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Plant distribution and diversity along altitudinal gradient of Sarrawat Mountains at Taif Province, Saudi Arabia

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The present study aims at investigating the floristic diversity and distribution pattern of plant species along the elevation gradients of Sarrawat Mountain at Taif, Saudi Arabia. Three hundred and fifty-eight stands were selected along various elevation levels (I: less than 1000 m, II: 1000-1300 m, III: 1300-1600, IV: 1600-1900, V: 1900-2200, and VI: more than 2200 m above sea level) to represent the vegetation physiognomy on the study area. There were 573 species belonging to 297 genera and 73 families was recorded at elevation 1900-2200 m a.s.l, while the lowest number was recorded at elevation < 1000 m a.s.l. Based on the floristic composition along the different elevations, the agglomerative clustering technique recognised three clusters: A) comprised > 1000 and 1000-1300 m elevation levels; B) included 1300-1600 m and 1600-1900 m levels; and C) comprised 1900-2200 m and > 2200 m a.s.l. Asteraceae was the most dominant family, followed by Poaceae and Fabaceae. The life form spectra and chorotype of the recorded species indicated the predominance of chamaephytes and mono-regionals, respectively. Ten species, representing 9.4% of the total endemic species in Saudi Arabia, were recorded as endemic taxa. About 77.7% of the total species were used for grazing, while 58.6% were medicinal. The species diversity of the recorded species had its highest values at 1900-2200 m a.s.l, while the lowest were recorded below 1000 m. The present study provides a keystone for biodiversity and conservation of important plant areas of Saudi Arabia.

Keywords: Sarrawat highland, floristic diversity, community, Taif, Saudi Arabia

INTRODUCTION

Plant diversity is the main component of terrestrial ecosystems that maintaining and protecting the environmental balance of a region (Cunningham et al., 2015). The floral diversity helps to stabilize soil improvement, and slopes and extreme weather extremes and provide habitat for wildlife fauna (Pearse and Hipp, 2009). A huge area of arid lands occupy Saudi Arabia (approximate more than 2.25 million km^2), which cover the large area of the Arabian Peninsula and is characterized using many ecosystems that differing in their plant diversity (Abdel Khalik et al., 2013). There are different habitats in the vast landscape of Saudi Arabia include mountains, wadis, raudhahs, sabkhahs and sandy and rocky deserts. Saudi Arabia can be divided into two distinct zones according to geographical viewpoint; the arid and hyper-arid lands of the interior and the rainy highlands of the western and southwestern regions (Al-Nafie, 2008). According to Collenette (1999) and Chaudhary (2001), the rain fed highlands of the western and southwestern regions have plants are rich compared to inland arid areas distributed throughout the country. Saudi Arabia flora of comes from Asia, Africa, and the Mediterranean (Al-Nafie, 2008); It is therefore the richest region in the Arabian Peninsula and has important genetic resources for plants and medicinal crops (Mossa et al., 1987).

The priority of conserving plant diversity in Saudi Arabia has become an important priority in which the impact is tangible, as there is an urgent need for scientific knowledge and good practice in this regard. The Saudi Wildlife Authority (SWA) has prolonged the partnership with IUCN Regional Office for West Asia (ROWA), based on a 20-year-partnership in protected areas management.

Noting the benefits arising from the use of genetic resources, they represent one of the objectives of the Convention on Biological Diversity (CBD), IUCN for ROWA have agreed with the IUCN Environmental Law Center to develop a Saudi strategy for the sharing of such genetic resource benefits.

Implementing strategic plans will also be developed for the documentation and collection of plant diversity related traditional knowledge and practices. This is part of the 2009 Plant Diversity Action Plan developed by both partners (http://www.iucn.org/). Both the radical change in vegetation and climate from the base (wadi) to the top of the mountain are fundamental characteristics of mountain ecosystems. Because of the richness of habitats and unique microclimate, the mountains contain many endemic species and shelter specialized plant communities (Cano-Ortiz et al., 2016). Mountains are of biogeographical, great floristic and ecological importance in the Middle East; they are centers of species richness and radiation (Körner, 2000). They provide refugia of several relict and disjunctive species (Ghazanfar and McDaniel, 2015). The mountains of Northwestern and southwestern Saudi Arabia are densely vegetated and occupied with approximately 70% of the country's plant species (Osman et al., 2014).

A series of interacting biological, environmental and historical factors governed the distribution of plant species along elevation gradients (Colwell and Lees, 2000). Many environmental variables are simultaneously affected by changes in height, which is a complex gradient (Austin et al., 1996). The gradient in elevation produces diversity in the climate and this along with different soil types promotes diversity in plant species (Brown, 2001; Lomolino, 2001). Linkages between species distribution and altitudes can help to understand the potential impacts of environmental changes, e.g., through the availability of associated baseline information, the impact of climate change and human changes on vegetation can be measured (Lomolino, 2001). The variations of species diversity can be associated with many ecological gradients (Huston, 1994; Wang et al., 2002); while altitude gradients are well known as one of the important factors that shaping the spatial patterns of different species (Brown, 2001).

Although an accurate and clear description of the pattern of elevation gradients in plant Diversity was defined about two centuries ago (Lomolino, 2001), this issue was still uncertain. Lomolino (2001) argued that whether the diversity-elevation gradient is increasing or decreasing will largely depend on Patterns of common variation and interaction between geographically distinct variables. Thus, the rapprochement of elevation trends in diversity between taxa and mountain ranges with standardized measurements of environmental variables and no sampling biases are needed for a more general theory of species diversity (Brown, 2001). On the other hand, a thousand years ago the Sarrawat mountains which estimated at 2.7 million hectares, were much more densely covered with woodlands with only remnants, still remain in the remote inaccessible areas. Therefore, the present study aims at investigating the floristic diversity and distribution pattern of plant species along the elevation gradients of Sarrawat Mountain at Taif Province, Saudi Arabia.

MATERIALS AND METHODS

Study area

Saudi Arabia extends over approximately 16º degrees of latitude, from 16º 22' at the borders with Yemen in the south to 32º 14' at the Jordanian border in the north, and between 34º 29'E and 55º 40` E. Longitude (Fig. 1). Taif region is located in the central foothills of the western mountains at an altitude of up to 2500 m above sea level with latitude of 21° 26' 14.1828'' N and longitude of 40° 30' 45.7704'' E. Sarrawat Mountains are distinguished by high altitudes for about 3700 meters above sea level near Abha city and decreasing gradually to north, associated with the heavy rains, high relative humidity and low temperature (Awdat et al., 1997). The highland slopes and foothills of Sarrawat Mountains are formed of resistant, coarse pink granite, mixed with grey diorite and granodiorite (Ady, 1995). The rocks are largely exposed, steep-faced, with almost no soil cover and sparsely covered with vegetation that is primarily limited to crevices or small depressions in which fine sediments have accumulated in pockets. However, large boulders, small stones and gravels are found in the steep runnels.

The climate of the study area is tropical and arid. The monthly mean of climatic variables recoded in Taif meteorological station for 1997–2009 (Anonymous 2008) indicated that the monthly average minimum and maximum ambient air temperatures (± SD) ranged from 7.9±1.2 to 23.4±0.8°C and 22.9±1.1 to 36.3±0.8°C, respectively with a monthly mean of 23.2±5.1°C (Fig. 2). The mean monthly relative humidity ranged from approximately 19.6±4.2 to 60.0±6.0%. Moreover, considerable inter-annual variation in the monthly amount (range 4.3±1.7-294.1±83.8 mm month^{-1}) and timing of rainfall were recognized.

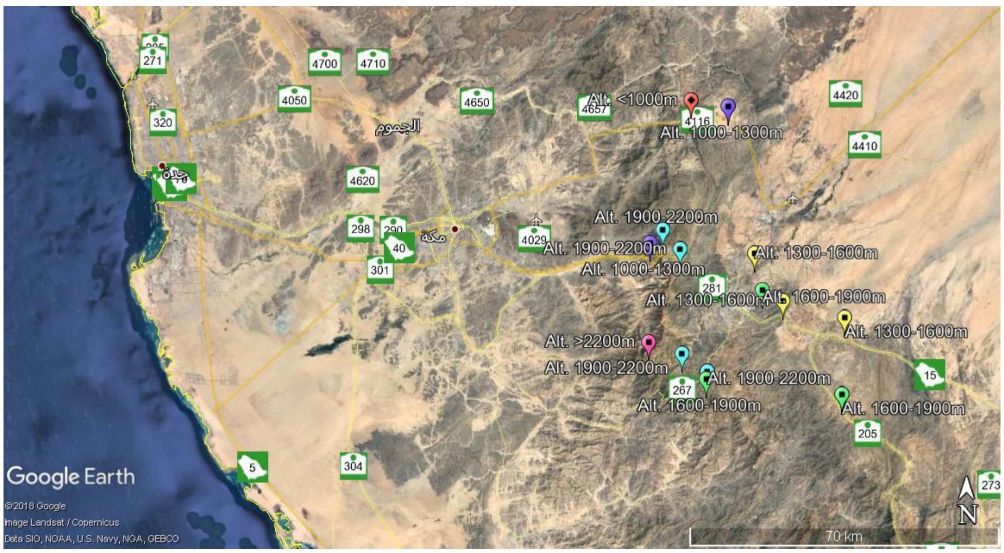

Figure 1. Location map of the study area showing the different altitudinal gradients at Taif Region.

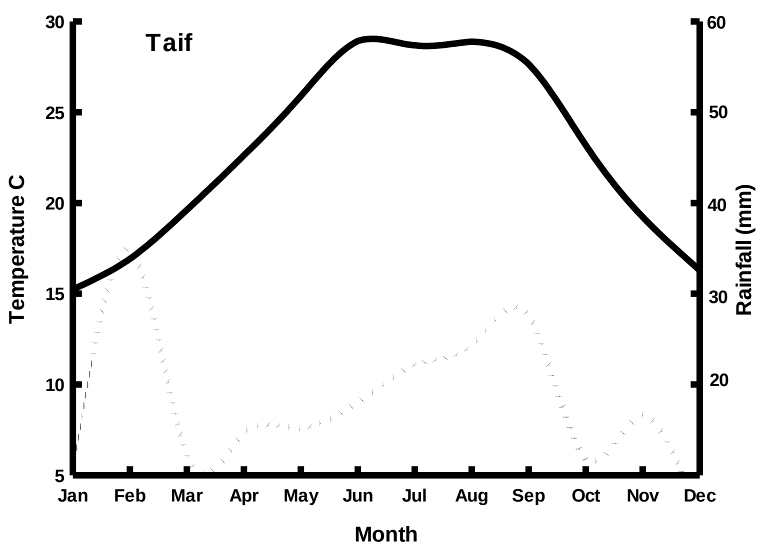

Figure 2. Climatic diagram showing the monthly variation in the ambient air temperature and rainfall from the meteorological station in Taif.

Data collection

Three hundred and fifty-eight stands were selected along the different elevation levels (I: less than 1000 m, II: 1000-1300 m, III: 1300-1600, IV: 1600-1900, V: 1900-2200, and VI: more than 2200 m above sea level) to represent the vegetation physiognomy on Sarrawat Mountains at Taif Province in the southwestern region of Saudi Arabia. The stand size was about 50 x 50 m, which approximates the minimal area of the plant communities. The stands were surveyed, species list, and visual estimate of the total cover and the cover of each species (%) were recorded. Identification and nomenclature were according Nomenclature of the recorded species was according to Migahid (1996), Chaudhary (1999, 2001), Collenette (1999) and Boulos (1999; 2000; 2002; 2005; 2009).

The life form spectra of the recorded species were identified following the Raunkiaer scheme (Raunkiaer, 1937). The global geographical distribution and abundance categories (cc: very common, c: common, r: rare and rr: very rare) of the recorded species were gathered from Täckholm (1974), Feinbrun-Dothan (1978, 1986); Zohary (1966, 1973) and Wickens (1977). The potential and actual economic uses of the recorded wild species were assessed on three bases of field observations, information collected from local inhabitants and the literature (e.g. Täckholm, 1974; El-Kady, 1980; Zohary, 1987; Feinbrun-Dothan, 1978, 1986; Danin, 1983; Boulos, 1983, 1989; Mossa et al., 1987; Mandaville, 1990; Ayyad, 1992; Belal and Springuel, 1996, and Shaltout, 1997). The economic uses were classified into five major categories: grazing, fuel, medicinal, edible and other uses (e.g. making mats, furniture, chairs and ornamental uses). Voucher specimens were deposited at the Herbarium of Biology Department, Faculty of Science, Taif University.

Data analysis

The agglomerative clustering techniques were applied to classify the altitudinal vegetation of Sarrawat Mountains, based on Euclidean distances as a measure of linkage distance (Kruscal, 1964). Some diversity indices were calculated for the different elevation of Sarrawat Mountain. Species richness (alpha-diversity) for each vegetation group was calculated as the average number of species per stand. Species turnover (beta-diversity) was calculated as a ratio between the total number of species recorded in a certain vegetation group and its alpha diversity (Whittaker, 1972). Relative evenness or equitability (Shannon-Weaver index) of the importance value of species was expressed as $\hat{H} = -\Sigma^s P_i (\log P_i)$, where S is the total number of species and Pi is the relative importance value (relative cover) of the i^{th} species. The relative concentration of dominance is the second group of heterogeneity indices and is expressed by Simpson's index: D= 1/C $\{C = \Sigma^s(P_i)^2\}$, where S is the total number of species and P_i is the relative importance value (relative cover) of species} (Pielou, 1975 and Magurran, 1988).

RESULTS

Floristic composition

The recorded species with their families, life forms, chorological types and abundance along the elevation gradient of Sarrawat Mountains were presented in Appendix (T1).The flora of Sarrawat Mountains at Taif area was represented by 573 species (175 annuals and 398 perennials) belonging to 297 genera and 73 families(Table 1). *Cheilanthes vellea* is an exclusive species of lower vascular plants belonging to Pteridaceae. Nine species were belonged to Gymnospermae; 4 of them for Cupressaceae (*Cupressus horizontalis, C. sempervirens, Juniperus phoenicea* and *J. sprocera*) and 5 for Ephedraceae (*Ephedra pachyclada* subsp. *sinaica, E. alata, E. aphylla, E. foeminea* and *E. foliata*). Of the recorded species, 26 taxa were under the specific rank; either subspecies (e.g. *Anthemis melampodina* subsp. *deserti, Launaea fragilis* subsp. *asirensis* and *Astragalus atropilosus* subsp. *abyssinicus*) or variety (e.g. *Dianthus strictus* var. *subenervis*, *Atriplex leucoclada* var. *turcomanica* and *Cucumis prophetarum* var. *dissectus*). The ratio of species to subspecies was about 22, while there are approximately 1.9 species for each genus and 4.1 genera for each family (Table 1). Moreover, 564 species were angiosperms (468 species dicotyledonous and 95 monocotyledonous). It worth to note that 2.6% of the total species were very common, while 49.7% were common, 46.5% were rare and 1.2% were very rare species (Fig. 3).

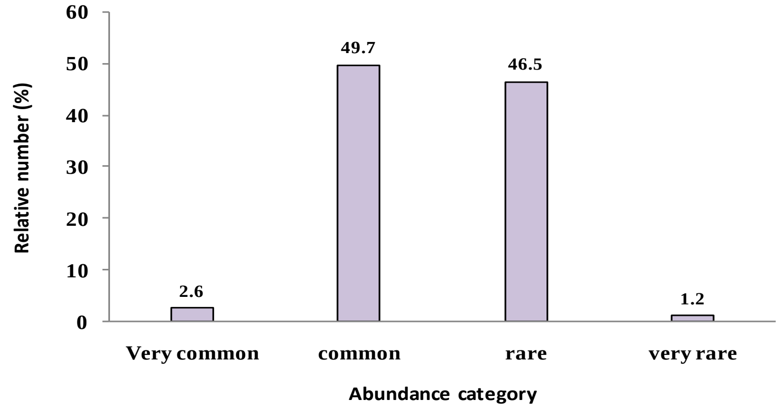

Figure 3. Abundance categories of the recorded species on Sarawat Mountains at Taif area.

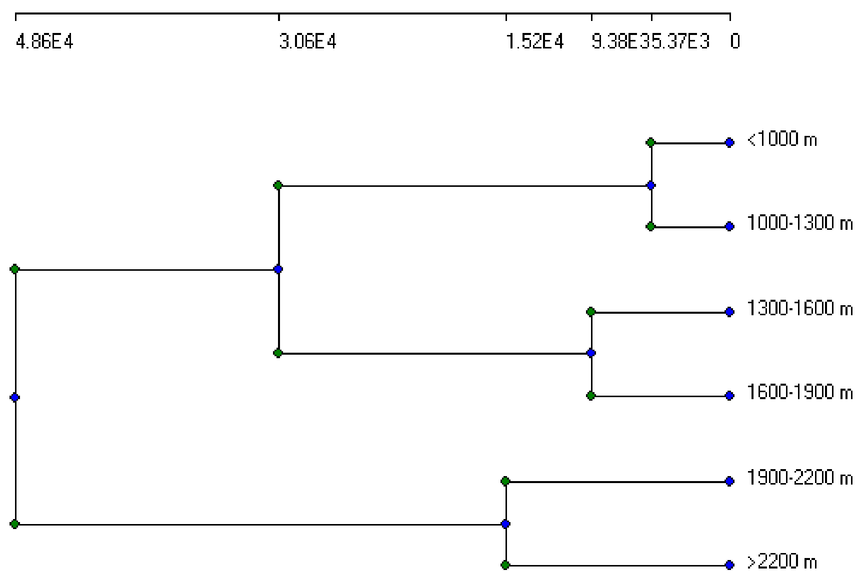

Figure 4. Hierarchical classification of the different elevations of Sarrawat Mountain based on their floristic composition.

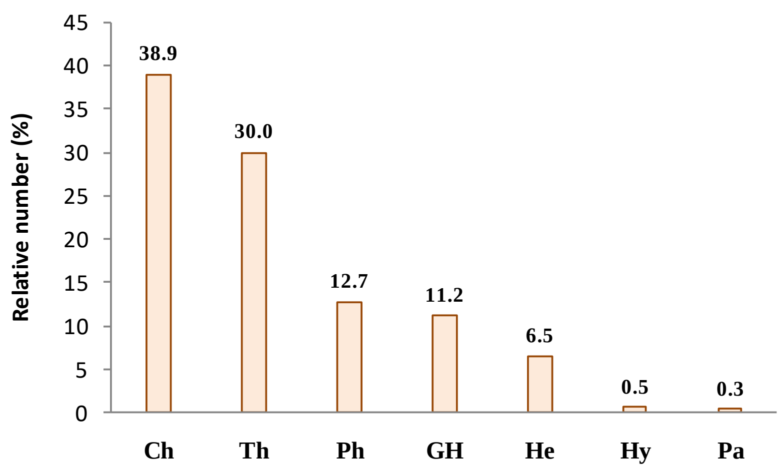

Figure 5. Life form spectra of the recorded species on Sarrawat Mountains at Taif area.

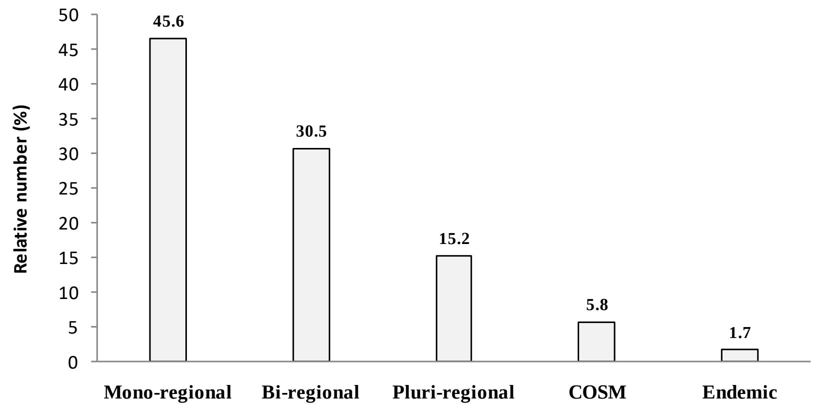

Figure 6. Chorotypes of the recorded species on Sarrawat Mountains at Taif area.

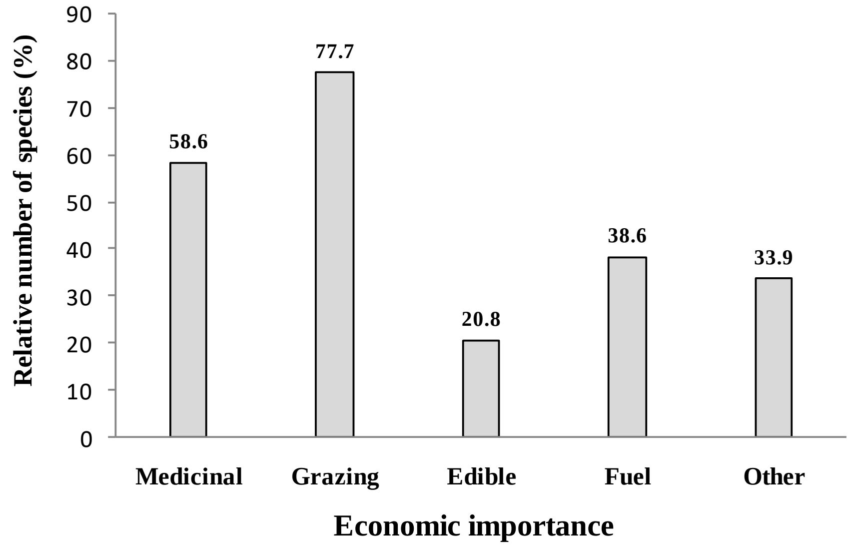

Figure 7. Economic importance of the recorded species on Sarrawat Mountains at Taif Province.

Table 1. Taxonomic diversity of the recorded species on Sarrawat Mountains at Taif Province.

Taxonomic group	Family	Genus	Species	Subsp /Var	S/Subs	S/G	G/F
Ptridophyta	1	1	1			1.00	1.00
Gymnospermae	2	3	9	1	9.0	3.00	1.50
Dicotyledonae							
Archichlmydae	41	129	265	12	22.1	2.05	3.15
Sympetalae	15	110	203	12	17.0	1.85	7.33
Monocotyledonae	14	54	95	1	95.0	1.76	3.86
Total	73	297	573	26	22.0	1.9	4.1

Table 2. Absolute and relative number of species of the top 10 families recorded along the different elevation of Sarrawat Mountain at Taif area.

Family	Elevation (m a.s.l)						Number of species	
	<1000	1000-1300	1300-1600	1600-1900	1900-2200	>2200	A	R
Asteraceae	1	1	35	35	45	23	87	15.2
Poaceae	3	4	33	43	23	8	64	11.1
Fabaceae	1	4	18	16	26	4	39	6.8
Chenopodiaceae		2	19	27	13	4	32	5.6
Lamiaceae			7	15	20	6	30	5.2
Euophorbiaceae	1		11	10	10	2	22	3.8
Brassicaceae		1	6	13	12	3	22	3.8
Solanaceae			10	11	14	8	18	3.1
Boraginaceae	1	2	7	5	6	1	16	2.8
Zygophyllaceae	1	2	9	10	10		15	2.6

Table 3. Life form spectra along the different elevation of Sarrawat Mountains at Taif area.

Life form	Elevation (m)											
	< 1000		1000-1300		1300-1600		1600-1900		1900-2200		> 2200	
	A	R	A	R	A	R	A	R	A	R	A	R
Chamaephytes	5	29.4	12	41.4	84	34.3	112	37.8	133	42.9	53	47.3
Geophytes-helophytes	3	17.7	3	10.3	26	10.6	32	10.8	30	9.7	9	8.0
Hemicry ptophytes	1	5.9	2	6.9	21	8.6	23	7.8	10	3.2	5	4.5
Hydrophytes	-	-	-	-	3	1.2	1	0.3	2	0.6	1	0.9
Parasites	-	-	-	-	1	0.4	-	-	1	0.3	-	-
Phanerophytes	4	23.5	7	24.1	41	16.7	42	14.2	47	15.2	15	13.4
Therophytes	4	23.5	5	17.2	69	28.2	86	29.1	87	28.1	29	25.9
Total	17		29		245		296		310		112	

Table 4. Floristic elements of the recorded species on Sarrawat Mountains at Taif area.

Chorotype	Number	
	Actual	Relative (%)
Sudano-Zambezian	242	42.16
Saharo-Arabian	226	39.37
Mediterranean	159	27.70
Irano-Turanean	142	24.74
Tropical	62	10.81
Cosmopolitan	33	5.75
Pantropical	20	3.48
Euro-Siberian	18	3.14
Paleotropical	14	2.44
Endemic	10	1.74
Neotropical	3	0.52

Table 5. Chorological analysis of the recorded species along the different elevation of Sarrawat Mountains at Taif area.

Chorotype	Elevation (m)											
	< 1000		1000-1300		1300-1600		1600-1900		1900-2200		> 2200	
	A	R	A	R	A	R	A	R	A	R	A	R
Cosmopolitan	2	12.5	2	6.9	19	7.8	23	7.8	20	6.5	6	5.4
Mono-regional	8	50.0	15	51.7	112	45.7	135	45.6	136	43.9	55	49.1
Bi-regional	3	18.8	6	20.7	71	29.0	84	28.4	98	31.6	32	28.6
Pluri-regional	4	18.8	6	20.7	42	17.1	52	17.6	48	15.5	17	15.2
Endemic	-	-	-	-	1	0.4	2	0.7	8	2.6	2	1.8
Total	17		29		245		296		310		112	

Table 6. Floristic diversity along the different elevations of Sarrawat Mountains at Taif Province.

Chorotype	Elevation (m)					
	< 1000	1000-1300	1300-1600	1600-1900	1900-2200	> 2200
Number of species	16	29	245	296	310	112
Species richness	12.4	5.7	16.9	17.1	21.8	15.4
Species turnover	1.3	5.1	14.5	17.3	14.2	7.3
Shannon index	2.5	2.8	4.8	5.0	4.9	4.2
Simpson index	9.1	10.9	82.9	90.9	75.8	41.9

Distribution of main taxa

The highest number of species (310 species) was recorded at elevation 1900-2200 m a.s.l, followed by 1600-1900 m (296 species), 1300-1600 m (245 species), while the lowest number (17 species) was recorded at elevation < 1000 m a.s.l (Appendix T1). Two species (*Argemon eochraleuca* and *Cynodon dactylon*) were exclusively recorded in all elevation levels, while four species (*Blepharis ciliaris, Acacia tortilis* subsp. *tortilis, Dodonaea angustifolia* and *Forsskaolea tenacissima*) were recorded in five elevation levels, 32 species (e.g. *Pulicaria crispa, Lavandula pubescens* and *Solanum villosum*) were recorded in four elevation levels, 83 species (e.g. *Rumex vesicarius, Fagonia Arabica* and *Plantago cylindrica*) were recorded in three elevation levels, 148 species (e.g. *Polypogon viridis, Solanum forsskalii* and *Viscum schimperi*) were recorded in two elevation levels and 304 species (e.g. *Kickxia aegyptiaca, Stipagrostis scoparia* and *Tribulus bimucronatus*) were exclusively recorded in one elevation level. Moreover, the number of families at each elevation in meters fell in the order 1900-2200 (65 species), 1600-1900 (53 species), 1300-1600 (43 species), > 2200 (42 species), 1000-1300 (19 species) and < 1000 (14 species).

Based on the floristic composition along the different elevations, the agglomerative clustering technique led to the recognition of three clusters: A) comprised > 1000 and 1000-1300 m elevation levels; B) included 1300-1600 m and 1600-1900 m levels; and C) comprised 1900-2200 m and > 2200 m a.s.l (Fig. 4).

The absolute and relative number of species of the top 10 families was presented in Table (2). Asteraceae was the most dominant family represented by 87 species (15.2% of the total species), followed by Poaceae (11.2%), Fabaceae (6.8%), Chenopodiaceae (5.6%) and Lamiaceae (5.2%). In addition, 23 families (e.g. Oxalidaceae, Loranthaceae and Oleaceae), representing 31.5% of the total families, had only one species. Asteraceae, Fabaceae, Lamiaceae, Solanaceae and Zygophyllaceae had their highest contribution (45, 26, 20, 14 and 10 species) at elevation 1900-2200 m a.sl, while Poaceae, Chenopodiaceae and Brassicaceae (43, 17 and 13 species) were dominated at elevation 1600-1900 m.

Life forms

The life form spectra of the obtained species

(Fig. 5) indicated the dominance of chamaephytes (223 species: 38.9% of total species), followed by therophytes (172 species: 30.0%), phanerophytes (73 species: 12.7%), geophytes-helophytes (64 species: 11.6%) and hemicryptophytes (37 species: 6.5%). However, hydrophytes and parasites had the lowest contribution (3 species: 0.5% and 2 species: 0.3%, respectively) to the flora of Taif area. Moreover, the highest contribution of chamaephytes, phanerophytes and therophytes (133, 47 and 87 species, respectively) was recorded at 1900-2200 m a.s.l, while the highest geophytes-helophytes and hemicryptophytes (32 and 23 species) was registered at 1600-1900 m a.s.l (**Table 3**). Meanwhile, hydrophytes (3 species) were recorded at elevations higher than 1300 m a.s.l, and 2 parasitic species were recorded on 1300-1600 m and 1900-2200 m. The lowest contribution of all life forms was recorded at elevation less than 1000 m a.s.l.

Chorological analysis

phytogeographical distribution of the rigesterd species repoeted the dominance of mono-regional taxa over the other ones (Fig. 6). Mono-regional elements were represented by 45.6% of the total species, followed by bi-regionals (30.5%), pluri-regionals (15.2%) and cosmopolitan (5.8%). However, 1.7% of the total species were endemic to Sarrawat Mountains at Taif Province. A total of 242 species (42.16% of the total species) were Sudano-Zambezian elements, while 226 species (39.37%) were Saharo-Arabians and 159 species (27.7%) were Mediterranean elements (Table 4). Neotropical elements had the lowest contribution (3 species: 0.5%).It was found that the highest contribution of cosmopolitan and pluri-regional taxa (23 and 52 species) was recorded at elevation 1600-1900 m a.s.l, while that of mono-regional, bi-regional elements and endemic elements (136, 98 and 8 species) was recorded at 1900-2200 m (Table 5). The lowest numbers of species of all chorotypes were recorded at elevations less than 1000 m a.s.l.

Economic Importance

The economic importance of the recorded species on the different elevations of Sarrawat Mountains showed that 77.7% of the total species were grazing (*Abutilon bidentatum, Asphodelus aestivus* and *Leptadenia pyrotechnica*), while 58.6% were medicinal (*Acacia asak, Astragalus tribuloides* and *Senna italic*), 38.6% used as fuel (*Acacia ehrenbergiana, Barleria bispinosa* and *Gomphocarpus fruticosus*), 33.9% had other uses (e.g. making mats, furniture, chairs and ornamental uses), and 20.8% were edible plants (Fig. 7).

Plant diversity

The measurement of species diversity of the recorded species along the altitudinal gradient of Sarrawat Mountains indicated that the highest number of species (310 species) and species richness (21.8 species stand^{-1}) was recorded at 1900-2200 m a.s.l, while the lowest number of species, turnover, Shannon index and Simpson index (16, 1.3, 2.5 and 9.1) were recorded below 1000 m (Table 6). On the other side, the highest species turnover, Shannon and Simpson indices (17.3, 5.0 and 90.9) were recorded at 1600-1900 m a.s.l.

Discussion

The recorded species on Sarrawat Mountain at Taif region (573 species) were represented by about 26.4% from total flora of the Kingdom Saudi Arabia, while their genera represent 35.3%; and their families represent 49.0% (Al-Nafie, 2004). According to Collenette (1999), these species represent 25.5% of the total flora of the Kingdom and their genera represent 35.6%; and families represent 51.4% (**Table 7**). From the floristic viewpoint, the present study is a part of Sarrawat Mountains, which are the richest flora of the Saudi Arabia. The low floristic diversity is one of the major parameters of the vegetation of Saudi Arabia. The total number of plant species recorded in the Saudi Arabia was 2172 species belong to 840 genera and 149 families, most of them were found in its south-western part, which include Sarrawat Mountains (Al-Nafie, 2004). According to Collenette (1999), the number of species increased to 2250, which belong to 835 genera and 142 families by adding subspecies, extinct and non-identified species. The number of families, species was low compared to the biggest land area in Saudi Arabia, possibly due to the harsh environmental conditions in the Arabian Desert, which cover a very large area of Saudi Arabia. The mountains of the western area of Saudi Arabia, which includes the study area, have approximately 74% of the total plant species and seem to be the greatest plant diversity of Saudi Arabia. This result may be attributed mainly to the greater rainfall in that area (Al-Nafie, 2008). Moreover, only one species (*Cheilanthes vellea*) representing 3.7% out of 27 species in the Kingdom (Collenette, 1999; Al-Nafie, 2004) of the

Table 7. Comparison between some floristic variables in the present study and the other previous studies.

Floristic Variables	Present Study	Collenette (1999)	Al-Nafei (2004)	Al-Sodany et al. (2014)	Al-Sodany et al. (2016)
Recorded species	573	2250	2172	191	55
Perennials	398	-	1398	135	41
Annuals	175	-	774	54	14
Families	73	142	149	56	27
Genera	297	835	840	145	48
Asteraceae	15.2	9.9	10.7	14.7	7.3
Poaceae%	11.2	11.6	12.1	7.9	9.1
Fabaceae	6.8	9.4	9.7	6.3	9.1

lower vascular plants was recorded in the study area.

The main striking feature in the flora of Sarrawat Mountains at Taif region is the bigger number of genera in attribution to that of the species (1.9 species/genus), which is a very small figure relative to the global average (13.6: Good 1947), but a close figure to 1.3 recorded by Alsherif and Fadl (2016) on Al-Shafa highland at Taif area. However, the Saudi Arabian flora was represented by 2.6 species per genus (Al-Nafie, 2008) and 2.7 species per genus (Collenette, 1999), which goes above the average level of Sarrawat Mountains. In addition, the Egyptian flora was represented by 2.1 species per genus (Zohary, 1973), which is a close figure to the flora of the Kingdom. This means that the plants of the Sarawat Mountains in the Taif region are relatively more prosperous than Saudi Arabia, the plants of Egypt, where the region with a certain number of species, each belonging to a different species, is relatively more diverse than an area with the same number of species, but belongs to a few number of genera (Hawksworth, 1995; Galal et al., 2012). In addition, the high number of genera relative to species number is a widespread feature of desert flora (Al-Nafie, 2008). Furthermore, 23 families (31.5% of the total families) were represented by one species (e.g., Aloaceae, Oxalidaceae and Loranthaceae) compared to 36 families (24.2% of the total families of Saudi Arabian flora) that represented by one species (Al-Nafie, 2008). It is an indication that other species that belong to these old families have adapted and appropriate in this environment, while others could not survive and become extinct (Al-Nafie, 2008).

It is evident that the Asteraceae and Poaceae have the highest contribution, followed by Fabaceae. Similar trend were found in the flora of Saudi Arabia, where these three families had the highest species in all the plants that are Asteraceae (233 species = 10.7%), Fabaceae (210 species = 9.7%) and Poaceae (262 species = 12.1%). Similar findings were mentioned by Al-Sodany et al. (2014, 2016), Al-Zahrani (2003) and Abdel Fattah and Ali (2005) in different areas of Taif Province; Mosallam (2007) on the vegetation of sereral areas of Prince Saud Al-Faisal Wildlife Research Center at Taif, Saudi Arabia; Al-Turki (2004) on the flora of Jabal Fayfa in south western of Saudi Arabia; and El-Ghanim et al. (2010), and Al-Turki and Al-Olayan (2003) on the flora of Hail region. The present study indicated that 23 families (31.5% of the total recorded families) were represented by only one species. These results similar to that of tropical and subtropical deserts including Saudi Arabia in which the several species belong to a limited number of families; i.e, Al-Nafie (2008) recorded 1586 species, which belonged to only 23 families (15.4% of the total families). In addition, 46 families (thirty percent of the families in the country) like *Burseraceae*, *Celastraceae, Aloaceae*, and *Commelinacea*e were presented only in Sarrawat Mountains (Al-Nafie, 2004). The dominance of Asteraceae along the different elevations of Sarrawat Mounatains is coincided with Alsherif and Fadl (2016) on Al-Shafa highland. This result may be attributed to global distribution and therefore wide environmental scale and large seed dispersal capacity of Asteraceae members in most elevation belts of the study region (Jeffrey, 2007).

A series of interacting biological, environmental and historical factors governed the distribution of plant species along elevation gradients (Colwell and Lees 2000). Elevation represents a complex gradient that changes along multiple environmental variables simultaneously (Austin et al., 1996). Elevation gradients provide a diverse climate, as well as changing soil characteristics accordingly; promoting diversity of plant species (Brown, 2001; Galal 2011). The lower elevations starting at 1300-1600 m a.s.l had relatively high number of species, which increased till elevation 1900-2200 m, and then decreased at > 2200 m. These results coincided with those of Hegazy et al., 1998) and Alsherif and Fadl (2016). According to Brown (2001), the increase in the number of species in the lower altitude may be due to the fact that this increase may have a greater amount of runoff water than higher ones.

Compared with other elevated regions of Saudi Arabia, the study area was more diverse than other regions such as Al-Shafa highlands (222 species: Alsherif and Fadl, 2016); Asir Mountains (189 species: Al-Yemeni and Sher, 2010); Bisha of the Asir region (145 species: Heneidy and Bidak, 2001); and Hail (El-Ghanim et al., 2010). Plant life form spectrum is generally thought to be a genetic modification of the environment and can be considered as a recording apparatus for habitats (Bakker 1966). When relevant information is available, it can be helpful to assess the response of vegetation to changes in environmental factors (Ayyad and El-Ghareeb, 1982). In the current experiment, chamaephytes were the predominant, followed by therophytes in agreement with Al-Sodany et al. (2014, 2016) on Taif Mountains; Heneidy and Bidak (2001) in Bisha, Asir area and El-Demerdash et al. (1994) in the southern region. They concluded that the dominance of chamaephytes and therophytes over the other life forms may be imputed to hot dry climate, topographic variations and biotic influences. In addition, Zahran (1982) and Danin (1996) attributed the high number of chamaephytes to the capability of these to counter salt stress, drought, sand gathering and grazing. Moreover, the results of the current research disagree with some studies in the same area (Mosallam, 2007), which demonstrated that therophytes had the highest contribution, and this may be attributed to the different sampling as well as the loss of chamaephytes may be due to overgrazing in the study region. Furthermore, the relative decrease in annual cover was associated with an increase in permanent cover over time, indicating a reduction in the imbalance that may be attributed to the termination of stock farming (Kraaij and Milton, 2006). The overriding of chamaephytes and therophytes in the vegetation of Sarrawat Mountains also harmonizes with the spectra of the vegetation in deserts and habitats in several parts of Saudi Arabia as mentioned by other investigators (Abd-El-Ghani, 1997; Fahmy and Hassan, 2005; El-Ghanim et al. 2010). This image is also similar to that of other parts of the Middle East (Danin and Orchan, 1990; Zahran and Willis, 1992; El-Bana and Al-Mathnani, 2009). The current study revealed that therophytes, chamaephytes and phanerophytes were enhanced with elevation, meanwhile geophytes, hemicryptophytes and hydrophytes reduced at high elevations. The increase in the percentage of therophytes at high elevations was coincided with Pavón et al. (2000) and Alsherif and Fadl (2016), whilst the depressed proportion of hemicryptophytes and high phanerophytes and chamaephytes at high elevations disagree with Alsherif and Fadl (2016).

The chorological dissection of the registered species reported the predominance of the mono-regional taxa over the other chorological elements. This result disagree with Galal and Fahmy (2012) on Wadi Gimal, Egypt and Zohary (1973), who referred the ascendancy of inter-regional species over mono regional ones to the presence interzonal habitats, like anthropogenic or hydro-, halo- and psammophilous sites. The percentage of endemic species is highest in insular floras, peninsulas and mountain chains (Strid 1986). The current study recorded 10 species (9.4% of the total endemic species in the kingdom) were recorded as endemic species to Saudi Arabia compared to 3 species recorded by Alsherif and Fadl (2016) on Al-Shafa highland. Al-Nafie (2008) reported that the most of Saudi Arabia's lands does not seem to be an important centre of diversity.

It is known that endemic varieties in the interior of the country are not common, where no endemic families are registered and only nineteen species can be regarded as endemic (*Carnulaca Arabica* and *Calligonum crinitum*), which are found in Al-Ruba Al-Khali. Most of the endemic species are found on Sarrawat, Al-Hijaz and Madian Mountains as well as their surroundings in the western region of Saudi Arabia, which have 88 endemic species representing 82.2% of the total endemic species in the Kingdom (Al-Nafie, 2004). Moreover, Alfarhan (1999) identified three chorological units in Saudi Arabia as centers of endemism: Saharo-Sindian regional zone. He extended the northern boundary of Nubo-Sindian local centre of endemism towards the eastern region to cover most of western Najd plateau.

From the phytogeographical viewpoint, the present study indicated that the Sudano-Zambezian elements (42.16% of the total species) were the most dominant chorotype, followed by Saharo-Arabian elements (39.4%) and Mediterranean (27.7%). Relative to other related studies, Al-Nafie (2008) reported that 36.1% of the total Saudi Arabian species are Saharo-Arabian elements and 20.1% are Sudano-Zambezian. The borders of these two regions in Saudi Arabia are difficult to delimit, still debatable, and ill-defined. The demarcation of the border between the two regions in the southern part of the peninsula resulted in some difficulties arising from the fact that the southern parts of the Arab desert region represented hot, dry and bare deserts such as the Al-Ruba Al-Khali, as well as vegetated sand dunes of Dahna and the Great Nafud. According to Wickens (1976), the study region is primarily influenced by the Saharo-Arabian elements; while White and Leonard (1991) reported that the Sudano-Zambezian region extends into western and southern Arabia. These impacts clarified why the elevated values for monoregional, bioregional and pluriegional species were recorded by the present study for Sudano-Zambesian and Saharo-Sindian elements. Moreover, several of the Saharo-Arabian elements are derived and improved from the neighboring regions, mainly the Sudano-Zambezian region in the south, Mediterranean and Irano-Turanian regions in the north and north-west, respectively (Zohary, 1973; Anton, 1984).

Nowadays, several medicinal plants face extinction or severe genetic loss, but there are a shortage in the information in this concern. A few studies have been conducted in Sarawat Mountains, especially at Taif region, and consequently the data available on medicinal plants as an important natural resources for potential use by local inhabitants is very scarce (Al-Sodany et al., 2013). Three hundred and thirty six species (58.6% of total recorded species) were medicinal plants, 445 species (77.7%) were grazing, 119 species (20.8%) were edible by man, 221 species (38.6%) were used as fuel, and 194 species (33.9%) had other economic values. So, we could arrange their values of the recorded species descendingly as follows: grazing **>** medicinal **>** fuel **>** other uses **>** human food. Similar trend was recorded by Al-Sodany et al. (2014) and Heneidy and Bidak (2001) in Bisha, Asir region. However, Mossa et al. (1987) recorded 149 plant species as medicinal plants in the Saudi Arabia. Despite the lack of information on the many uses of natural species, many of the materials we use in our daily lives are plant products. However, many uses of many plant species are still unknown. Medical plants are the main sources of medicines and many industrial products (Heneidy and Bidak, 2004). The plant diversity of the recorded species along the elevation gradients of Sarrawat Mountains showed an increase in the species richness and number of species with increasing elevations till they reach their maximum at 1900 – 2200 m a.s.l., and then decreased. Our results are in accordance with those obtained by several investigations (Gentry and Dodson, 1987; Wolf and Flamenco-S, 2003). The high species richness between 1900 and 2200 m may be explained by the presence of a zone where the altitudinal distributions of many species overlap (Jacquemyn et al. 2005). The fluctuations demonstrated by species richness along the elevational gradient might be a response to the complexity of vegetation-environment relation (Wang et al. 2002).

CONCLUSION

The flora of Sarrawat Mountains at Taif Province was characterized with high diversity compared with the other region of Saudi Arabia as well as the global flora. Plant diversity was found to increase with elevation till reach its maximum at 1900 – 2200 m a.s.l., and then markedly decreased. Ten species, representing 9.4% of the total endemic species in Saudi Arabia, were recorded as endemic taxa. The authors have observed during their field visits the destruction of the original vegetation in some areas by natural or artificial means. Therefore, analysis of changing environmental factors affecting the distribution and growth of individual plant species and communities is therefore a necessary condition for successful management and restoration of depleted habitats in highlands of arid and semi-arid sites. This study provides the cornerstone of biodiversity and conservation of important plant areas in the Sarawat Mountains of Taif providence, Saudi Arabia.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Hatim Al-Yasi collected the field data and help in the writing of the manuscript, Saqer Alotaibi help in collecting field data and writing the manuscript, Yassin Al-Sodany collected the field data, tabulate the results, made the statistical analysis and revise the manuscript, and Tarek Galal write the manuscript and submit it for publishing.

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