

An account on the eastern limits of Afro-Arabian plants in South Asia

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Abstract

A brief analysis on the distribution range of some of the species dominating in the arid and extra arid regions of North Africa and Arabian Peninsula is presented. These species are belonging to three phytogeographical categories namely: Saharo-Sindian, Sudano-Deccanian and Tropical African-Indian elements. Species included for this study are either disjunct or they have a wider distribution, some of which have even extended their presence deep into the Indian phytogeographical region. A broad floristic analysis has been carried out on individual state/regional floras outside the eastern limit of the Saharo-Sindian phytogeographical zone in India to explore the share of Afro-Arabian floristic elements. Among the two arid regions in India, where majority of Afro-Arabian plants exist, western arid land adjoining Pakistan contains the highest number of Afro-Arabian plants whereas the largest share of the flora of the semi arid land in the peninsular part of India comes from the species of the tropical and other eastern phytogeographical zones, including Indian floristic elements. Various domain names prevailing in the region and the reasons for the gradual increase of Afro-Arabian share in the Indian flora are also discussed briefly.

Keywords: Phytogeography, Saharo-Sindian, Sudano-Deccanian, Desert vegetation, West Asia, Arabian Peninsula, India

Introduction

The arid regions between North Africa and India are somewhat heterogeneous due to the presence of a variety of landscapes and chorological units, each differ from the other for its peculiarity and

composition of flora. The present-day flora of the West Asia in general and of arid regions in particular, to a certain extent, is the result of the evolutions taken place in the palaeotropical flora of ancient times. The present study examines the extent of distribution of arid species found in a

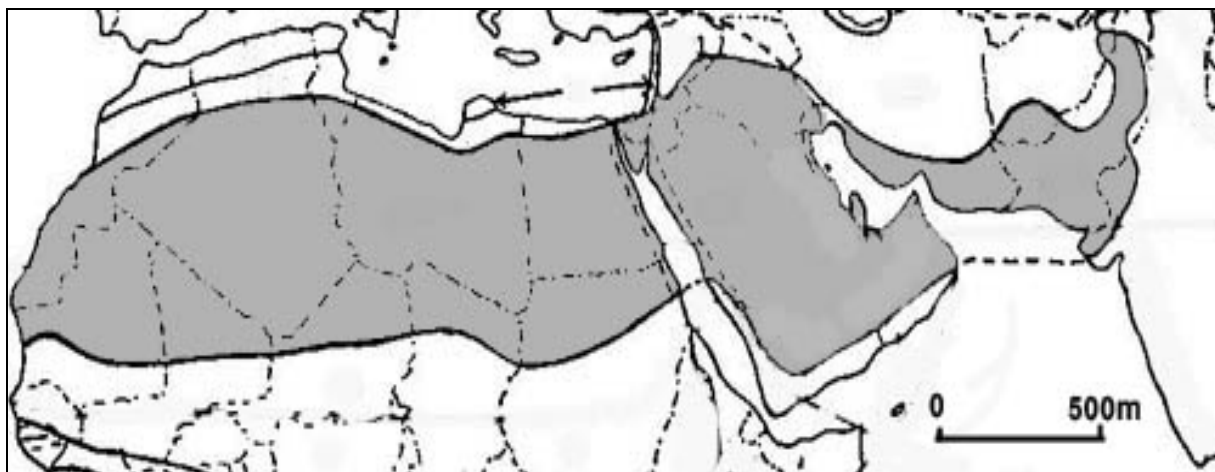
number of ecologically similar habitats that spread into a significant number of countries in the north, and north-east Africa, Arabian Peninsula, Iraq, Iran, Afghanistan, Pakistan and India. The region consists of small mountains with peaks reaching above 1000 m and low lying wadis; and from fertile lands such as the alluvial soils of estuaries and meadows, banks of Suez Canal and lowlands of Iraq to almost rainless 'sandseas' of North Africa, Arabian Peninsula and India

Species belonging to the arid parts of Africa and West Asia are distributed into 3 general categories, namely: the species of the Saharo-Sindian Zone (Eig 1931), Sudano-Deccanian zone (in a broad sense) and the species of the Tropical African-Indian category. Although there are several opinions about the phytogeographical regions of this arid land, the authors have taken some of the popular names prevailing in this region for this investigation. According to White and Leonard (1991) the Saharo-Sindian Zone consists of three sub-zones; namely the Saharan regional subzone in the west, an Arabian regional subzone in the middle and a Nubo-Sindian regional sub zone in the east. The Sudano-Deccanian zone, on the other hand, is segregated into two categories: the Somali-Mazai regional centre of endemism (the low altitude mountainous regions of North East Africa and Arabian Peninsula) and the Afro-Arabian archipelago-like regional center of endemism (regions covering the high altitude areas); and included all species that have a presence in all countries east of Arabian Peninsula to the Nubo-Sindian sub zone (White & Leonard 1991, Alfarhan 1995). Phytogeographical regions of Saharo-Sindian and Sudano-Deccanian regions are clearly demarcated in all countries in

the region except in areas from Iraq to India, where these two regions are, more or less, seen as a single entity (Arldt 1919-1922, Zohary 1973).

1. Saharo-Sindian Zone

The Saharo-Sindian Zone consists of gravel and stony open plains, hillocks, valleys (wadis), rocky and sandy deserts, salt pans (Sabkhas) and lava areas (Harrats). It covers the arid parts of the countries involved and considers one of the largest phytogeographical regions of the world with comparatively lesser number of endemics (Map 1). This vast region consists of about 1500 species of higher plants including some 100 endemic species (Boulos et al 1994). Dominant part of this zone in North Africa is the Sahara desert, which covers about 8.2 million sq. km, from the Atlantic on the West to the Red Sea on the east. Climate of this vast region varies from arid climate in the deserts to subhumid climate in the low altitude mountainous regions. The entire region, including the northeast Africa, is hot throughout the year with erratic rainfall in most of the areas except in the southern belt. In the sandy and stony deserts of North Africa and Arabian Peninsula the day temperature usually reach between 45⁰ and 50⁰ C during summer and can fall below freezing at night during winter. In the humid areas, the temperature reaches up to 32⁰ C in summer and 10⁰ C in winter. The region receives from less than 100 mm/year in some places to virtually no rainfall (Rub Al-Khali-the largest, continuous sand body in the world) for several consecutive years. Southern parts of Iraq, Iran and Afghanistan, where the vegetation is dominated by Saharo-Sindian plants, the topography is mainly of stony and sandy deserts



Map 1: Saharo-Sindian Region

with sand thickness reaching from 10 to 30 m. Sandy deserts, particularly in Iran, are discontinuous and receive less than 150 mm rain/year (Rechinger 1949, Freitag 1986). In Pakistan the Saharo-Sindian and Sudanian regions, although not separated, cover about 75% of the country's land surface. This part of the region in Pakistan experiences mild winters, erratic rainfall and prolonged hot summers (Map 2).

The arid regions in India are discontinuous and are seen as two separate blocks; one in the north-western side which is part of the Saharo-Sindian desert zone and the other in the south, comprising the plateau of Deccan and Coimbatore. These two arid zones are demarcated by a chain of mountains called Satpuda Range and a fertile, Tapi basin. These arid zones are characterized by the alternation of long dry period with temperature rose up to 45⁰ C and short rainy season. Typical Saharo-Sindian region in India is spread into Rajasthan and Gujarat States (north western region). This region, generally, consists of sandy deserts with a rainfall of less than 400 mm/annum and a dry period extending for more than nine months. The other arid zone in India (outside Saharo-Sindian phytogeographical

zone), located in the rain shadow region of the south Central India, is somewhat a stony, semi arid part with temperature rising up to 38⁰ C in summer and an average precipitation of about 145 mm/annum.



Map. 2: Arid regions in India (North western arid zone is the eastern limit of Saharo-Sindian Zone)

2. Sudano-Deccanian Zone or Sudano-Rajasthanian Zone (*sensu* Meher-Homji 1965)

The Sudano-Deccanian region is a semi arid region covering the southern parts of the Saharo-Sindian Zone in North Africa, the western and southern semi arid regions of Arabian Peninsula, southern fringes of Iraq, Iran and Afghanistan, Pakistan and the Deccan Plateau in India. Saharo-Sindian and Sudano-Deccanian Regions from Iraq to India, however, are not clearly demarcated by phytogeographers due to the lack of any substantial species' associations and community formations of their own. Several phytogeographers in India too have not segregated the Sudano-Deccanian region from Saharo-Sindian because of the merging of the species' populations of these two categories and their close association with forests types and vegetation types of India (Thomas et al 2005).

The term Sudano-Deccanian was coined by Eig (1931). There are contradictory views about the name of this phytogeographical region because of the differences in the bioclimatic conditions prevailing in this region (Lavranos 1978). "North African Steppe Elements" is another name for designating the floristic elements of this region. As the components of this group consist of several vegetation types, ranging from savanna to thorn forests, the term North African steppe elements was not approved by many phytogeographers. According to Meher-Homji (1965), the climates of Sub-Saharan Africa to Rajasthan desert and further to Deccan region are entirely different and most of the African elements, dominating in the arid parts of western India (5.4%), have not penetrated into the Deccan Region. He, therefore, proposed the name 'Sudano-

Rajasthanian' to symbolize this region. He also pointed out other substantial evidences to elucidate his views. The climate of various stations in the region extending from Senegambia to the regions outside Deccan shows that, the true characteristics of the climate of the Sudano-Deccanian region does not enter into Deccan Province, rather it ends in the north western arid regions of India (Meher-Homji 1983). Therefore, geographically, the northwestern region has more similarity with the Sudanese region rather than Deccan.

Observations and Analysis

Although all previous phytogeographical records show that the eastern limits of Saharo-Sindian species are found only in the arid parts of western India, some of the species of this region have managed to penetrate into the low altitude parts of Satpuda Mountains and even further towards south and east (Map 2). A significant number of species dominating in the North African countries and the Arabian Peninsula have not reached the eastern edge of the Saharo-Sindian zone (Table 1) while others have an extensive distribution, some of which have even penetrated into areas dominated by Indian elements (Takhtajan 1969). Some of the typical plants of this category that have extended their distribution into the Satpuda region (south east of Saharo-Sindian zone) are *Arnebia hispidissima*, *Citrullus colocynthis*, *Convolvulus prostratus*, *Fagonia indica*, *Salvadora persica*, *Ziziphus nummularia*, etc. A total of 11 species are recorded in this category, which is more or less equally distributed into 8 families. All plants of this group are occurring in

areas where the vegetation is dominated by *Hardwickia-Acacia-Ziziphus* communities.

In addition to the characteristic species of this region, several paleotropical elements (e.g. *Indigofera linifolia*, *Tribulus terrestris*), Sudano-Deccanian (e.g. *Dactyloctenium scindicum*, *Calotropis procera*), Tropical African-Indian

elements (e.g. *Balanites aegyptiaca*, *Capparis decidua*) can also be seen in this region either as dominant or co-dominant with typical species of Saharo-Sindian phytogeographical unit. All previous records indicated that, the highest representation of arid species is seen in the eastern edge of the Saharo-Sindian zone where the rep-

Table 1: Distribution of some of the important disjunct taxa of the Saharo-Sindian and the Sudano-Deccanian phytogeographical zones dominating in North Africa and the Arabian Peninsula

Dominant species of Afro-Arabian species	N.Africa	Arab.Pen.	Iraq	Iran	Afgha	Pakistan	India (W.Arid)	India (S.Arid)
<i>Acacia ehrenbergiana</i>	+	+	+	+		+	+	
<i>Acacia gerrardii</i>	+	+	+					
<i>Acacia senegal</i>	+						+	
<i>Acacia tortilis</i>	+	+	+	+		+	+	
<i>Aerva javanica</i>	+	+	+	+	+	+	+	
<i>Artemisia monosperma</i>	+	+	+					
<i>Artemisia sieberi</i>	+	+	+	+	+	+		
<i>Asp. Eragus africanus</i>	+	+						
<i>Blepharis ciliaris</i>	+	+	+	+		+		
<i>Capparis cartilaginea</i>	+	+	+	+	+	+		
<i>Capparis decidua</i>	+	+	+	+	+	+	+	+
<i>Citrullus colocynthis</i>	+	+	+	+	+	+	+	+
<i>Cornulaca spp.</i>	+	+	+	+	+	+		
<i>Ficus palmata</i>	+	+	+	+	+	+		
<i>Forsskaolea tenacissima</i>	+	+	+	+	+	+		
<i>Frankenia pulverulenta</i>	+	+	+	+	+	+		
<i>Gymnocarpus decander</i>	+	+	+	+		+		
<i>Halocnemum strobilaceum</i>	+	+	+	+				
<i>Halothamnus bottae</i>	+	+	+	+		+		
<i>Haloxyton persicum</i>	+	+	+	+	+	+		
<i>Haloxyton salicornicum</i>	+	+	+	+	+	+	+	
<i>Indigofera spinosa</i>	+	+						
<i>Leptadenia pyrotechnica</i>	+	+	+			+	+	
<i>Lycium shawii</i>	+	+	+					
<i>Maerua carssifolia</i>	+	+	+	+		+		
<i>Maerua oblongifolia</i>	+	+	+	+		+	+	
<i>Moltkiopsis ciliata</i>	+	+	+	+				
<i>Nitraria retusa</i>	+	+	+					
<i>Nurada procumbens</i>	+	+	+	+	+	+	+	
<i>Ochradenus baccatus</i>	+	+	+	+	+	+		
<i>Panicum turgidum</i>	+	+	+	+	+	+	+	
<i>Pennisetum sativum</i>	+	+	+					
<i>Pergularia tomentosa</i>	+	+	+	+		+		
<i>Pulicaria crispa</i>	+	+	+	+	+	+	+	+
<i>Retama raetam</i>	+	+	+	+				
<i>Rhanterium epapposum</i>	+	+	+					
<i>Rhazya stricta</i>	+	+	+	+	+	+		
<i>Seidlitzia rosmarinus</i>	+	+	+	+				
<i>Senna italica</i>	+	+	+	+		+	+	
<i>Solanum incanum</i>	+	+	+	+		+	+	
<i>Withania somnifera</i>	+	+	+	+	+	+	+	
<i>Zilla spinosa</i>	+	+	+					
<i>Ziziphus nummularia</i>	+	+	+	+	+	+	+	

representation of Afro-Arabian species accounts for almost 50% of the total flora (Bhandari 1995). In the southern arid block, however, contains only 9.4% of the Afro-Arabian species (North-African Indian desert: 1.9%; North African steppe: 2.6%; Tropical African-Indian: 4.9%, Bharucha & Meher-Homji 1965). Analysis conducted on the floras of another two states in the south, namely, Karnataka and Tamil Nadu also contains about 2% of Saharo-Sindian elements (Legris & Meher-Homji 1968); while in Kerala (where the rainfall is more than 600 cm) the representation of Afro-Arabian elements is negligible.

The chief elements of the Sudanian region that have extended their distribution into southern parts of India are *Aerva javanica*, *Asparagus africanus*, *Calotropis procera*, *Dactyloctenium scindicum*, *Dinebra retroflexa*, *Ficus palmata*, *Octochloa compressa*, *Orthosiphon pallidus*, *Panicum antidotale*, *Solanum incanum* and *Withania somnifera*. An approximately 2.66 % of the flora is reported in areas just outside the western arid region and percentages varies from 1.5-3 % in other states in the Peninsular India.

Several species of this category, such as *Aerva javanica*, *Aristida funiculata*, *A. mutabilis*, *Calotropis procera*, *Cenchrus ciliaris*, *C. setigerus*, *Dactyloctenium scindicum*, *Eragrostis ciliaris*, *Octochloa compressa*, etc. form communities in their typical habitats in the Western Rajasthan (Western arid region). All these species or at least some of them are common on sand dunes & interdunal areas and sandy & hummocky plains over a wide area including the northern parts of Gujarat State. Towards the southern part of Gujarat and on the southern

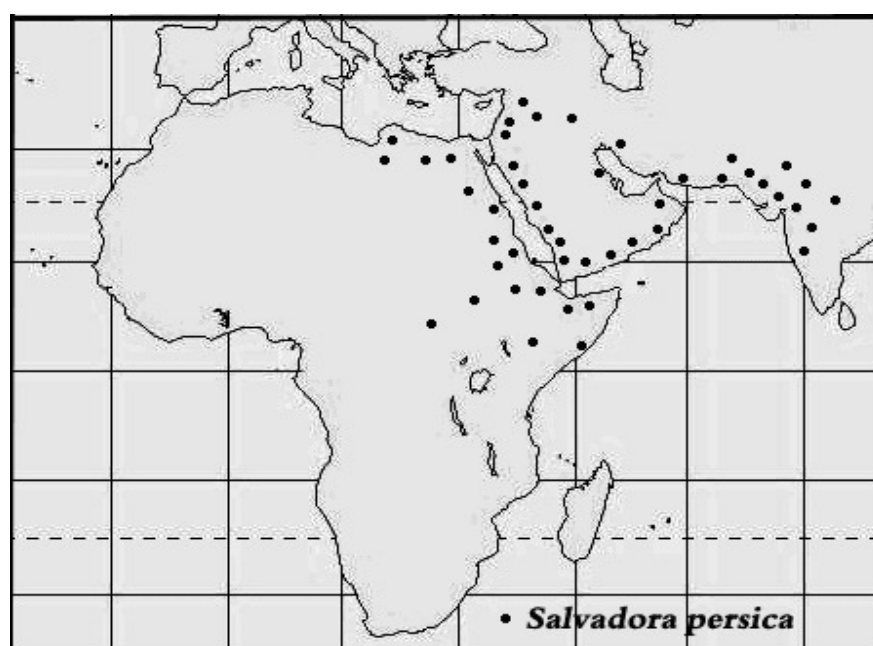
parts of the low lying areas of Satpuda region, the density of the vegetation comprising the above species gradually weakens and is represented by very thin populations. Legris & Meher-Homji (1968) reported the combined contribution of Saharo-Sindian and Sudano-Rajasthanian elements in various vegetation of India. The highest contribution is reported from their typical habitat and at the entry point, i.e. the Western India with 42% in the *Calligonum* desert community and 41% in the *Salvadora oleoides-Prosopis cineraria* thorny thicket. The representation of these elements decreases as one examines their presence towards east, north and south. 25% is reported in the *Anogeissus pendula* forest of Aravallis, 19% and 13% in the *Acacia-Capparis decidua* thorny thicket of Northern Gujarat and Deccan respectively. Eight percent of species in the dry deciduous teak forests of Madhya Pradesh is also of African elements. In the southern semi arid zone, representation of the western elements varies: less in Saharo-Sindian category (1.9%), moderate in Sudanian category (2.6%) and significant in the Tropical African-Indian Group (4.9%). In all other areas of India except the western arid region, the highest category of floral elements is that of Indian origin.

Tropical African-Indian elements are regarded as one of the ancient group of floristic elements in India. Razi (1955) considered the Tropical African-Indian elements as Palaeo-African to segregate it from the East African-Arabian-Baluchistan element (Sudano-Deccanian or Sudano-Rajasthanian in the current sense) and the Saharo-Sindian elements.

According to plant geographers, species of African origin have entered India several centuries ago, majority of which, however, do not have a continuous distribution between Africa and India (Razi 1955, Meher-Homji 1965). Variations in climate along the southern parts of Arabian Peninsula, Iraq, Iran, Pakistan and the extreme arid climate of the western Indian Region prevents majority of species to distribute their populations in an evenly manner (Kürschner 1986, Le Houèrou 2003). However, patches of areas in southern Arabia and Pakistan favour the growth of significant number species of this phytochorion. Some of the species common in these areas and also in areas east or south of the Saharo-Sindian zone are: *Kohautia aspera*, *Dicoma tomentosa*, *Grewia flavescens*, *Laggera aurita*, *Pedaliium murex*, *Enicostemma axillare*, *Grewia tenax*, *Tephrosia villosa*, *Aristolochia bracteolata*, *Kalanchoe laciniata*, *Sida ovata*, etc. Tree species are comparatively very few in this category (e.g. *Tamarindus indica*, *Lawsonia inermis*, *Balanites aegyptiaca*). Approximately

7.8% of Tropical African-Indian origin is reported in areas just south-east of the western arid zone; whereas the representation of this group in the southern arid zone is about 4.9% (Thomas et al 2005).

Although most of the species representing this category have a disjunct distribution in the Sudano-Deccanian or Nubo-Sindian region, species such as *Salvadora persica*, *Capparis decidua*, *Cyperus rubicundus*, *Dichanthium annulatum*, *Grewia villosa*, *Kohautia aspera*, *Lawsonia inermis*, *Maerua oblongifolia*, *Ricinus communis*, *Tamarindus indica*, *Tephrosia pumila*, *Trichodesma africanum*, etc have a continuous distribution throughout the region, i.e. Africa, Arabian Peninsula, West Asia, Pakistan and India (Map 3). However, within India, very few species of this category have shown continuity in their distribution; and as far as the existing floristic knowledge of the region reveals that most of the elements of the Tropical African-Indian floristic elements limit their distribution along the western arid region. The distribution of *Capparis de-*



Map 3: World distribution of *Salvadora persica* L.

cidua inside India is a typical example of a disjunct occurrence. It is a common plant of Tropical African origin, widely distributed in the tropical and northern regions of Africa, Arabian Peninsula, West Asia, Pakistan and Western India. In India, it is seen in the arid parts of Rajasthan, Northern Gujarat and the Deccan region from Khandesh to Sholapur and also in the extreme southeast corner of the Peninsula (Ramanathapuram-Tirunelveli Districts), a region that is also regarded as semi arid.

According to Blatter & Halberg (1918), the number of western elements in the desert regions of India is about 7 times more than the eastern elements (Indian & Indo-Malayan flora). The demarcation line of the western and eastern elements is thus proved to be north of Gulf of Cambay, along the Aravallis (Drude 1913, Blatter & Halberg 1918, Biswas & Sheshagiri Rao 1953). This view of the above phytogeographers was further supported by other findings which showed that the ratio of eastern and western elements is 1:3 or even less in the east Rajasthan, Delhi, Gujarat, etc. compared to the high ratio of 1:7 in the western arid region of India. Vyas (1964) is of the opinion that the transition line between Perso-Arabian and Indian or Indo-Malayan elements should be in an area where these two merge in equal proportions and therefore he proposed that the line of demarcation should be shifted further eastwards (outside western arid zone) where the western elements are no longer dominant. It is clear from the previous studies that the percentage of western elements gradually decreases from west to east or in other words, the Saharan or Arabian elements dominates in the arid parts of India while

the Indian and Indo-Malayan elements dominate in the humid regions of India.

Conclusions

Endemism is virtually nil at the Indian side of the Saharo-Sindian zone. However, in Pakistan, the areas covered by the Saharo-Sindian zone contain about 6 endemic monotypic genera; most of which are seen in the northern edge of the Saharo-Sindian region, bordering with Irano-Turanian and the Sino-Japanese phytogeographical zones (Rechinger 1949). The analysis conducted on the various state floras in India revealed that the density and frequency of Saharo-Sindian elements, although few in number, are more towards the southern states except the Western Ghats than towards east and north. It is also noticed that the representations of Tropical African elements are slightly higher compared to Saharo-Sindian and Sudano-Deccanian (Sudano-Rajasthanian, *auct* Meher-Homji 1965) elements. The percentages of Saharo-Sindian and Sudano-Deccanian elements are decreasing from the desert regions of Western India to the interior parts of the semi arid, sub humid and humid regions of India. The south eastern side of the Saharo-Sindian zone where the Satpuda Mountain is situated, only 11 and 32 species of Saharo-Sindian and Sudano-Deccanian regions respectively are present against 136 and 122 species respectively of the Indian desert region (Bhandari 1995). The presence of such elements in the interior parts of India proved that, at least some of the Saharo-Sindian and Sudano-Deccanian elements have been dispersed widely than anticipated (Table 2). The previous and current floristic accounts of the state floras also indicated that the rate of penetrations of such elements in the

past one or two decades has been dramatically increased, probably due to the climate change and subsequent increase in aridity (Thomas et al 2005) or due to anthropogenic movements as well.

Table 2: Share of western elements in India

Category	Western arid Zone	Satpuda and other adjoining regions in the E and SE parts of the Saharo-Sindian Zone	Southern arid Zone
Saharo-Sindian Zone	9.1%	0.89%	1.9%
Sudano-Deccanian	5.4%	2.66%	2.6%
Tropical African-Indian origin	4.9%	7.08%	4.9%

Citrullus colocynthis, *Ziziphus nummularia*, *Salvadora persica*, *Cenchrus biflorus*, *Fagonia indica*, etc. have an extensive distribution in the arid parts of India. Western Ghats, the Deccan region, Gujarat and the tribal areas in the Western Madhya Pradesh State also have a slight representation of these species; whereas *Trachyspermum ammi* and *Arnebia hispidissima* have a restricted distribution and are not extended beyond the drier parts of Gujarat and Maharashtra states. Unlike the plants of western arid parts, most of the species of Saharo-Sindian origin in southern India are in a relatively healthy condition due to better moisture.

There are various views about the migratory route of African elements into India. It is popularly believed that, the entry of African elements was happened at a time when two regions were united into a single mass or the entry into the flora of non arid regions is probably through NE

Africa, Southern Arabia, Southern part of Iran and Pakistan during the Miocene period (Razi 1955). Another possible migratory route, as suggested by Meher-Homji (1973), is that there was a constant and important horse trade between Africa, Arabia and India in the past and that during this period there has been an accidental introduction of the seeds along with fodders of several African elements into India.

Among the continuous and discontinuous taxa, the species belonging to the Saharo-Sindian and Sudano Deccanian are evenly distributed and are present in almost all countries of the region. As the name implies, the Saharo-Sindian elements are dominating in the northern parts of Africa and Arabia whereas the Sudano-Deccanian elements are restricted their distributions along the eastern African coast and the low altitude regions of western and southern Arabian Peninsula. The distribution range of these floristic elements of the above two phytogeographic regions, however, does not show any distinction as one moves eastwards, such as through Iraq, Iran, Afghanistan and Pakistan. In Iran, Pakistan and even in the western arid region, there are no clear cut differentiations between these two types of floristic elements. In India, Saharo-Sindian elements are largely restricted to the arid parts of Rajasthan and Gujarat while the Sudano-Rajasthanian elements have shown a much more wider distribution, some of which are even seen in parts of Karnataka, Tamil Nadu, Kerala and several other states in the north and east of the country (e.g. *Calotropis procera*, *Cenchrus ciliaris*, *Withania somnifera*, etc.). According to the present estimates, approximately 2.5% of genera belonging to Satpuda Mountains and Deccan region came from Africa, some of which

do not have any presence in Arabia or in any other West Asian countries. Some of the countries in the Far East Asia too have a representation of these African genera, despite the lack of any dispersal mechanisms in their disseminules. Since there is no evidence indicating the presence of any direct land connections between Africa and SE Asia or Australia, it is interesting to study the possible migratory route of these taxa from one place to another. Plant geographers have different opinions about the presence of disjunct genera in many countries. Good (1974) considered long range dispersal agents like ocean currents, winds, birds and man to be responsible for all disjunctions or because of the occurrence of a possible migratory route that existed be-

tween Africa and Australia via India, some 125-170 million years ago (Raven 1972). Another obvious explanation by Thorne (1978) for the disjunct genera in the Asian continent and India in particular is that, continuous rainforest existed between tropical Africa and India through the humid corridors of Arabia, Iran, and Pakistan and that genera became disjunct or locally extinct in certain parts are due to increasing aridity and deliberate habitat destructions.

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