic data matrix of the 57 stands and 124 species was prepared after the removal of more than unicate species occurring at a single stand. A chronological analysis of the floristic categories of species was made to assign the recorded species to World geographical groups according to Wickens (1978) and Zohary (1983). For the vegetation analysis, the two way indicator species analysis (TWINISPAN; Hill, 1979) based on species with frequency of more than 5% in at least two sites in the study area. In addition, the Detrended Correspondence Analysis (DCA), which is an indirect gradient analysis technique that plots sites against axes, based on species composition and abundance was employed using the CANOCO software version 3.12 (Ter Braak, 1994) was also used for classification and ordination of plant vegetation. Both types of vegetation analysis were conducted using the CAP (2002) Community Analysis Package. In addition, species richness (alpha diversity) was calculated as the average number of species per site in the study area and species diversity, that measures the species turnover between different areas, was determined according to Magurran (2003). According to Magurran (2003) also, the Shanon-Wiener and Simpson indices were also calculated, in addition to these indices, the recurrence index that reflects species distribution in the different habitats in the study area in five groups was also calculated.

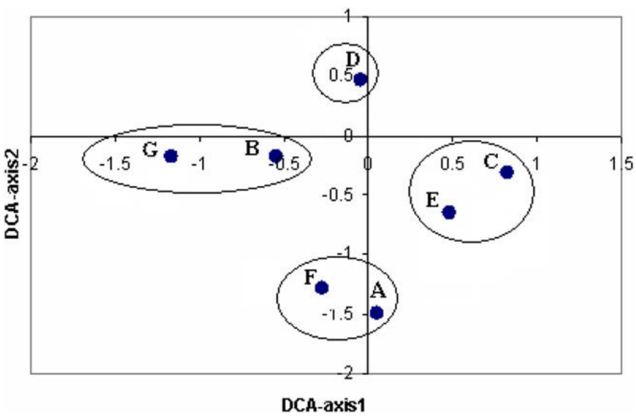

Figure 3 DCA ordination of the seven vegetation groups identified using TWINSPAN analysis of the 57 sampled stands in the study area.

4. Results

The final list of 124 species that were recorded in at least two sites in the study area, represent 34 families of flowering plants (Table 1); 15 families are only represented by one species; examples include Acanthaceae, Convolvulaceae, Moraceae, Nyctaginaceae and Primulaceae. The large family Compositae (Asteraceae) is represented by 21 species while the grass family Graminae (Poaceae) and Cruciferae (Brassicaceae) are represented by 17 and 10 species, respectively. The life form spectra of the recorded species in the study area according to Raunkiaer's (1937) classification are given in Table 2. The therophytes are the dominating life form in the study area amounting to 49.20% of the collected species. Chamaephytes were represented by 36 species (29.00% of the total species) while hemicryptophytes were represented by 14 species (11.29% of the total species). Geophytes and Hydrophytes are each represented by only one species (*Asphodelus tenuifolius* and *Phragmites australis*), respectively.

Table 4 Characteristics of the seven vegetation groups derived after the application of TWINSPAN on the 57 stands in Hail area. VG: vegetation group; N: number of stands; NS: number of species per group; RU: ruderals, CP: cultivated plots, WA: wadies, MA: mountainous area and SD: sand dunes.

VG	N	NS	Habitats					Species richness	Shannon index	Simpson index
			RU	CP	WA	MA	SD			
A	3	3	100					3.0	1.1	3.0
B	19	57			100	54.5		16.2	6.2	41.7
C	18	63	30.8		73.8	15.4	80	15.5	6.0	45.6
D	8	52	37.5	62.5				15.8	3.5	26.0
E	5	19	100					8.8	2.5	11.8
F	3	2	100					2.0	0.7	2.0
G	2	3			100			2.5	0.8	2.1

Table 5 A list of the two most dominant species in the seven TWINSPAN groups and the percentage of their presence (P) in the sites of the study area (species).

VG.	1st Dominant	P (%)	2nd Dominant	P (%)
A	*Phragmites australis*	100	*Imperata cylindrica*	100
B	*Launaea mucronata*	85.7	*Trigonella stellata*	57.1
C	*Gymnocarpos decandrus*	53.8	*Ochradenus baccatus*	42.6
D	*Plantago albicans*	75	*Rumex vesicarius*	75
E	*Senecio glaucus* subsp. *coronopifolius*	35.8	*Polygonum equisetiforme*	33.8
F	*Euphorbia peplus*	100	*Sisymbrium irio*	100
G	*Ficus palmata*	100	*Fagonia bruguieri*	100

The chronological analysis of species in the study area (Table 3) revealed that mono-regional species representing 23.4% of the total species. The Sahro-Sindian elements are dominating as mono-regional elements with a species number of 25 representing 20.2% of the total species. Bi-regional elements amount to 48 species representing 38.7% of total number of species; the Sahro-Sindian and the Sudano-Zambezian elements together are represented by 29 species that represent 23.4% of the total species. Meanwhile pluri-regional elements are presented by 28 species representing 22.58% of the total species. The floristic composition of the study area also includes 11 Cosmopolitan species, 5 pantropic species and three Palaeotropic species (Table 3).

The application of TWINSPAN on the cover and presence estimates of the 124 species, recorded in the 57 sampled stands, in the Hail region indicated the recognition of seven vegetation groups (Fig. 2). The application of DCA on the same set of data indicated a reasonable aggregation of these groups along the ordination plane of axes 1 and 2 (Fig. 3). The characteristics of these seven vegetation groups and the presence and number of species per each group and their vegetation type are given in Table 4; this table also includes the values of species richness, Shanon's index and Simpson's index. The two most common species in each group and the percentage of their occurrence in the seven groups are listed in Table 5. Two groups have been found most common in the ruderal habitats, these are groups A and F dominated by *P. australis*, *Imperata cylindrical* (A) and *Euphorbia peplus* and *Sisymbrium irio* (F), respectively. Two other vegetation groups (B and G) have been recognized in the mountains and slopes dominated by *Launaea mucronata* and *Trigonella stellata* (B) and *Ficus palmate* and *Fagonia bruguieri* (G). The species in the two groups (C and D) inhabit the desert and mountainous wadies; these are represented by *Gymnocarpos decandrus* and *Ochradenus baccatus* (C) and *Plantago albicans* and *Rumex vesicarius* (D). On the other hand, one group (E) inhabits the cultivated plots and is represented by *Senecio glaucus* subsp. *coronopifolius* and *Polygonum equisetiforme*. Group B has the highest number of species (52) as well as the highest value of species richness (16.2) as well as the highest Simpson's index (45.6). The two groups C and D also have high values for species richness, and the Shanon's and Simpson's indices. On the other hand, the groups A, F and G have the low diversity index and also low values for the Shanon's and Simpson's indices (see Tables 4 and 5).

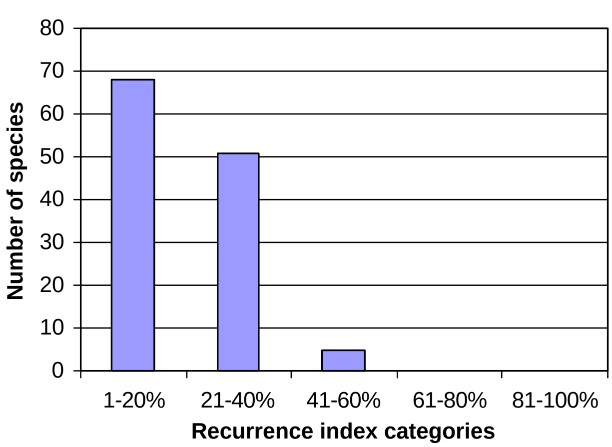

Figure 4 Histogram illustrating the recurrence index distribution of the species collected from the different habitats in the study area of Hail region.

Fig. 4 illustrates the recurrence index distribution of the species from the different habitats in the study area. The highest number of species is 68 in the category 1–20% followed by 51 species in the category 21–40% and only five species in the category 41–60%. However, no species have been assigned to the two categories 61–80% and 80–100%. From this figure, it may be observed that the widely distributed species i.e. species present in all habitats are not represented in these two categories. The presence of the highest number of species (68) in the category 1–20% recurrence index indicates that the majority of species in the study area are restricted to one habitat. Examples of these species include *Abutilon pannosum* (Group B), *Aerva javanica* (Group C), *Amaranthus lividus* (Group E), *Alternanthera sessilis* (Group E) and *Ficus palmata* (group G).

5. Discussion and conclusions

The floristic composition and vegetation features in the Hail area were studied for two years. The floristic composition analysis showed that the family Asteraceae, which is the largest family of angiosperms, is represented by the highest number of species, in the study area. Another large family; the Poaceae is represented by 17 species and the Brassicaceae is represented by 10 species. Meanwhile, 15 families including Primulaceae, Acanthaceae, Convolvulaceae, Moraceae and Nyctaginaceae, are represented by a single species each. A floristic analysis shows that majority of plants in the study area are annuals while the minority group is in the tree. The dominance of members of Asteraceae, Poaceae and Brassicaceae coincides with the findings reported by Al-Turki and Al-Olayan (2003), the only detailed study available on the Flora of Hail region. The most common genera are *Euphorbia* (Euphorbia), *Heliotropium* (Boraginaceae) and *Plantago* (Plantaginaceae) with three species for each family. In the Al-Turki and Al-Olayan (2003) study, *Plantago* and *Astragalus* (Fabaceae) were the most common genera in the whole region of Hail.

A number of species from the study area have been identified by Al-Turki and Al-Olayan (2003) as endemic-endangered, such as *Anthemis sheilae* A Ghaloor and TA AI-Turki, *Arabidopsis erysimoides* Hedge and Kit, *Astragalus collenettiae* Hedge and Podl. and *Trisetan'a chaudharyana* Scholz Meanwhile other species such as *Echinops glaberrimus* DC, *E. hystrichoides* Kit Tan, *Ochradenus arahicus* Chaudhary Hille and A.G Miller and *Zygophyllum propinquum Decne*. ssp. *migahidii* (Hadidi) J.'lbomas and Chaudhary were classified as endemic to Saudi Arabia. However, these species were not encountered in our survey as they are rare and grow only in the region's mountains that house the endemic and rare species, which are often not encountered in ecological studies based on collecting plants from fixed stands in fixed sites in the study area.

The biological spectrum of the study area indicates the prevailing of therophytes (49.2%) and chaemophytes (29.0%). These results also coincide with the findings of Al-Turki and Al-Olayan (2003). The higher number of species recorded in their report might be due to the larger area covered in their survey. The domination of therophytes and chaemophytes in the vegetation spectra of Hail also agrees with the spectra of vegetation in deserts and semi-desert habitats in other parts of Saudi Arabia as described by some other authors (e.g. Abd-El-Ghani, 1997; Fahmy and Hassan, 2005). This picture is also congruent with the vegetation spectra in other parts of the Middle East (Danin and Orchan, 1990; Zahran and Willis, 1992; El-Bana and Al-Mathnani, 2009).

These results showed that Hail region comprises diverse ecosystems and presents very interesting aspects for vegetation studies. The application of TWINSPAN classification techniques to the vegetation data produced seven groups and the application of DECORANA to the same data showed resemblances among some of these groups. The two groups A and F, which covers the moist and ruderal areas as indicated by the domination of *P. australis–Imperata cylindrica* (A), and *E. peplus–S. irio* (F), whereas the group E comprises 19 species and characterizes the urban areas in Hail town that includes the species *S. glaucus* subsp. c*oronopifolius* and *P. equisetiforme*. Meanwhile, the species in group C, which comprises species dominated by *G. decandrus* and *O. baccatus*, as indicator species, are characteristic of the desert plains in the An-Nafud desert coinciding with the results reported by Chaudhary (1983).

The vegetation group B dominated by *L. mucronata*, *T. stellata* and group C dominated by *G. decandrus* and *O. baccatus*, comprise higher numbers of species (40 and 49, respectively) and together include the most widely distributed elements in the study area. However, group D comprises the highest number of species (52) dominated by *P. albicans* and *R. vesicarius* as weedy dominant species for the cultivated plots. This group also includes several intrusive weeds such as *Avena fatua*, *Chenopodium murale*, *Convolvulus arvensis*, *Lolium perenne* and *Polypogon monospeliensis* and ruderal elements such as *Aizoon canariensis*, *Anagalis arvensis*, *P. australis* and *Salsola imbricata*. The elements of this vegetation group show abundance of the introduced ruderal elements and weeds of cultivated plots and indicate the increasing agriculture development in the Hail region.

The two groups B (*L. mucronata–T. stellata*) and G (*F. palmata–F. bruguieri*) characterize the Mountainous areas of Hail region. Group G comprises 40 species that are more common in the mountains slope; *L. mucronata* and *T. stellata* are associated with *Artemisia judaica, Euphorbia retusa, Lycium shawii*, *Pennisetum divisum, Rhantarum epaposum* and *Stipa capensis* to form the dominant vegetation elements in the mountain slopes. On the other hand, group G comprises only six species; *F. palmata* and *F. bruguieri* are associated with *Ephedra alata* and *Rhus tripartita* and characterize the mountains. These results also agree with the reports of Chaudhary (1983) and add to the contribution to the: Hail Flora as reported by Al-Turki and Al-Olayan (2003).

A glimpse on the floristic composition of these two groups indicates the need to consider the Aja Mountains and their wadies in Hail as a protected area. This area provides all the supplements for the conservation on natural vegetation in a region exposed to increasing agricultural activities. During the past five decades, extensive human activities (livestock grazing, fuel wood cutting and temporary arid land cultivation) have put great pressure on vegetation in all regions of Saudi Arabia and lead to vegetation change. The results of the present study point out the need for further studies on the diverse and changing vegetation of the Hail region. This paper also points out the need for managerial practices to conserve plant diversity in Saudi Arabia.

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