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Phytogeographical Analysis of the Vegetation of Eleven Wadis in Gebel Elba, Egypt

IMAN H. AL-GOHARY[1]
Plant Taxonomy Unit Desert Research Centre, Al –Mataria, Cairo, Egypt
[1]Corresponding author's e-mail: algoharyi@yahoo.com

ABSTRACT

Multivariate analysis of floristic composition at the species level was performed on eleven wadis in Gebel Elba, S.E. Egypt. A total of 377 species, in 74 families and their distribution relationships in 35 floristic elements were subjected to numerical analysis using the un-weighted pair- group average linkage method (UPGMA). The main elements of phytochory, in species numbers, are: Saharo-Sindian 29.5%; Somalia- Masai 17.2%; Sahel 12.1% (mono-, bi-, tri- & pluri-regional). The Saharo-Sindian element of phytochory includes: 25.7%. Saharo-Arabian (SS_2); 17.4% Nubo-Sindian (SS_3) and 16.2% Sahara regional subzone (SS_1). Boreal element (Mediterranean, West Asia, Euras) is represented by only 9.9% of the taxa.

Key Words: Chorology; Gebel Elba; Phytogeographical analysis; UPGMA

INTRODUCTION

Schnell (1970-71) reviewed the development of phytogeography since Linnaeus (1737, 1745). Ahti *et al.* (1968) suggested that the majority of phytogeographical studies can be classified as belonging to one of three categories: bioclimatic, edaphic–topographic or floristic. The current tendency is towards a more multi-disciplined approach to plant distribution on a global scale by Ahti *et al*. (1968), Clayton and Hepper (1974), Croizat (1962), Léonard (1988), Walter (1964–1968), White (1965, 1976, 1983) and Zohary (1973).

White (1965) proposed a sketch map of African chorology and distinguished between six or eventually seven regions. Of these regions, the Mediterranean and the Saharo-Sindian regions are represented in Egypt. The same author in 1983 proposed a chorological classification of Africa into 18 phytochoria comprising 9 Regional Centres of Endemism, separated by six Regional Transitional Zones and three Mosaics. Three of these phytochoria, viz. Sahel regional transition zone, Sahara regional zone and Mediterranean-Sahara regional transition zone are represented in Egypt.

White's system was extended by Léonard (1988, 1989) to cover S.W. Asia. White and Léonard (1991) adopted one map of the African phytochoria and those extending to S.W. Asia with slight modification of some phytochoria.

El-Hadidi and Hosni (1996) showed that Egypt is the meeting point of floristic elements belonging to four phytogeographical regions: the African Sudano-Zembesian; the Asiatic Irano-Turanian; the Afro-Asiatic Saharo- Sindian and the Euro-Afro-Asiatic Mediterranean.

There have been few phytogeographical studies of the flora of Egypt e.g., the work of El-Hadidi and Fayed (1994, 1995), El-Hadidi and Hosni (1996), El-Hadidi *et al*. (1996), Khedr (1999) and El-Hadidi (2000).

Therefore, the present investigation of the flora of eleven wadis in Gebel Elba (Map 1) based on field work throughout the region in February 2000-2002 as well as study and revision of the collections of CAI, CAIM, CAIH abbreviations according to Holmgren *et al.* (1990), from Gebel Elba.

MATERIALS AND METHODS

In this work the phytogeographical deductions of 377 species examined from within the surveyed wadis of Gebel Elba were accuracy identified according the latter works of Boulus (1999-2005) and El-Hadidi (2000). Available information on their overall distribution was obtained from the floras of Egypt, African and neighboring regions as well as specimens from other regions of Africa, Asia and Europe kept in CAI, CAIM and CAIH.

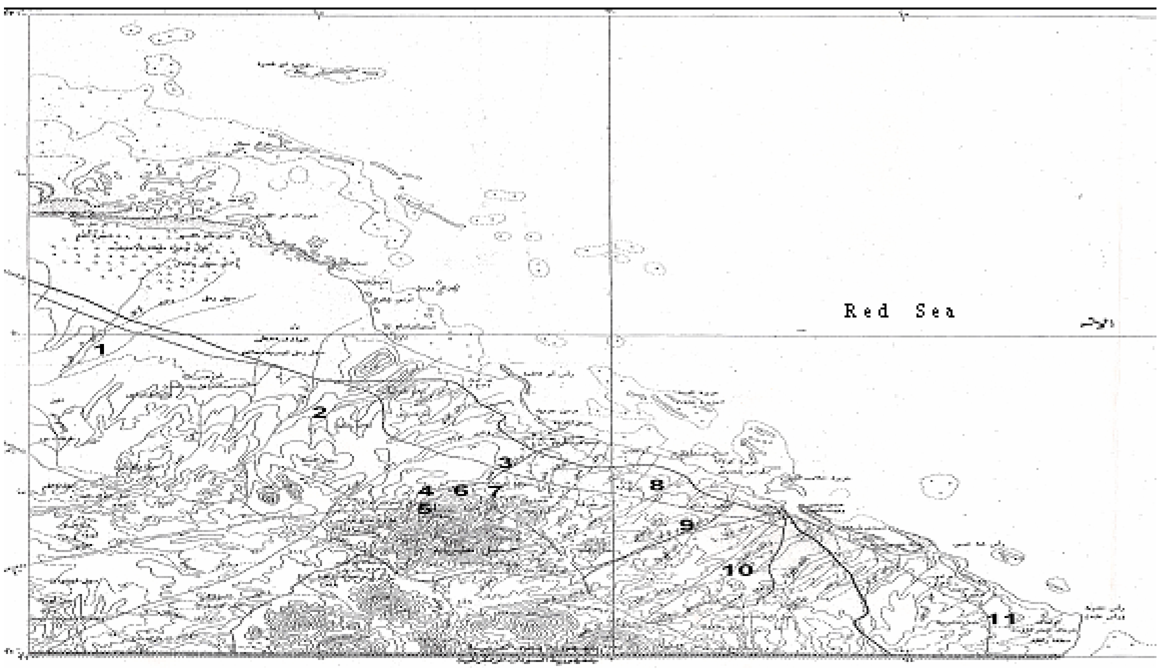
The phytogeographical treatment of the present study is in accordance with the recent map put by White and Léonard (1991), White (1993) and Friis (1998).

The phytogeographical analysis of 377 species recorded in eleven survyed wadis of Gebel Elba and their distribution relationships in 35 primary areas have been demonstrated as dendrogram by using un-weighted pair-group average linkage method (UPGMA) as a sorting strategy (Kovach, 1987). The dendrogram produced as a result of cluster analysis represent a hierarchical classification at numerically defined levels conveniently represented on the ordinate by similarity coefficient scale multiplied by 100 to give percentage values.

RESULTS AND DISCUSSION

The phytogeographical analysis of the flora of 11 wadis of Gebel Elba is given in Table I. The distribution of some

Map 1. Showing the studied wadis of Gebel Elba district



1. W. Di-ib
2. W. Bashowia
3. W. Aidieb
4. W. Yahamib
5. W. Acow
6. W. Kansisrob
7. W. Tetuila
8. W. Sarimatai
9. W. Merkwan
10. W. Shellal
11. W. Hedriba

29.5% taxa lies in the Saharo-Sindian (Afro-Indian) element (SS), 17.2% in Somalia–Masai (SM) and 12.1% Sahel (Sa). Taxa of each of these three phytochoria were mono-, bi-, tri- and pluri-regional. The analysis also reveals the presence of a strong (25.7%) affinity of Elba flora with SS_2 followed by (17.4%) affinity with SS_3; 245 and 166 species, respectively. The Sahara regional subzone (SS_1) is represented by 155 species (16.2%). Popov and Zeller (1963) noted that southern Arabia (SS_3) and Somalia–Masai (SM) have the same characteristic genera as *Commiphora*, *Boswellia*, cactiform *Euphorbia* and *Dracaena* and Sahelian species such as *Acacia tortilis* and *Salvadora persica.*

The percentage of distribution patterns of the Elba montane element was obtained from an examination of the distribution map of the floristic elements (Map 2). The distribution of 377 taxa was divided into the 35 primary areas (Fig. 1) resulting from the UPGMA analysis on the basis of similarities in their species composition and shown in Fig. 2. Four centres of origin can be identified in (Figs. 1 & 2): (i) Saharo-Sindian, (ii) Tropical East Africa, (iii) Sahelian region and (iv) Eurasia (Boreal). The Saharo- Sindian centre is clearly distinguished, with 281 taxa restricted to the primary areas as defined in Fig. 2. This phytochoria linked with Deccan region (D) at 38% similarity and with Guineo-Congo region (GC) at 28% similarity level. The common plant species distributed in these phytochoria, are: *Maytenus senegalensis Grewia tenax*, *Indigofera hochstetteri* and *Pulicaria undulata*. Zohary (1962) and Davis and Hedge (1971) reported that the Saharo-Sindian flora has been

Map 2. The percentages of migration routes of the species from the main phytochoria to Gebel Elba

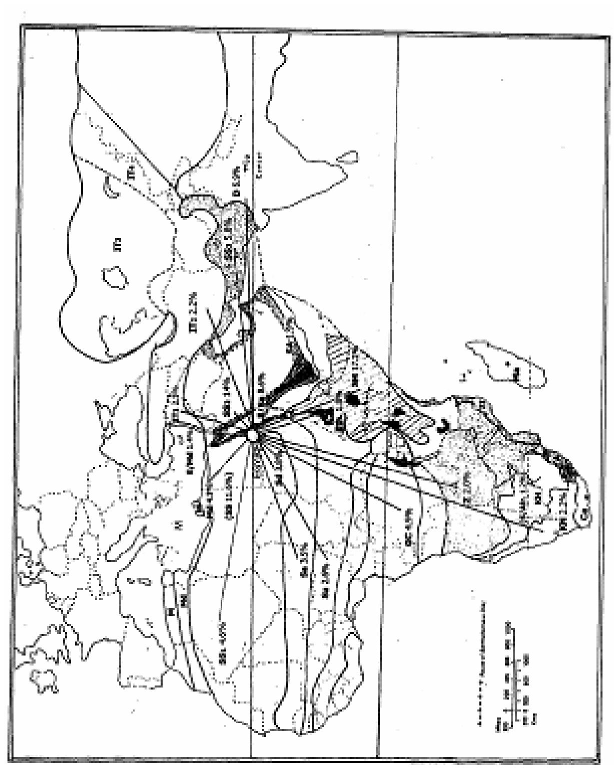


Fig. 1. Histogram showing the percentage of the species of 35 floristic elements contributed to the flora of Gebel Elba territory; for key to elements names and abbreviations see legend to Table I

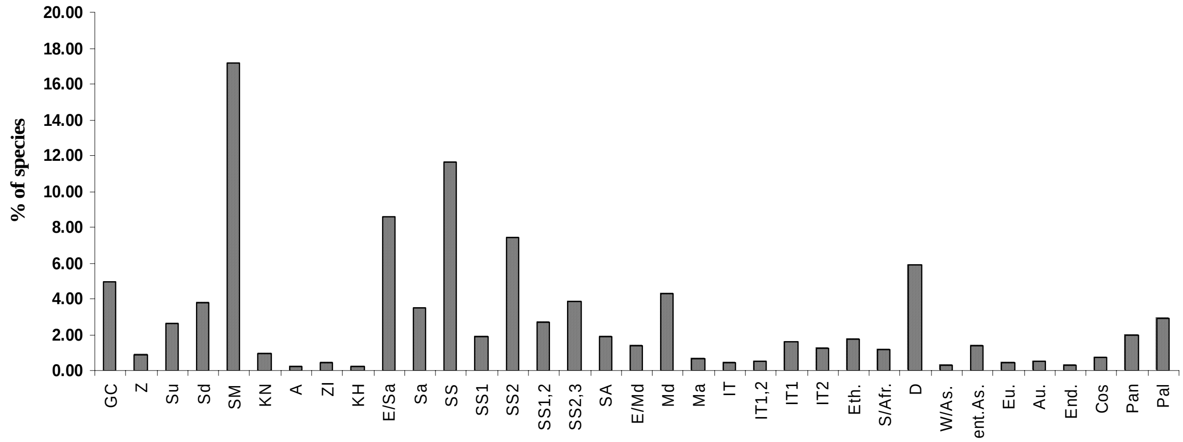
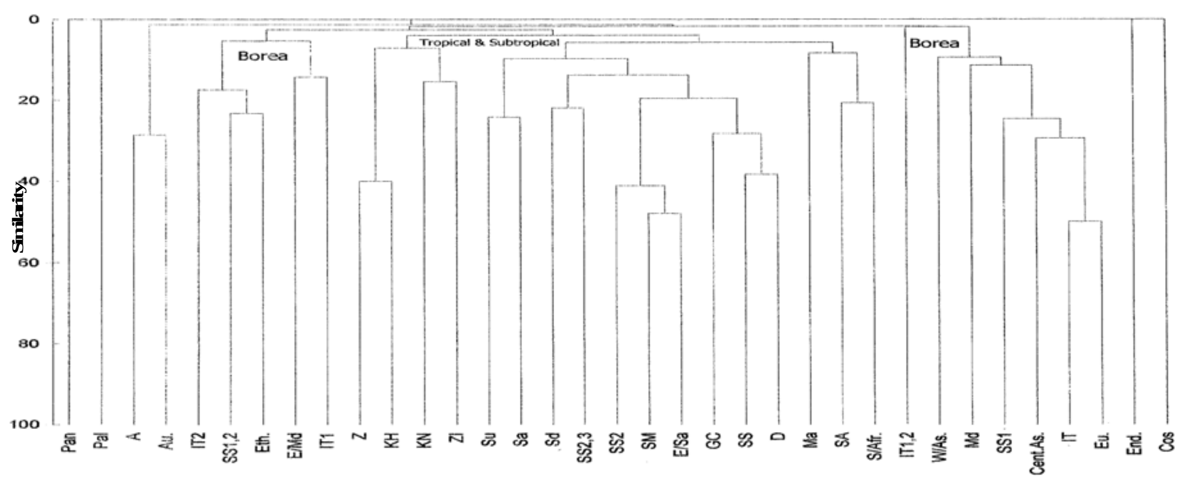


Fig. 2. Cluster analysis of the 35 primary phytogeographical areas occurring in Africa and S.W. Asia based on the degree of similarity in their species composition and using UPGMA program



derived from Mediterranean, Sudanian and to a lesser extent, Irano-Turanian stock. Quézel (1965) considered the region to be partially in Holarctic and Palaeotropic kingdoms.

In recognizing SM as a regional centre of endemism, an un-expectedly high number of taxa (166 species or 17.2%) was found in common with SS_2 and E/Sa (Fig. 2). Le Houérou (2001) showed that the equator–ward increasing importance of the tropical element that becomes dominant in the Southern Sahara and almost exclusive in Sahel. Wickens (1977) stated that Sahelian extension is similar to the SM with a number of important species in common, e.g., *Acacia nubica*, *A. senegal*, *A. seyal.*, etc.

The Sahelo-Sudanian (i.e., Paleotropical), Sa and Su showing linkage together at 25% similarity level and the common taxa distributed in these two phytochoria are: *Boscia angustifolia*, *Bidens schimperi*, *Justicia ladanoides*, *Umbilicus botryoides*, *Salsola imbricata* subsp. *gaetula*, *Solanum forsskaolii* and *S. incanum*. The deserts of South Africa are also linked in a cluster represented by Z and KH at 42% similarity level and KN with ZI at low similarity level 18%. These four phytochoria originated from Tropical Africa (Wickens, 1977) and included taxa with or more widespread distribution of SM and SS, e.g., *Lanata viburnoides*, *Ipomoea sinensis* subsp. *blepharosepala*, *Salvadora persica* and *Sporobolus spicatus*.

The Boreal element (Mediterranean- West Asia - Euras) present two distinct subgroups obtained from the dendrogram; each with extreme internal similarities. European region (Eu) and Irano-Turanian (IT) are strongly linked at similarity level of 55% i.e., the same species distributed in these two phytochoria e.g., *Lotus glaber*, *Malva parviflora*, *Galium mollugo*, *Chrozophora tinctoria*, *Geranium molle* and *Misopates orontium*. These two phytochoria with linkage Cent. As, SS_1, Md, W/As and $IT_{1,2}$, the cluster showing degradation in low similarity until it joint with the other sub- group of IT_2, $SS_{1,2}$, Eth, E/Md and IT_1. Nevertheless, Ethiopian montane elements is generally defined since its component taxa are generally widely distributed throughout the floristic elements of this sub-group (Table I).

Table I. A detailed chorological analysis of the flora of studied wadis in Gebel Elba district

Chorology	Total species	Chorology	Total species	%
Cos.			7	1.9
Pan.			18	4.8
Pal.			28	7.4
End			3	0.8
SS_1				
SS_1+E/Md+IT_2	1	SS_1+IT+Cent. As	1	
SS_1+E/Md+IT+Cent.As	1	SS_1+IT+Eu	1	
SS_1+Md	2	SS_1+W/As+Eu	1	
SS_1+Md+IT_1	1	SS_1 +Cent.As+Eu	1	
SS_1+IT_1	2	SS_1+Eth	1	
			12	3.2
$SS_{1,2}$				
$SS_{1,2}$	5	$SS_{1,2}$+$IT_{1,2}$	1	
$SS_{1,2}$+E/Md	4	$SS_{1,2}$+Eth+IT_2	2	
$SS_{1,2}$+E/Md+IT_2	1	$SS_{1,2}$+Eth.	1	
$SS_{1,2}$+IT_1	1			
			15	4.0
SS_2				
SS_2	2	SS_2+Md+IT_2	1	
SS_2+E/Md	1	SS_2+IT_1	2	
SS_2+Md	3	SS_2+$IT_{1,2}$	1	
			10	2.7
$SS_{2,3}$				
$SS_{2,3}$	1	$SS_{2,3}$+Md+D+W/As	1	
$SS_{2,3}$+Md	1	$SS_{2,3}$+Md+D+Cent.As	1	
$SS_{2,3}$+Md+D	1	$SS_{2,3}$+Cent.As	1	
			6	1.6
SS				
SS	18	SS+$IT_{1,2}$	1	
SS+E/Md	4	SS+IT_2	1	
SS+Md	4	SS+D	6	
SS+Md+Cent.As	1	SS+Eth.+D	1	
SS+Md+S/Afr.	1	SS+KN+ZI+	1	
SS+IT_1	3	SS+Cent.	2	
	3	SS+Z+KN+	1	
			47	12.5
Md				
E/Md+IT_1	2	Md+Cent.As	1	
Md	4	Md+IT+Cent.As+Eu	1	
			8	2.1
Sa				
Sa	1	E/Sa+SA+Eth.	1	
E/Sa	2	E/Sa+Md+W/AS.	1	
E/Sa+SS_2	6	Sa+SS_1	2	
E/Sa+SS_2+Eth.	4	Sa+SS	1	
E/Sa+$SS_{2,3}$	1	Sa+SS+KN	2	
E/Sa+SS	2	Sa+SS+D	1	
E/Sa+SA	2	Sa+Eth.	1	
Sd				
Sd	1	Sd +SM+SS+D	1	
Sd+SM+$SS_{1,2}$	1	Sd+SS_2	6	
Sd+SM+$SS_{1,2}$+Eth.	1	Sd+SS_2+A	1	
Sd+SM+$SS_{1,2}$+IT_1	1	Sd+SS_2+Ma	1	
Sd+SM+SS_2	4	Sd+$SS_{2,3}$	1	
Sd+SM+SS_2+IT_2	1	Sd+$SS_{2,3}$+Md	1	
Sd+SM+$SS_{2,3}$	2	Sd+$SS_{2,3}$+Eth.	1	
Sd+SM+$SS_{2,3}$+E/Md	1	Sd+SS	1	
Sd+SM+$SS_{2,3}$+Au	1	Sd+SS+E/Md	1	
Sd+SM+SS	1	Sd+SS+E/Md+Eth.	1	
Sd+SM+SS+Md	1	Sd+SS+Eth.+D	1	
Sd+SM+SS+IT_1+D	1			

Table I. Continue

Table I. Continue

Chorology	Total species	Chorology	Total species	%
			32	8.5
SM				
SM	1	SM+Sa+$SS_{2,3}$	1	
SM+ZI+E/Sa+SS_2	1	SM+Sa+$SS_{2,3}$+D	2	
SM+E/Sa	6	SM+Sa+SS	4	
SM+E/Sa+SA	6	SM+Sa+SS+$IT_{1,2}$	1	
SM+E/Sa+SA+KN	1	SM+Sa+SS+D	1	
SM+E/Sa+SA+Ma	1	SM+Sa+SA	1	
SM+E/Sa+SS_1	1	SM+$SS_{1,2}$	2	
SM+E/Sa+$SS_{1,2}$	2	SM+$SS_{1,2}$+S/Afr.	1	
SM+E/Sa+SS_2	18	SM+$SS_{1,2}$+IT_2	1	
SM+E/Sa+$SS_{2,3}$	1	SM+SS_2	4	
SM+E/Sa+KN+$SS_{2,3}$+D	2	SM+SS_2+D	1	
SM+E/Sa+$SS_{2,3}$+D	1	SM+$SS_{2,3}$	1	
SM+E/Sa+$SS_{2,3}$+D+Au	1	SM+$SS_{2,3}$+Ma+D	1	
SM+E/Sa+SS_2+S/Afr.	1	SM+$SS_{2,3}$+Md+Au	1	
SM+E/Sa+SS_2+Ma+D	1	SM+SS	7	
SM+E/Sa+SS	2	SM+SS+E/Md	1	
SM+Sa	2	SM+SS+E/M d+IT_2	1	
SM+Sa+SS_1	1	SM+SS+Md	3	
SM+Sa+$SS_{1,2}$	1	SM+SS+IT_2	2	
SM+Sa+$SS_{1,2}$+Eth.	1	SM+SS+D	4	
SM+Sa+SS_2	1	SM+Ma	1	
			93	24.7
Su				
Su+SM	2	Su+SM+SS	1	
Su+SM+E/Sa+D	1	Su+SM+SS+D	2	
Su+SM+Sa	1	Su+Sa+SS_1	1	
Su+SM+Sa+S/Afr.	1	Su+Sa+SS	1	
Su+E/Sa+SA+Eth.	1	Su+Sa+SS+D	1	
Su+E/Sa+SA+S/Afr.	1	Su+$SS_{2,3}$.	1	
Su+SM+SS_1	1	Su+$SS_{2,3}$+D	1	
Su+SM+SS_2	1	Su+SS+Md+D+Au	1	
Su+SM+$SS_{2,3}$	1			
			19	5.0
GC				
GC+Z+Su+SM+KH	1	GC+SM+SS_2	2	
GC+Z+Su+E/Sa	1	GC+SM+SS_2+D	1	
GC+Z+SM+E/Sa+SS_2	1	GC+SM+$SS_{2,3}$	1	
GC+Z+SM+SA+Ma	1	GC+SM+$SS_{2,3}$+D	2	
GC+Su	1	GC+SM+SS	3	
GC+Su+SM+$SS_{2,3}$+D	1	GC+SM+SS+Md+IT_1	1	
GC+Su+Sa +$SS_{2,3}$	1	GC+SM+SS+$IT_{1,2}$+Cent.As	1	
GC+Sd+SM+$SS_{2,3}$	1	GC+SM+SS+Cent.As	1	
GC+Sd+SM+SS+D	1	GC +SM+SS+S/Afr.+D	1	
GC+SM	3	GC+SM+SS+D	4	
GC+SM+E/Sa	1	GC+SM+SS+KN	1	
GC+SM+E/Sa +SS_2+S/Afr..	2	GC+SM+SA	1	
GC+SM+E/Sa+SS_2+D.	1	GC+SM+SA+S/Afr.	1	
GC+SM+E/Sa+$SS_{2,3}$+Cent.As	2	GC+SM+SA+Au	1	
GC+SM+E/Sa+SS+D	1	GC+E/Sa	1	
GC+SM+ E/Sa+SA+S/Afr.	1	GC+Sa+Md	1	
GC+SM+E/Sa+S/AFr.	1	GC+SS	1	
GC+SM+Sa+$SS_{2,3}$+D	1	GC+SS+D	1	
Z		Z+SM+KH+SS_2	47	12.5
Z+Su+SM+Sa+$SS_{1,2}$	1	ZI+Sa+SS	1	
Z+Sd+SM+ZI+SS_2	1		1	
Total	27	7.2	4	1.1
			377	100

Wickens (1977) stated that Ethiopian element can be identified a northerly extension along the Red Sea hills and the Yemen into the eastern Mediterranean, with one species, *Polygala abyssinica* extending to the Himalayas and it can be considered a western Mediterranean extension consisting of *Andrachne aspera, Argyrolobium arabicum, Scrophularia arguta* and *Bromus pectinatus.* These four species are also represented on Gebel Elba. The Himalayan genetic element recognized by Hedberg (1965) and represented on Gebel Elba by *Otostegia fruticosa* not by *Polygala abyssinica*. On other hand, Wickens (1977) showed that the Red Sea Hills and the Nuba Mountains were probably better afforested. The former almost certainly acted as a migration route between the Mediterranean and Ethiopia. The evidence for this stems from the distribution pattern of many Afro-montane taxa of Boreal affinity.

The number of collected plant species in the surveyed eleven wadis is 377 species of 427 taxa of the flora of this district (El-Hadidi, 2000). The phytogeographical analysis of these collected species and their distribution relationship to the Mediterranean, Saharo- Sindian, West and Central Asia, tropical and subtropical Africa reveals the SS_2, SS_3, SM and

Keys

Key to Location		**Key to Chorology**		
1. Wadi Di-ib	*End.*	*Endemic*	*SS*	*Sahara- Sindian regional zone*
2. Wadi Bashowia	*Cos.*	*Cosmopolitan*	*SS_1*	*Sahara regional subzone*
3. Wadi Aidieb	*Pan.*	*Pantropical*	*SS_2*	*Arabian regional subzone*
4. Wadi Yahamib	*Pal.*	*Palaeotropical*	*SS_3*	*Nubo- sindian local center of endemism*
5. Wadi Acow	*GC.*	*Guineo-Congolian regional centre of endomism*	*SA*	*South Arabian*
6. Wadi Kansisrob			*Md*	*Mediterranean – Sahara regional transitional zone*
7. Wadi Tetuila	*Z.*	*Zambeziam regional centre of endemism*	*Ma*	*Malagasy regional center of endemism*
8. Wadi Sarimatai	*Su*	*Sudanian regional centre of endemism*	*IT*	*Irano- Turanian regional centre of endemism*
9. Wadi Merkwan	*Sd*	*Sudanian domain*	*IT_1*	*Western Irano –Turanian regional subcenter*
10. Wadi Shellal	*SM*	*Somalia-Masai Regional centre of endemism*	*IT_2*	*Southern Irano- Turanian Regional subcentre*
11. Wadi Hedriba	*KN*	*Karoo- Namib regional centre of endemism*	*D*	*Deccan region*
	A	*Afromontane archipelago-like regional centre of endemism*	*Au*	*Australian region*
			Eu	*European region*
	Eth.	*Ethiopian montane*	*Cent.As*	*Centeral Asia region (meridional zone)*
	ZI	*Zanzibar – Inhambane regional mosaic*	*Prefix E /*	*Eastern*
	KH	*Kalahari- Highveld regional transition zone*	*Prefix W/*	*Western*
	Sa	*Sahel regional transition zone*	*Prefix S/*	*Southern*

Sa are well the most species represented in Elba area. The Boreal (Mediterranean & W/Asia) element itself does not represent more than 9.9% species. Both elements SS_2 (25.7%) and SS_3 (17.4%) followed by SM (17.2%) and Sa (12.1%) are the main constituents of this district vegetation. It is not, therefore a homogenous genetic unit but merely an ecological aggregation of species of different kinships and origins. The ratio of species to genera is low in the flora of Elba and there are few endemic. This is interpreted the flora of Gebel Elba was derived not developed. It can be, therefore, concluded that the Elba flora was derived and not developed. El- Hadidi (2000) showed that the species of Sa and SS_3 are well represented in Elba district and he added that species of tropical and Sudanian elements predominate the vegetation of this territory. Le Houérou (2001) reported that the equator-ward was increasingly importance of the tropical element that becomes dominant in the Southern Sahara and almost exclusive in the Sahel.

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