ON THE FLORAL ELEMENTS OF THE SEMI-ARID ZONES OF INDIA AND THEIR ECOLOGICAL SIGNIFICANCE

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Summary

Two zones of semi-arid climate are recognized in India, one in the north contiguous with the desert of Thar, extending into Rajasthan, the Punjab and North Gujarat and the other in parts of the Deccan and Madras State in the south.

Analysis of the flora of these regions reveals that seventeen types of floral elements are represented in these semi-arid zones. The Southern zone has higher percentages of the Indian element and, to some extent, of the Indo-Malayan. On the other hand, the northern zone is richer in the North African–Indian Desert (Saharo-Sindian) element, North African Steppe element and in the Mediterranean–Oriental element. The elements of tropical and warm countries as well as the cosmopolitan element are equally frequent in both the zones. The percentage of the endemic element is very low in these regions, not exceeding 2.5%.

The pattern of distribution of these floral elements is explained on the basis of the bioclimatic conditions prevailing in the Afro-Asian continents.

Finally, it is shown that contrasting seasonal aspects in the annual cycle of the climate—the alternation of a very long dry period with a short rainy season and of a cool and short-day winter with a hot long-day summer—permit the development of several floral elements.

Introduction

Two zones of semi-arid climate are recognized in India (Fig. 1). One, in the north, is contiguous with the desert of Thar, extending into Rajasthan, the Punjab, parts of Uttar Pradesh, Kutch, Saurashtra (the Mountainous region of Gir excluded) and North Gujarat. The other semi-arid zone is situated in the south. It includes the Deccan plateau, the Coimbatore plateau located in the shadow of the Nilgiri and Palni hills and the extreme south-east corner of Madras State comprising Ramanathapuram and Tirunelveli districts. The semi-arid zones of north and south are separated by a narrow humid strip composed of the Satpura range and the plain of the Tapti river.

Phytogeographic terminology

In order to discuss the subject of floral elements we have to define certain phytogeographic terms. First comes the *flora:* this is the residuum of the composition of various plants which have succeeded one another in a territory. It may also be defined as a comprehensive list of plant species growing in a country.

The biggest division of the flora is the *floral empire.* Three main types are recognized: the tropical zone, the boreal cold temperate zone and the austral cold temperate zone. Further divisions of these three types into floristic kingdoms like Palaeotropis, Neotropis,

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Capensis, Holarctis. Australis and Antarctis, and their sub-divisions into sub-kingdoms and regions have been suggested (Eig, 1931).

The floral empire is far from being homogeneous from the ecological and floristic points of views and provides conditions differing both in ecology and in floral and vegetational compositions. Different parts of the floral empire of which flora and vegetation form a natural assemblage both from the floristic (heritage-of-the-past epoch) as well as from physiognomic-vegetational aspects (expression of the ecological conditions prevailing to-day) are called the *phytogeographic* or the *floral regions*. They are characterized physically by the characteristic hydrothermic (ombrothermic) diagrams, floristically by the

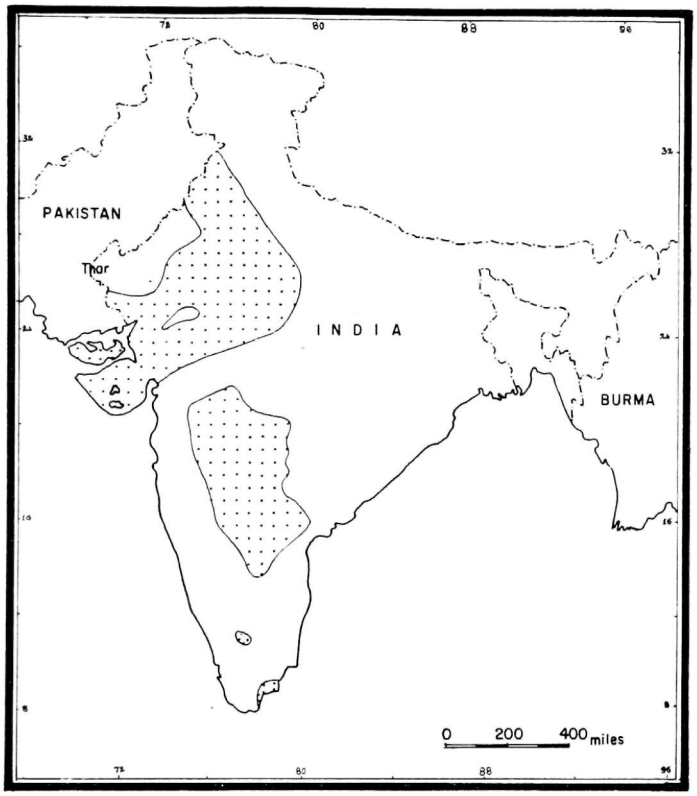


Fig. 1. Map of Indian sub-continent to show the two semi-arid regions (stippled areas) recognized.

endemics of the superior systematic orders (families and genera) and physiognomically by special climax vegetation types.

Within a phytogeographic region the *floral provinces* may be distinguished in which the generic endemism is feeble but the specific endemism is well marked. Sometimes the term 'domain' is used instead of province.

Each of the natural phytogeographic provinces possesses a more or less individual flora. Its special flora is an expression of its individuality. This characteristic flora of a given phytogeographic province constitutes the *floral element* of that particular province.

However, a phytogeographic province in addition to its special flora also contains the floral elements of other phytogeographic regions by way of *penetrations* (or irradiations). These penetrations are due to various causes. Firstly, they may be the residue of the

ancient area of the element, for some representatives of the element, succeed in conserving their place after a change in the climate has taken place. A second reason is that a natural region may possess special conditions towards its boundary. Lastly, the penetrations may depend on a particular ecological condition created by seasonal changes.

Floral elements

The data concerning the floral elements present in a given region are of considerable interest. An investigation of the origin and history of the development of a flora is based on an analysis of the area of the species of which the given flora is composed.

Wulff (1943) distinguished the division of a flora into (floral) elements on the basis of the following five principles.

Geographical elements. Species grouped on the geographical principle, according to the types of their areas, to their geographical distribution within the region whose flora is under investigation and also, where necessary, according to their altitudinal distribution.

Genetic elements. Species grouped according to their region of origin, thus reflecting the genesis of the given flora.

Migration elements. Species grouped according to the routes by which they migrated to the given floral region.

Historical elements. Species grouped according to the time when they became a part of the given flora.

Ecological elements. Species grouped according to habitat preferences.

From this it may be seen that the term 'element' includes many meanings. Some workers maintain that the term 'element' should only be applied to 'geographical element' because Christ (1867), who coined this term, used it only in a geographical sense. Others insist that the word 'element' may be used for 'genetic elements' as was done by Engler (1879, 1882). To settle this discussion a number of proposals were made to designate various categories of elements by different names. Thus Reichert (1921) proposed to designate as 'floral elements' only genetic elements; as 'components' the geographical elements, and as 'migrants' the migrational elements. Wangerin (1932) proposed the term 'areal type' to indicate geographical element. Hooker (1855) in his *Flora Indica* grouped species into types (European, Siberian, Malayan, etc.) having much the same concept as Wangerin.

Whatever their nomenclature, the geographical elements are fundamental for an understanding of the flora and an analysis of the flora should begin with this element (Wulff, 1943). Walter (1927) maintains that geographical elements constitute the only reliable basis for sub-dividing a flora into its constituent parts. The work of Eig (1931) is of particular interest in determining the floral elements of Palestine by consideration of the geographical aspect of the distribution of the species. The elements are termed as Saharo-Sindian, Sudano-Deccanian, Irano-Turanian, Mediterranean, etc., according to the area of distribution of the species. When a species is distributed over two or three regions then Eig speaks of link (liaison) elements as for example a link element of Saharo-Sindian–Sudano-Deccanian regions or a link of Saharo-Sindian–Sudano-Deccanian–Mediterranean regions. If a species is very widely distributed, covering many regions, then Eig describes the element as 'polychore' or 'pluriregional'; for example a Mediterraneo-Irano-Turanian–Saharo-Sindian–Tropical element.

For the present study of the floral elements of the semi-arid zones of India we have based our units on the geographical aspect of the distribution of the species and for this we have selected the classification of Blatter, McCann and Sabnis (1929) which is precise

and avoids cumbersome terminologies like those of Eig. Seventeen types of floral elements are recognized from the geographical distribution of the species. We now review these elements.

1. *The Endemic element* or the element restricted to the semi-arid regions.

2. *The Indian element.* Chatterjee (1939) considers as endemic all those species which are confined to the Indian sub-continent. In this work we shall consider as endemic those species which are limited to the semi-arid regions only. What has been termed endemic by Chatterjee we shall call the Indian element.

3. *The Indo-Malayan* element includes those species which are distributed over India, Malaya, and which sometimes extend as far east as Polynesia and North Australia or to South China.

4. *The North African–Indian Desert element.* The characteristic area of this element includes Sahara, Arabia (except the South), Mesopotamia, Persia and North-West India both according to Blatter *et al.* (1929) and Good (1953). This element corresponds with the 'Saharo-Sindian element' of Eig (1931).

5. *The Tropical and North African–Indian Desert element*, also known under the name of *North African Steppe element.* Eig (1931) has designated this element by the term 'Sudano-Deccanian.'

6. *The Tropical African–Indian element.* This element includes the species common to the tropical parts of the African continent and the Indian sub-continent. Razi (1955–56) terms this element as Palaeo-African to distinguish it from East African–Arabian–Baluchistan element, i.e. nos. 4 and 5 mentioned above. According to him, whereas the Palaeo-African element is the result of direct land connections between India and Africa, the entry of the East African–Arabian–Baluchistan element was made possible into the Peninsular India only during the Miocene.

The remaining elements are:

7. *The element of the tropics of the Old World*
8. *The element of the tropics*
9. *The element of the warm countries*
10. *The element of the tropical and the sub-tropical regions of the Old World*
11. *The element of the warm parts of the Old World*
12. *The element of the sub-tropical and temperate regions*
13. *The Mediterranean element*
14. *The oriental (East Mediterranean) element*
15. *The European element*
16. *The cosmopolitan ('polychore' or 'pluriregional') and sporadic element*
17. *The American element*

We may group these 17 floral elements into five main classes.

(i) *Endemic element* = (1)
(ii) *Indian element* = (2)
(iii) *Eastern element* = Indo-Malayan element (3)
(iv) *Western element* = (a) North African–Indian Desert element (4)
(b) North African steppe element (5)
(c) Tropical African–Indian element (6)
(d) Mediterranean–Oriental–European elements (13, 14, 15)
(v) *General element* = (a) Tropical element (7, 8, 17)
(b) Element of warm countries (9, 10, 11)

(c) Temperate element (12)
(d) Cosmopolitan element (16)

RELATIVE PERCENTAGES OF THE FLORAL ELEMENTS PRESENT IN THE SEMI-ARID ZONES AND THEIR ECOLOGICAL SIGNIFICANCE

The percentages of the floral elements of the Northern and the Southern semi-arid zones are presented in Table 1. They are shown in diagrammatic forms in Figs. 2 and 3. To arrive at these percentages a list was prepared of all the indigenous species and the well-established aliens of the semi-arid zones with their area of distribution (Meher-Homji, 1962).

Table 1. *Percentages of floral elements in the Northern and the Southern semi-arid zones of India*

Floral element	Northern zone		Southern zone	
	No. of species	Percentage	No. of species	Percentage
Endemic element: restricted to the semi-arid regions	23	2.3	21	1.7
Indian element	227	23.4	483	41.0
Eastern element: Indo-Malayan	109	11.2	178	15.0
Western element:				
(a) North African–Indian Desert	89	9.1	23	1.9
(b) North African steppe	53	5.4	31	2.6
(c) Tropical African–Indian	48	4.9	59	4.9
(d) Mediterranean–Oriental–European	37+18+14=69	7.1	12+3+3 = 18	1.5
Total Western element	(259)	(26.5)	(131)	(10.9)
General element:				
(a) Tropical				
Tropics of Old World and Pan tropical	198		231	
Tropical America	11		12	
Total	209	21.5	243	20.5
(b) Warm countries				
Warm countries	71		68	
Tropical and sub-tropical countries	14		16	
Warm parts of Old World	6		7	
Total	91	9.3	91	7.7
(c) Temperate element	30	3.0	16	1.3
(d) Cosmopolitan element	21	2.1	21	1.7
Total General element	(251)	(35.9)	(371)	(31.2)

Here we would like to point out that the object of the present study is to demonstrate a relationship between the bioclimates and the floral elements. All plant-geographical studies are based on statistics of distribution of genera and species and so is this study but, in the present case, added evidence is brought from modern bioclimatological studies to the statistical data. This does not mean that we are unmindful of the biotic influences on certain species. However, this aspect is beyond the scope of the present study.

Table 1 and Figs. 1 and 2 reveal that:

(i) Endemism is very low in these semi-arid zones. Only 2.3 % of the total species are endemic in the north and 1.7 % in the south.

(ii) The Indian element is as high as 41 % in the southern zone but only 23.4 % in the northern zone. From the climatic point of view it has been shown that the northern zone

is drier than the southern (Meher-Homji, 1962). The more pronounced climatic conditions of the north coupled with an equally dry sandy substratum appear to be a barrier to the Indian element.

(iii) The eastern, i.e. the Indo-Malayan, element is somewhat higher in the south (15.0%) as against 11.2% in the north. The comparatively low percentage of this element

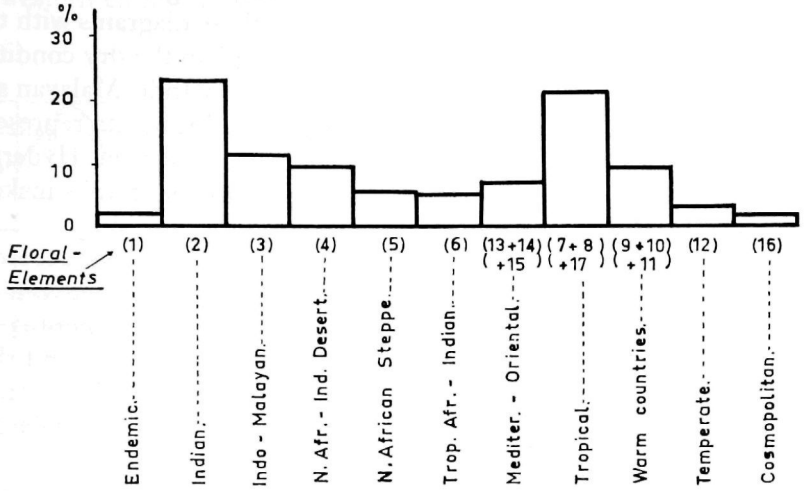


Fig. 2. Histograms of percentage contributions of the seventeen floral elements to the northern semi-arid region.

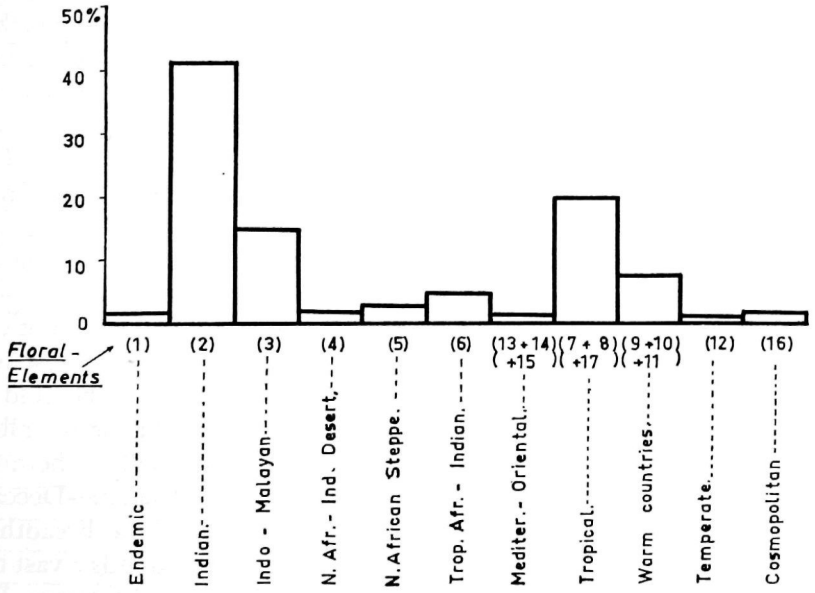


Fig. 3. Histograms of percentage contributions of the seventeen floral elements to the southern semi-arid region.

in the semi-arid regions may be explained by the fact that the Indo-Malayan species are the denizens of humid climates which cannot tolerate dry conditions. In a humid region like Bengal, the percentage of this element is as high as 53% (Agharkar and Ghose, 1931). It becomes extremely low for the Indus Delta (Sind) and for the Thar (Indian) Desert ranging from 5.7 to 6.1% (Blatter and Hallberg, 1918; Blatter *et al.*, 1929).

Santapau (1958) states that in Rajasthan the Indian and the Indo-Malayan elements occur only on the moist sites whereas the African element is dominant on dry substrata. Again Saxton and Sedgwick (1918) have shown that in North Gujarat the Perso-Arabian plants are the occupants of the sandy tract whereas the Indo-Malayan species are mainly the denizens of the more humid forest system of Malwa.

A study based on the ombrothermic* (hydrothermic) diagrams of the stations of the Indo-Malayan region (Fig. 4) and the comparison of these diagrams with those of the stations of the semi-arid regions of India, enables us to explain the dry conditions of the semi-arid regions which do not readily permit the entry of the Indo-Malayan species into these regions. Fig. 4(a, b and c) for Singapore, Rangoon and Calcutta represent stations of the Indo-Malayan region whereas Fig. 4(d, e and f) for Malegaon, Hyderabad (Dn.) and Gadag represent the semi-arid regions. Examination of these graphs makes clear the climatic differences in the two regions.

In Fig. 5 the bioclimates of the Afro-Asian Continents are shown according to the work of one of us (Meher-Homji, 1960). It shows the difference between the humid bioclimates (types 9 and 10, i.e. tropical bioclimates with 5–6 dry months or 3–4 dry months respectively) which accommodate the Indo-Malayan element, and the dry bioclimates (type 8a, i.e. tropical accentuated, 7–8 months dry, sector of poor rain, <1000 mm; and type 5, i.e. tropical sub-desert) which do not favour the Indo-Malayan element.

(iv) The strength of the Western element is 26.5 % in the northern semi-arid zone but only 10.9 % in the south. The Western element was divided by us into four fractions (p. 333) and it is desirable to consider each of these separately.

(a) The North African–Indian Desert element is 9.1 % in the north but only 1.9 % in the south. The continuity of the African–Arabian–Thar desert with the Northern zone, as also the prevalence of drier conditions in the north, account for this element being four times greater in the north than in the south. However, the size of this element is not large even for the northern semi-arid zone. We should expect a higher percentage of this element in the arid regions like the deserts. Actually in the Thar or the Indian Desert, the percentage of this element is 16.2 % (Blatter and Hallberg, 1918). In the Indus Delta (Sind) the percentage of this element is 21.7 % (Blatter *et al.*, 1929).

(b) The North African steppe element is 5.4 % in the north but only 2.6 % in the south. Thus the element is twice as common in the north than in the south.

It may be pointed out that the term 'North African *steppe* element' is not completely justifiable. Firstly, this element includes species of savannah and thorn-forest and not of a true steppe and secondly, steppe vegetation-type is an expression of the cold semi-arid climates. Trochain (1954) has proposed the term 'pseudosteppe' for the so-called steppe-like vegetation of North Africa, for true, climax steppe is restricted to chernozem soils.

As stated previously, this element is termed by Eig (1931) 'Sudano-Deccanian'. He defines the Sudano-Deccanian region as stretching throughout the breadth of Africa where, between the Sahara and the tropical forest region, there extends a vast territory of savannah and steppe which runs from Senegambia to Ethiopia and Eritraea. Beyond the Red Sea this territory continues into tropical Arabia and seems to terminate in India where certain parts, especially of the Deccan show many ecological and floristic analogies with Sudanian–Ethiopean savannahs and steppes.

However, Eig remarked that the Indian part was floristically distinct from the rest. In recent years, the question of a Sudano-Deccanian element has been considered in further detail by Gruenberg-Fertig (1954) who stressed that only a very negligible percentage of

* Ombros = rain. For details of ombrothermic diagram see Bagnouls and Meher-Homji (1959, p. 228).

the flora of Sudan and south-west Arabia occurs in the Deccan Peninsula and on this ground, she suggested the separation of the African and the Arabian parts of Eig's 'Sudano-Deccanian' region from the Deccan as an independent Sudanian region.

The Eastern limit of this Sudanian region (which comprises two sub-regions, viz. (1) West Sudanian and (2) Eritraeo-Arabian) was judged to stretch up to Baluchistan through the south-western corner of Arabia and Southern Iran (Zohary, 1962).

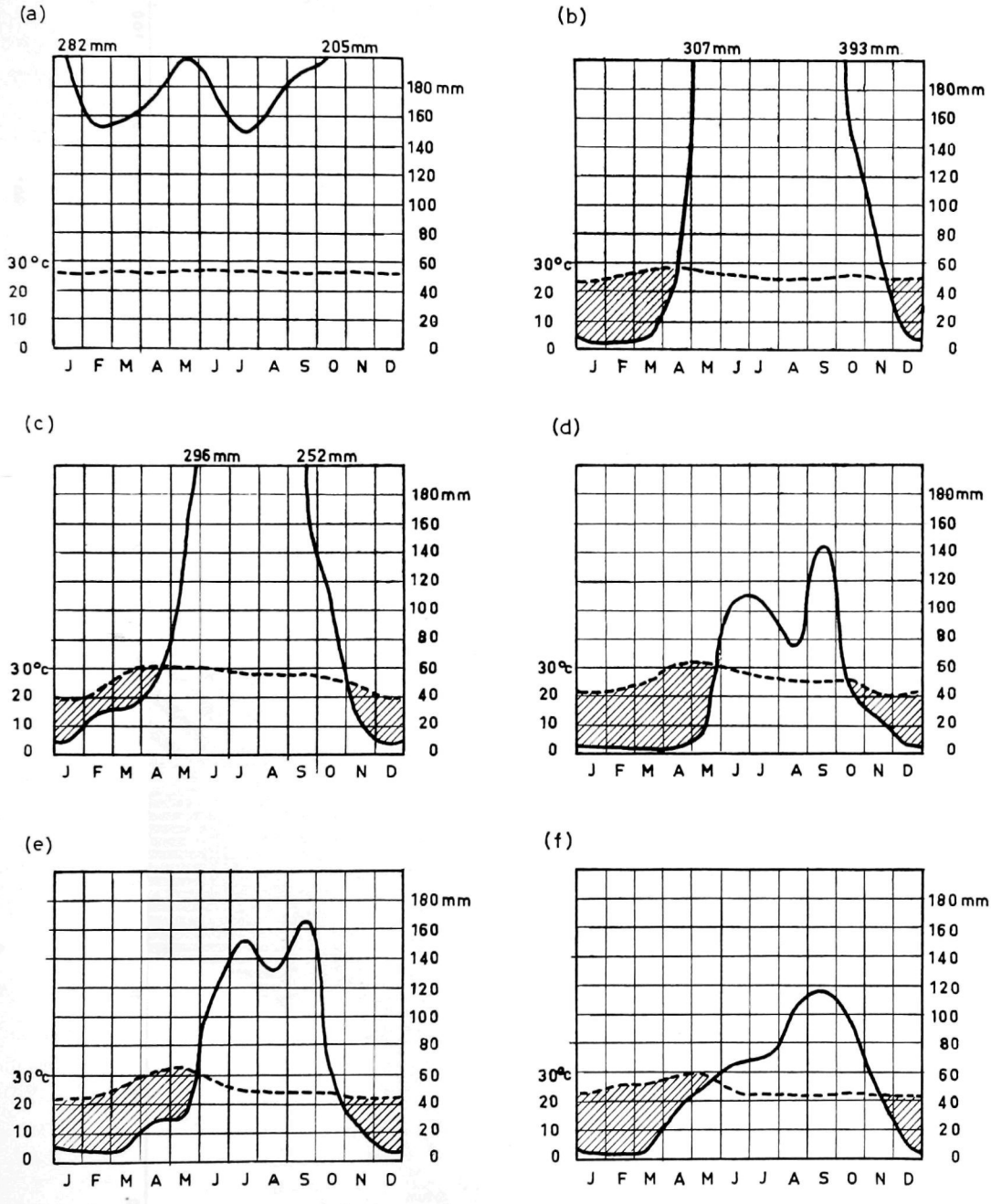
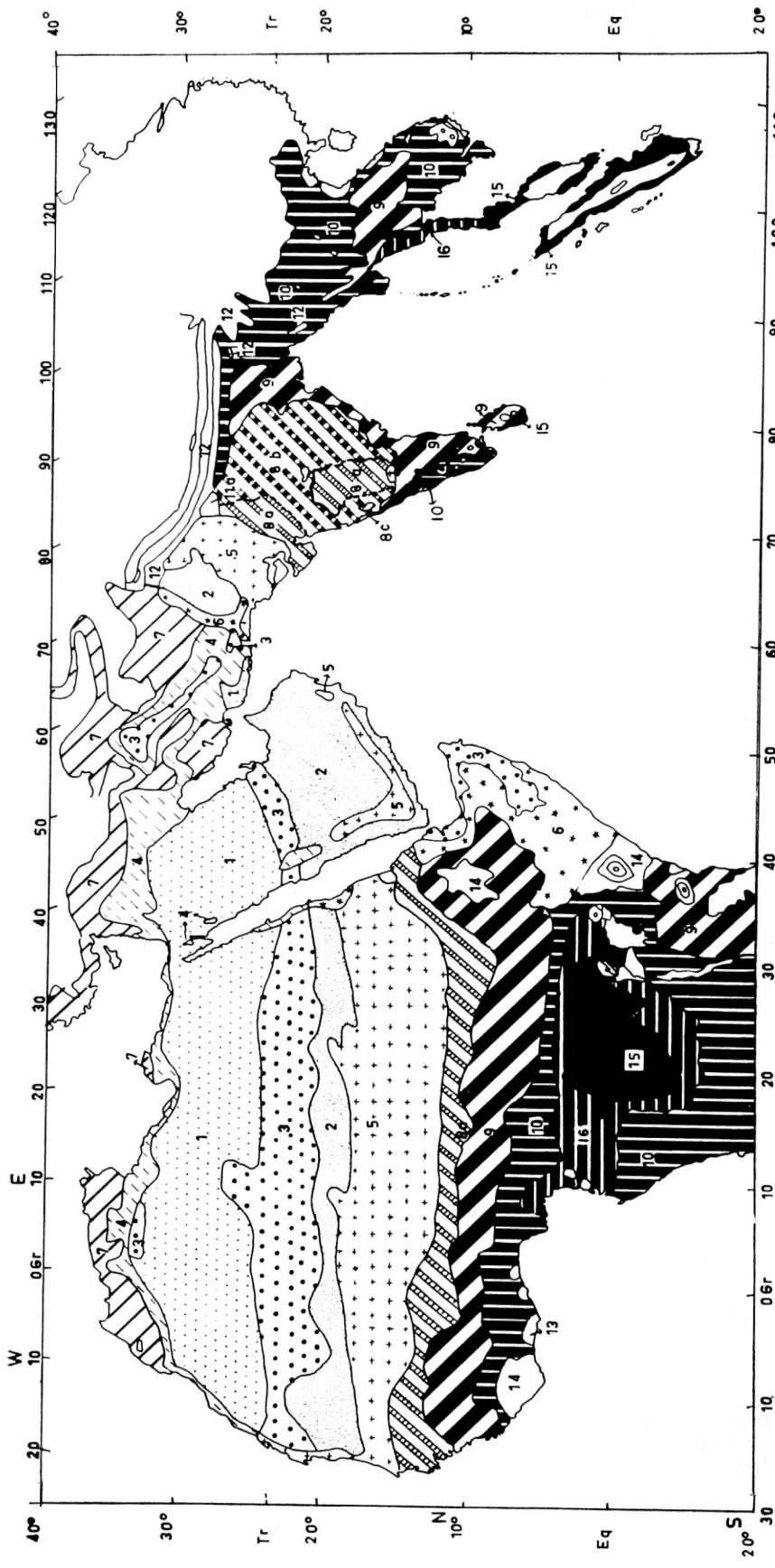


Fig. 4. Ombrothermic diagrams for typical stations of the Indo-Malayan region: (a) Singapore, (b) Rangoon, (c) Calcutta; and the semi-arid regions of India: (d) Malegaon, (e) Hyderabad, (f) Gadag. ———, Precipitation; – – – –, temperature; shaded area, dry period.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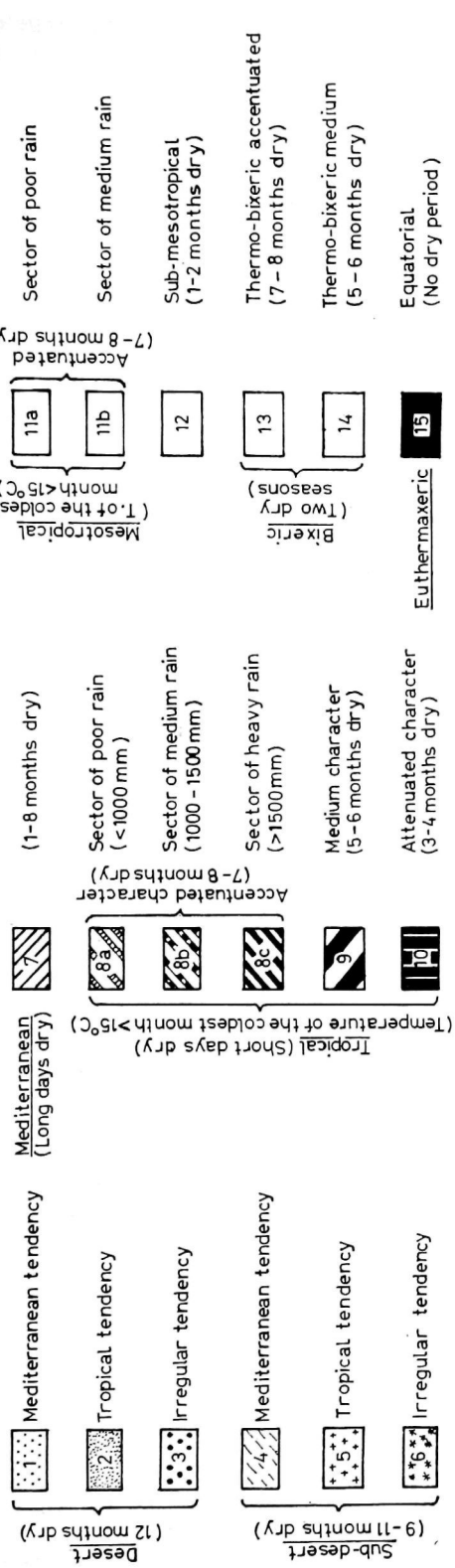

Fig. 5. Map to illustrate the bio-climates of the Afro-Asian continents (after Meher-Homji, 1963).

Our present study supports these views in that the percentage of Sudano-Deccanian element is only 2.6 % for the southern semi-arid zone including the Deccan. This element is somewhat better represented in the northern zone (5.4 %) and this may be explained by the closer analogies in the ombrothermic diagrams of the stations of the Sudanese region (Fig. 6 a–d for Néma, Timbuctoo, El Fasher and Kidal) with those of the Northern zone (Fig. 6e for Bhuj, Gujarat and Fig. 6f for Jodhpur, Rajasthan). On the other hand,

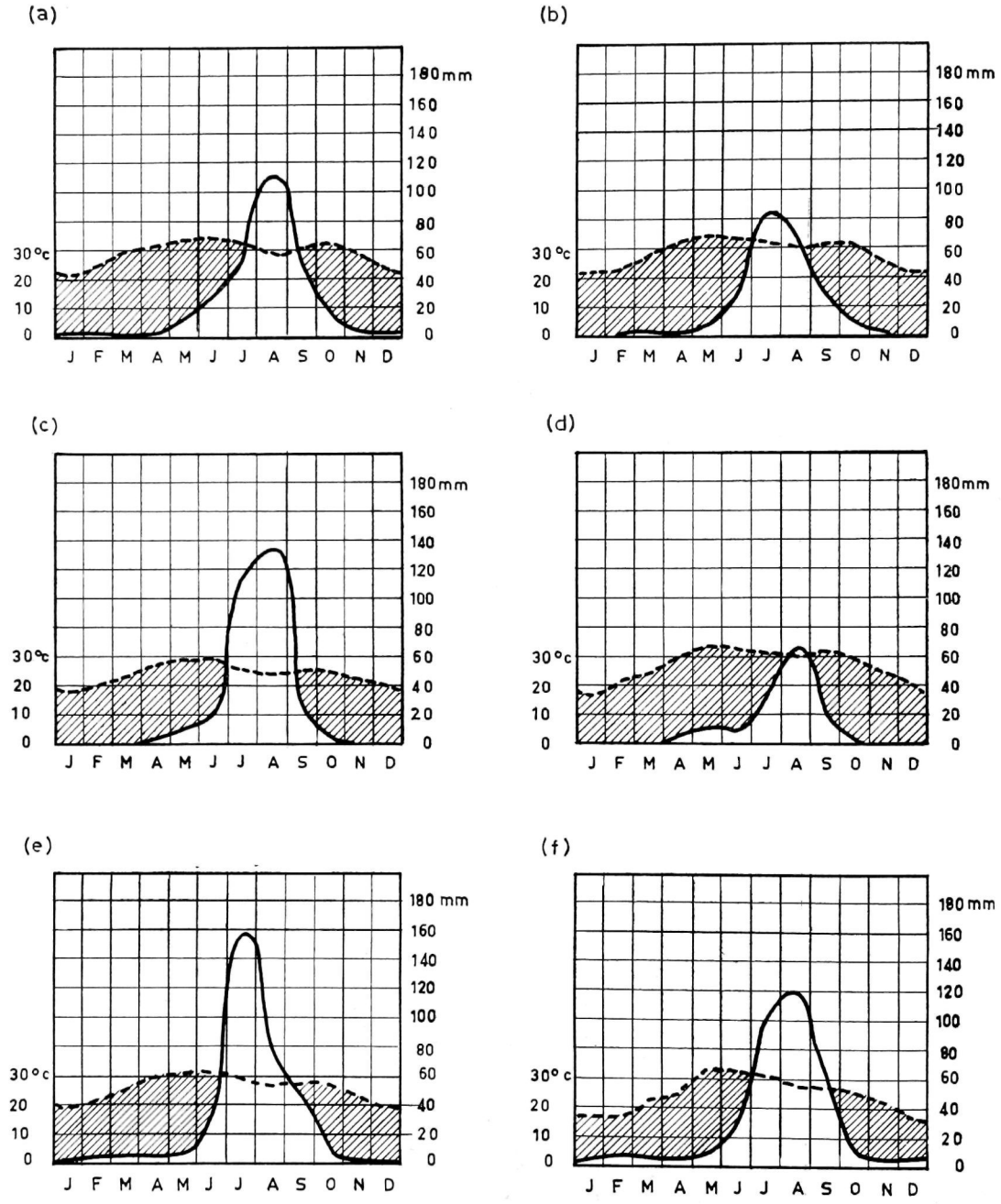

Fig. 6. Ombrothermic diagrams for typical stations of the Sudanese region: (a) Néma, (b) Timbuctoo, (c) El-Fasher, (d) Kidal; and the northern semi-arid region: (e) Bhuj, and (f) Jodhpur. ———, Precipitation; – – – –, temperature; shaded area, dry period.

the diagrams of the stations of the Deccan (Fig. 4 d–f for Malegaon, Hyderabad (Dn) and Gadag) differ from those of the Sudanese stations.

(c) The tropical African–Indian element is equal in both the northern and the southern semi-arid regions—viz. 4.9 %. This element reflects tropical conditions. It may be remembered that this element is also considered as Palaeo-African and is supposed to be the result of direct land connections between India and Africa.

(d) The Mediterranean–Oriental–European element is 7.1 % in the north but only 1.5 % in the south. The relative importance of this element in the north may be due to the vicinity of the mediterranean climate in West Pakistan (Fig. 5). The ombrothermic diagrams of Dalbandin and Quetta (Pakistan) (Fig. 7 a and b) show a dry Mediterranean type of climate with winter rains and mild temperatures during rainy months. Being in the neighbourhood of the Mediterranean region, the strength of the element is 7 % in the north.

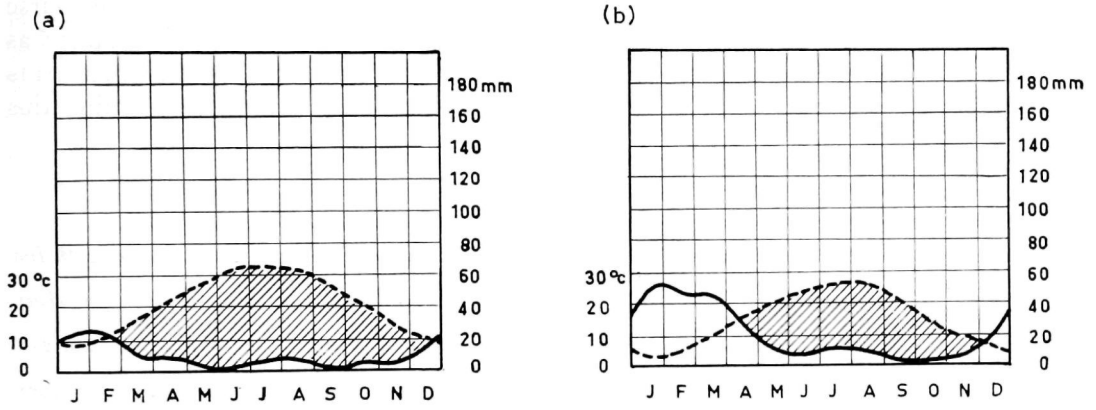

Fig. 7. Ombrothermic diagrams for (a) Dalbandin and (b) Quetta, to illustrate the dry Mediterranean type of climate. ———, Precipitation; – – – –, temperature; shaded area, dry period.

(v) The general element is 35.9 % in the northern zone and 31.2 % in the southern. The general element was further sub-divided (p. 334) and the contribution of each of these units differs. The element of the tropical countries is 21.5 % in the north and 20.5 % in the south; that of warm-countries 9.3 % in the north and 7.7 % in the south, i.e. almost equal in the two zones. The element of the temperate countries is 3.0 % in the northern zone against 1.3 % in the southern. The lower temperature of the winter months of the northern zone may be responsible for accommodating somewhat higher percentage of the temperate species.

The cosmopolitan element is 2.1 % in the north and 1.7 % in the south. These cosmopolitan species are either aquatic in nature like *Nymphaea lotus*, *Lemna gibba*, *Wolffia arrhiza*, *Sagittaria sagittifolia* and others or they are cultivated species like *Amaranthus paniculatus*, *Capsicum annuum*, *Morus alba*, *Indigofera tinctoria* and *Parkinsonia aculeata*. The wide distribution of aquatic plants is due perhaps to the fact that birds are responsible for their dispersal and also because an aquatic habitat constitutes a most homogeneous ecological medium.

Finally, it is of interest to note that so many types of floral elements are present in the semi-arid regions. The Northern zone deserves particular mention. It has a very dry type

of climate with a long dry season of 8–10 months alternating with a very short rainy period. Winters are cold especially in the Punjab and Rajasthan with the mean temperature of the coldest month, January, 13–18.8° C and with the mean of the minimum of that month 5–10.5° C. Summers, however, are very hot with the mean temperature of the hottest months, May and June, reaching 33–35.5° C and with the mean maxima at 39–41.5° C. There is also alternation in the hours of the day length during summer and winter. These seasonal changes in the climate are reflected in the overlapping of several floral elements. Dry and hot conditions favour the North African–Indian Desert (Saharo-Sindian) element and the North African steppe element. The low percentage of the Indo-Malayan element that is present seeks shelter in humid sites and develops in the rainy season. A tropical type of climate accommodates elements of tropical and warm countries but the cold winter period permits the penetration of temperate and Mediterranean–Oriental elements.

Janaki Ammal (1960) at the Symposium on 'Distribution pattern of plants in India' has pointed out the probable consequences of seasonal changes in the climate in the course of a single year on the intermingling of several floras in the northern parts of India. It was also stated that the problem of seasonal aspects and the overlapping of the floral elements had not then been examined. Our present study provides evidence concerning this problem.

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