

FLORA
OF INDIA
SERIES - 2

FLORA OF RAJASTHAN

EDITED BY

B.V. SHETTY, V. SINGH



BOTANICAL SURVEY OF INDIA

ABOUT THE BOOK

Flora of Rajasthan contains about 2000 species of vascular plants in two volumes. Besides up-to-date nomenclature, important synonyms, short diagnostic description, local names, phenological and ecological data, dichotomous keys from family to infra-specific level, the selected specimens on which descriptions are based have also been cited to indicate distribution pattern of the taxa in the state. The introductory chapters not only include important references of previous work, geological position and physiography, geology and soil types, climatic data etc., but also deal with floral composition of different habitats in various physiographic units. The cultivated species have been arranged alphabetically at the end of respective families and so also the doubtful taxa whose occurrence or identity was found doubtful.

Besides this about 20 black and white & 16 colour photographs of vegetation types along with 10 photographs of individual plants are included in this work.

The authors have studied the herbarium specimens deposited in various Indian herbaria and consulted all available literature on the vegetation of Rajasthan to bring out this comprehensive work. They would welcome any suggestions from its readers that may be valuable in the further improvement of this flora.

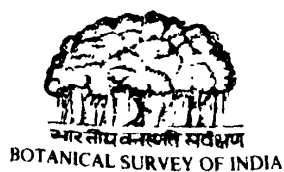
FLORA OF INDIA
Series 2
FLORA OF RAJASTHAN
Volume 1

EDITORS

B.V. SHETTY and V. SINGH

With contributions by

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FOREWORD

Botanical Survey of India has started publishing the Flora of India under four series viz. (1) National flora of India, (2) State flora/analysis, (3) District flora or flora of such other similar region and (4) Monographs and works which would not be covered under series 1-3. Flora of Rajasthan is being published under series 2.

Rajasthan is one of the large states of India, located on western border of the country. The ecological features and vegetation of Rajasthan have attracted the attention of botanists and phytogeographers and as a result a large number of scientific papers have been published during last fifty years. Recently published floras have not only enriched our knowledge on the flora and floristic composition of about seven districts of the state but also accelerated Botanical Survey of India to bring out a comprehensive flora of the state as a whole.

The Flora of Rajasthan in two volumes by Shri B.V. Shetty and Dr. V. Singh (Editors) with contributions by Dr. V. Singh, S/Shri P.J. Parmar and R.P. Pandey, is one of the pioneer comprehensive works on phytogeographically interesting region. The Flora of Rajasthan presented here gives an up-to-date knowledge on the floristic wealth of the state. The flora presents simplified dichotomous keys from family to infraspecific level, up-to-date nomenclature, short diagnostic description, phenological data, ecological notes. Local names dealt under each species have made the work further useful.

I hope, the present flora should not only serve the purpose of identification, but also should be useful for students, teachers, ecologists, agriculturists, foresters and persons concerned with the utilization and conservation of plant resources. The information will also be useful for phytogeographers, environmental biologists and those revising the National flora of India.

The editors and authors have done their best in bringing out this book at a time when interest in desert ecosystems is getting prominent attention.

Calcutta

Date 23.2.1988

M.P. NAYAR
Director
Botanical Survey of India

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The editors and authors of this flora are grateful to the Director, Botanical Survey of India, Calcutta for the encouragement and facilities provided during the course of the present study. They are also thankful to the authorities of various institutions viz. National Botanical Research Institute, Lucknow, Forest Research Institute and Colleges, Dehra Dun, St. Xaviers College, Bombay, Central National Herbarium, Calcutta, Regional offices of Botanical Survey of India located at Allahabad, Pune and Dehra Dun, and Central Arid Zone Research Institute, Jodhpur for the facilities provided to work in their herbaria.

Thanks are also extended to the Heads of Botany Departments of Rajasthan University, Jaipur, Mohanlal Sukhadia University, Udaipur, Jodhpur University, Jodhpur and Government College, Ajmer for the facilities extended to work in their herbaria.

They are highly indebted to the staff of Botanical Survey of India, Jodhpur and authorities of the Forest Department, Govt. of Rajasthan for their help in various ways in the field and laboratory.



Common land form of unestablished barren sand-dunes in the Western Rajasthan.



Partially established sand-dunes colonised by *Calotropis procera* (Ait.) Ait. f., *Capparis decidua* (Forssk.) Edgew. *Aerva javanica* (Burm. f.) Juss. ex Schult. etc. in the desert.



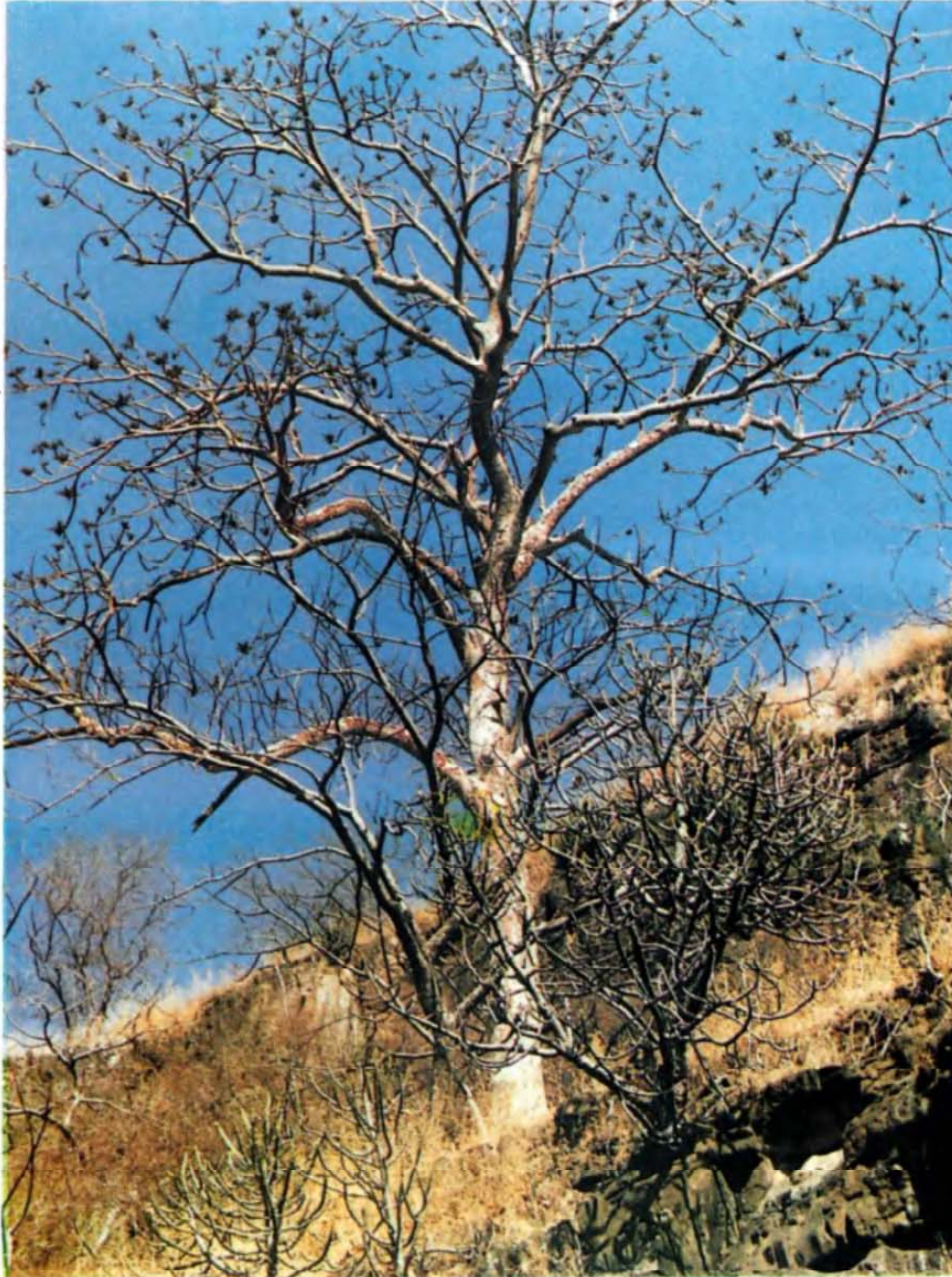
Rocky plateau dominated by *Euphorbia caducifolia* Haines, in the West of Aravalli.



Dichrostachys cinerea (L.) Wt. & Arn. - A chief component of open forest.



Gloriosa superba L. - A beautiful climber in deciduous forest.



Sterculia urens Roxb. - An associate of *Anogeissus* in deciduous forest.



Phoenix sylvestris (L.) Roxb. - forming pure stands in low sands in the east of Aravalli.



Plumbago zeylanica L. -



Maerua arenaria (DC.) Hook.f.



A view of biotic pressure on the vegetation by way of grazing.



Ranthambhor Tiger Reserve - A suitable habitat for wild-life.



A view of Ranthambhore Tiger Reserve.



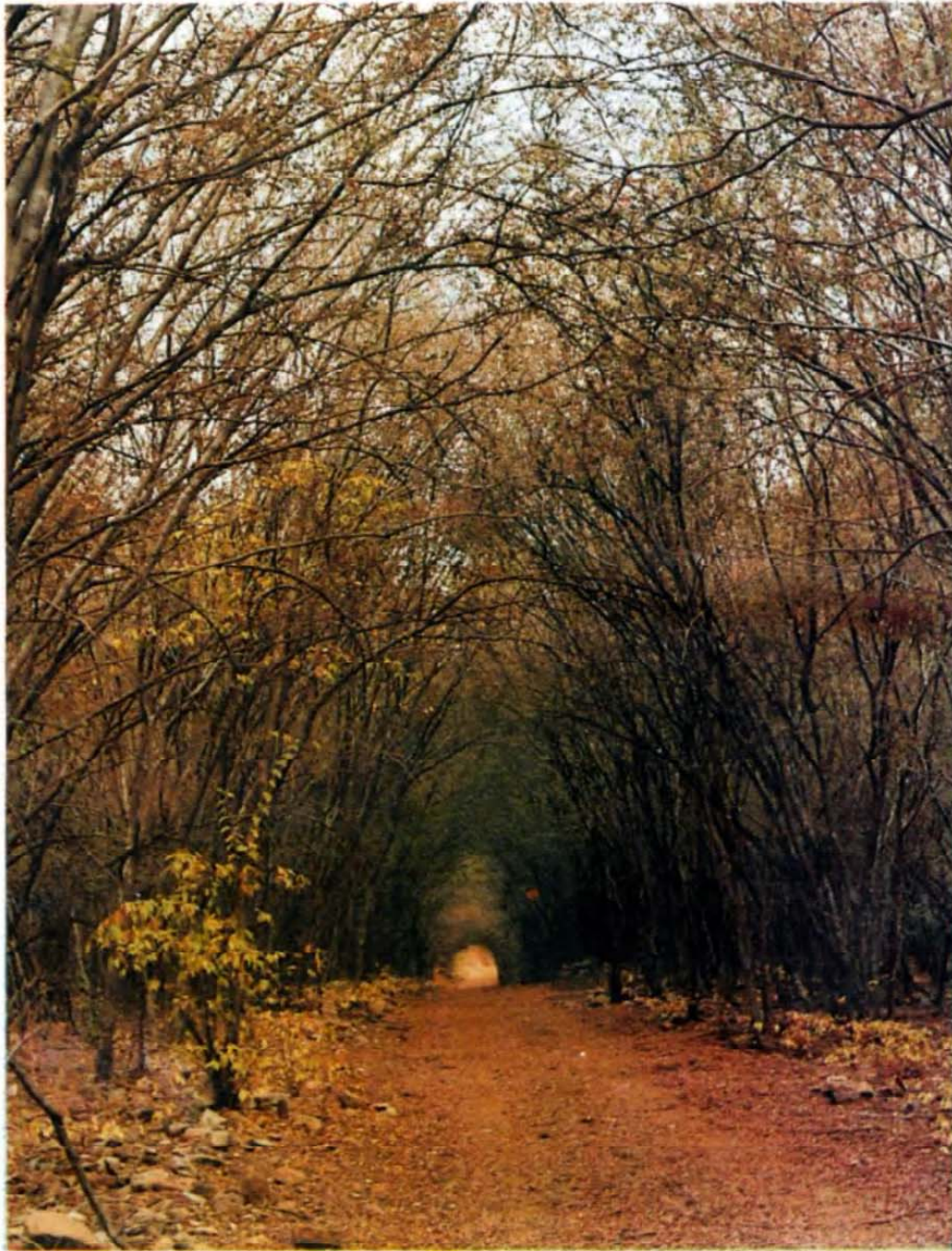
Deep gorge caused by water erosion in rocky plateau maintaining deciduous flora.



**Outskirts of forest, maintain a good pasture lands (*Aristida* spp. - in view).
in the east of Aravalli.**



A view of deciduous forest of *Anogeissus*, *Lannea* and *Boswelia* at Ranthambhore Tiger Reserve.



Dense forest at Ranthambhore Tiger Reserve.

INTRODUCTION

The state of Rajasthan, formed by the union of numerous large and small princely states, is the second largest state of India. It occupies an area of about 3,42,274 sq km i.e. nearly 11 per cent of the total area of India. It has a wide range of habitats, climatic factors, physiography, soil types and geological antiquity. Phytogeographically, the state of Rajasthan forms the eastern extremity of the great arid and semi-arid belt of the world; the great Sahara desert belt passes through the western part of Rajasthan state. The major part of eastern and south-eastern region forms the western part of the gangetic plains; the southern region forms a part of Malva plateau and south-eastern region a part of Deccan plateau.

Prior to the publication of Hooker's flora (1872-97), local floras and lists were available for several regions of India, but almost nothing was written for Rajasthan. The lacuna was, however, very amply filled during the middle part of the century and a large number of technical and semi-technical papers were published. The four floras published recently from Rajasthan have further enriched our knowledge regarding the flora and floral composition of the different regions of the state. However, a comprehensive flora of the state as a whole is not available. Therefore, the present work was undertaken to bring out a detailed flora of the state dealing mainly with the angiosperms, in two volumes.

PREVIOUS WORK AND PRESENT STUDY

The earliest recorded information on botanical explorations in Rajasthan is about Jacquemont's journey in 1832 from Delhi to Bombay via Ajmer and Neemuch. Later in 1868, Sir George King made collections in Rajasthan which resulted in his paper "Sketch of the flora of Rajputana, 1878" In the year 1869-70, Brandis botanized Rajputana forests which appeared in his "Forest Flora of N.W. & C. India, 1874" The next work on the botany of Rajputana was a report of tour by Duthie (1886). In 1890, Macadam published a list of plants from Mt. Abu. Adans (1899) in his book "The western Rajputana states" listed about 50 species of plants. Between 1918 and 1921, Blatter and Hallberg published the "Flora of the Indian

Desert" which for about 30 years remained the only authentic systematic account of the plants of Rajasthan. Parker (1918) recorded a number of plants from Jaipur and Duthie (1903-29) in his "Flora of the Upper Gangetic Plain" included the major part of eastern and south-eastern Rajasthan. Ramachandra Rao (1941) and Sankhala (1951) published lists of some plants of the desert region.

In recent years a large number of publications dealing with the flora, floral composition, ecology etc. of Rajasthan have been published. These have been reviewed by Jain (1972), Bhandari (1978), Majumdar (1979), Shetty & Pandey (1979) and Sharma (1980). The important contributions from different physiographic regions of the state are summarized below.

The aridity and other factors influencing the vegetation in the west of Aravalli have attracted the attention of the whole nation and also the UNESCO. As a result, a number of lists of plants and accounts on the vegetation of Rajasthan desert have been published during the last 35 years (Das and Sarup, 1951; Biswas, 1952; Biswas and Rolla, 1953; Sarup, 1953, 54, 57, 58a, 1958b; Joshi, 1956, 58; Nair and Nathawat, 1956; Nair & Joshi, 1957; Sarup and Vyas, 1957, 58; Tondon, 1958; Sarup & Puri, 1960; Rolla & Kanodia, 1962, 63; Kanodia & Gupta, 1969 etc.) More recently Puri *et al.* (1964), Bhandari (1978), Dawre *et al.* (1981); Pandey *et al.* (1983), Pandey & Shetty (1984), Pandey (1984), Parmar *et al.* (1985), Pandey *et al.* (1986) etc. have further contributed to our knowledge of the flora of Rajasthan desert.

Detailed ecological studies on the vegetation of Rajasthan desert have also been undertaken by a number of workers (Krishnaswamy & Gupta, 1952; Sarup & Dutta, 1954; Barucha, 1960; Verma, 1964; Sharma, 1967, 68 etc.). Air photograph analysis of plant communities in the desertic zone of Rajasthan was undertaken by Gupta & Abhichandani (1968). The influence of climate on dry zone vegetation has been studied by Waheed Khan (1959), Raheja (1965), Meher-Homji (1977) etc. Badhwar *et al.* (1948), Banerjee (1952), Nair (1954), Sen (1962), Puri & Jain (1962), Bhimaya & Kaul (1962), Bhimaya *et al.* (1964), Mulay & Joshi (1964), Verma (1965), Bora (1973), etc. have added to our knowledge on suitable species for afforestation in arid and semi-arid regions of Rajasthan.

A perusal of literature on the flora of Rajasthan revealed that Mt. Abu, the highest peak between the Nilgiris and the Himalayas, has also attracted

the attention of many botanists after Macadam's work (1890) due to its altitudinal, climatic and edaphic factors and the characteristic vegetation. The important contributions are those of Sutaria (1941), McCann (1942-43), Mahabale & Kharadi (1946), Raizada (1954), Puri & Jain (1958), Chavan & Sabnis (1960), Jain (1962, 67), Ahluwalia (1965), Kanodia & Rolla (1965), Shah & Patel (1967), Kanodia & Deshpande (1967), Gupta & Saxena (1968) etc.

After the publication of Duthie's "Flora of the Upper Gangetic Plain 1903-29", the floristic contributions from eastern Rajasthan were negligible till 1950. Since then, however, a large number of papers have been published on the vegetation of the Aravallis and the parts in the east of it. The notable contributions are those of Mulay & Ratnam (1950), Bakshi (1954), Nair & Nathawat (1956, 57), Joshi (1957, 58), Sharma (1958), Nair (1961), Nair *et al.* (1959, 61), Jain & Kotwal (1960), Sharma (1961), Vyas (1962, 64, 65, 67), Raizada & Sharma (1962), Gupta (1965), Vyas & Ramdeo (1965, 69), Majumdar (1971, 73, 79a, 79b), Maheshwari & Singh (1974, 75, 76), Singh (1975, 77, 80), Singh & Pandey (1979), Parmar & Singh (1982) etc.

The publication of the "Flora of N.E. Rajasthan" (Sharma & Tiagi, 1979), "Flora of Banswara" (Singh, 1983) and "Flora of Tonk district" (Shetty & Pandey, 1983) have further added to our knowledge of the flora and floral composition of eastern Rajasthan.

Phytogeographical studies on different physiographic regions have also received due consideration during recent years (Vyas, 1964; Sharma, 1967; Jain, 1967; Singh, 1978 etc.), as also phytosociological studies (Vyas, 1964; Bhandari & Sharma, 1977; Singh, 1978 etc.).

Some of the genera which are well represented in Rajasthan or N.W. India like *Aristida* L. (Kanodia & Nanda, 1968), *Cassia* L. (Singh, 1976), *Eragrostis* P. Beauv. (Roy, 1976), *Indigofera* L. (Nair & Koshy, 1963), *Ipomoea* L. (Johri & Sharma, 1984) have been studied in greater detail.

Since studies on ethnobotany and economic botany can play a vital role in the economic development of an area, adequate attention has also been given to these aspects with a view to focus attention on these potential resources for the benefit of the local people (King, 1969, 70; Chopra & Abrol, 1964; Singh, 1964; Bhandari, 1974; Gupta & Saxena, 1977; Roa & Shiva, 1977; Srivastava, 1977; Singh & Shetty, 1977; Singh & Pandey,

1980, 81a, 81b, 83; Singh & Parmar, 1980, 81a, 81b; Singh & Singh, 1981, 82, 83; Singh, 1983 etc.).

Thus, the perusal of literature and the examination of the specimens in the various Indian herbaria revealed that a lot of work has been done on the different aspects of the vegetation of Rajasthan, but no comprehensive flora of the state as a whole has been published so far.

GEOGRAPHICAL POSITION AND PHYSIOGRAPHY

Rajasthan is situated in the north-western part of India between 23°3' and 30°12' N. latitude and 69°30' and 78°17' E. longitude, occupying an area of about 3,42,274 sq km. The elevation of land surface varies from 214 to 1375 m. In shape, it is an irregular rhomb with north-south and east-west diagonals, the former about 784 km and the latter 850 km long. The western and north-western boundaries are marked by Pakistan. In the north and north-east, it is bounded by Punjab, Haryana and Uttar Pradesh, in the east and south-east by Madhya Pradesh and in the south-west by Gujarat states of India.

The present state of Rajasthan is the product of successive merger of nineteen princely states between 1948-1956. Rajasthan state has been divided into 27 administrative units/districts, namely Ganganagar, Bikaner, Jaisalmer, Barmer, Jodhpur, Churu, Nagaur, Pali, Jalore, Jhunjhunu, Sikar, Ajmer, Sirohi, Alwar, Bharatpur, Dholpur, Jaipur, Tonk, Sawaimadhopur, Bhilwara, Bundi, Kota, Jhalawar, Chittorgarh, Udaipur, Dungarpur and Banswara.

The remarkable feature of Rajasthan is the Aravalli range, perhaps the oldest folded mountain range in the world. It intersects Rajasthan from end to end, diagonally running from Delhi to the plains of Gujarat for a distance of about 692 km. Within Rajasthan, the range runs from Khetri in the north-east to Khed Brahma in the south-west for a length of about 550 km. The elevation of Aravalli range gradually rises in south-west direction, as it is 335 m at Delhi and in Rajasthan 792 m at Khetri, 913 m at Harshnath, 920 m at Kho, 1055 m at Raghunathgarh, 1100 m at Bijapur and 1727 m at Mt. Abu. Further south-westwards, the elevation gradually decreases to the plains in Gujarat. The loftiest and the most clearly defined section of the Aravalli is between Mt. Abu and Ajmer where the range stands like a barricade. Beyond Ajmer to the north-east, there are gaps in

the Aravalli range near Sambhar, east of Sikar etc. Structurally, it is composed of rocks belonging originally to the Delhi system, folded in a synclinalorium occupying the site of geosyncline which has been deeply eroded.

Aravalli range divides the whole of Rajasthan in to two natural divisions i.e. three fifth lying on north-west and two fifth on the east and south-east.

1. North-western Region :

This region is known as western sandy plain or the Rajasthan desert. It covers a total area of about 1,96,150 sq km spread over the districts of Ganganagar, Bikaner, Jaisalmer, Barmer, Jodhpur, Churu, and parts of Nagaur (96%), Jalore (88%), Jhunjhunu (69%), Sikar (65%), Pali (45%) and Ajmer (9%). Physiographically, it is the eastern extension of Sahara-Thar desert covered by shifting and the fixed sand deposits. The western 2/3 part extending over Bikaner, Jaisalmer, Churu, western parts of Nagaur and western 2/3 parts of Barmer and Jodhpur districts is covered by shifting and stabilised sand-dunes of various types, magnitude and orientation like longitudinal, barkhan, transverse etc. This sandy arid plain tract is also known as Marusthali. The rock outcrops are also a common feature here, particularly in Barmer-Jaisalmer-Bikaner tract where slightly elevated areas of Jurassic and Eocene rocks protrude through the sandy surface.

The eastern 1/3 part lying between sandy arid plains in the west and the Aravallis in the east is semi-arid transitional plain. Here the older rocks protrude above the surrounding sandy surface more frequently. The southern part between the foot of the Aravallis and the Luni river is fertile and known as the Luni basin. The topography is marked with hills with steep slopes and extensive alluvium plains covered with aeolian sand deposits. Gullying is also a common feature in submontane region. North of the Luni basin upto the Rajasthan border is the plain area of interior drainage. This plain is full of sand hills, sand scapes and several low depressions in which salt and soda are deposited on drying. The important salt lakes in this area are Sambhar, Degana, Kuchaman and Didwana. The Ganganagar district, further north, forms the Ghaggar plain where the Ghaggar river used to flow in the past, and now has been filled up by sand deposits forming fertile agricultural plains with few sand ridges. The advent

of Gang canal and other irrigation facilities have further intensified the reclamation process for agriculture in the Ghaggar plain.

2. Eastern Region :

The eastern plains cover the north-east, east and south-east of the main Aravalli range. The Aravalli hills spread out in the east, particularly in the north-east and south-east, in the form of outliers. Vindhyan hills also enter in the south-east and spread out west-wards. Thus, almost the entire region in the east of Aravallis presents a topography of isolated chain of hills, undulating tectonic plains and alluvium plains or agricultural plains.

The eastern part of Sirohi, the major part of Udaipur and the entire Dungarpur district fall under "Bhorat Plateau", with an average elevation of 1225 m. The highest section of Aravalli range lies north-west of Udaipur between Kumbalgarh and Gogunda. North of Bhorat plateau lies the north-eastern hilly tract where the elevation varies from 550-670 m, specially in the Alwar hills.

The eastern part of Udaipur, western Chittorgarh, Bhilwara, Tonk, Jaipur, western Sawaimadhopur and the southern part of Alwar districts constitute a gneissic plain sloping eastwards and drained by the river Banas and its tributaries like Khari, Sodra, Moshi, Morel etc. joining on the left, and Berach, Bajaan and Galwa on the right. The maximum height of Banas basin is 582 m near Deogarh. The alluvium deposits are more conspicuous in the east rather than the west where the plain is higher and more irregular.

The south eastern part of Udaipur, Banswara and southern part of Chittorgarh district are drained by Mahi and its tributaries. The land in the south is deeply and intricately dissected resulting in the formation of separate hillocks. This plain is called Chappan plain with red and black fertile soils.

The area falling between Banas and Chambal rivers is called the Vindhyan scarpland extending over Bharatpur, Dholpur and Sawaimadhopur districts at an average elevation between 350-580 m. These scarplands are formed in massive sandstones separated by shales. They are facing towards south-south-east.

The western part of Vindhyan plateau of Madhya Pradesh extends as a triple plateau of three concentric scraps formed by the outcrop of three strong sandstones with intervening shales. This physiographic unit extends

over Kota, Bundi and Jhalawar districts and is called 'Pathar' or "Deccan Lava plateau". It is a wide and stony upland. The river Chambal and its tributaries namely Kali Sindh and Parbati form a triangular alluvial basin in Kota district. Occasional tracts of black soils are also evident in river valleys.

3. Drainage :

The area in the west of Aravalli has inland drainage system with a large number of separate drainage basins like Kanti basin, Sota, Sahobi basin, Barah basin and misfit streams in Luni basin. The water in all these basins sinks into the desert tract. There is no perennial river in this physiographic unit. The only significant water course is the Luni river which originates at Ana Sagar at Ajmer and flows towards the south-west through the districts of Jodhpur, Barmer and Jalore. The river ends itself in brine near the Rann of Kutch. It is a seasonal river which receives a tributary from Pushkar valley and several hill torrents from the western slope of the Aravalli range like Lalri, Ghuhia, Bandi, Sukri, Jawai, Jojri and Sagai.

In the east of Aravalli, the river Chambal, its tributaries and riverlets form a network in the area. The Chambal originates in the Vindhya and enters Rajasthan near Kaukhera village (Chittorgarh district). Up to Kota city it passes through bare rocks and hilly tracts. Near Kota city, it enters the alluvial plains and passes through tectonic plain up to Sawaimadhopur. Ultimately Chambal joins the river Yamuna in Uttar Pradesh passing through Dholpur district.

On its way, the river Chambal receives many tributaries like Kali Sindh, Parbati, Banas, Mej, Parvan etc. These tributaries are also fed by a number of riverlets like Kali Sindh by Amjhar, Parvan by Chhapi, Dhar, Ajnar, Ghora Pachhar and Nevas, Parbati by Andheri and Koolu, Mej by Talera and Mangli. The tributary Banas originates in the catchment area lying between Kankroli and Nathdwara and flows towards east up to Mandhalgarh and then towards north-east up to Tonk. Later, it flows towards south to join Chambal. Its main feeding riverlets are Khari, Sodra, Moshi and Morel on the left bank and Berach, Najaen and Galwa on the right.

The river Ban Ganga rises in Jaipur and flows eastwards through Bharatpur and Dholpur to join Yamuna in Uttar Pradesh. Its beds are sandy

and dry up after rains. The southern part of Rajasthan has the network of Mahi and its tributaries. The river Mahi originates in Madhya Pradesh and enters Banswara district from the east. It flows in northerly, westerly and south-westerly directions in Banswara district forming a natural boundary between Banswara and Dungarpur districts. Ultimately, it falls in the Arabian Sea passing through Gujarat state. The river Mahi receives a number of tributaries on its way. Anas, originating in Madhya Pradesh and fed by Haran stream on its way, joins Mahi in Banswara district. Som river, originating in Udaipur district, joins Mahi at Baneshwar in Dungarpur district; it is fed by the stream Jhalam. A small stream originating in Chittorgarh district receives several hilly torrents on its way and joins directly Mahi in Banswara district. The stream Chap, originating in the hills north-east of Kalinjara, joins Mahi on the western border of Banswara district.

The bottom and beds of the rivers like Mahi and Chambal and most of the tributaries are stony. In the hilly tracts they form deep gorges and in tectonic and sandy or alluvial plains form ravines which are very conspicuous in Kota, Sawaimadhopur and Dholpur districts. Luxuriant vegetation can be seen on the sandy beds and where some soil accumulates in rocky habitats.

Lakes, Tanks, Ponds etc :

There are no natural fresh water lakes in Rajasthan. The only considerable basin are the salt lakes at Sambhar, Pachpadra, Lunkarnsar and Didwana. The Sambhar lake is situated about 60 km west of Jaipur on Jaipur-Jodhpur railway line at a height of about 360 m. Along the south-west and north-west of the lake, the Aravalli spurs form a natural barrier, protecting it from aeolian desert sand. It covers an area of about 234 sq km. during rainy season. During summers the area sinks to 130 sq km.

Pachpadra lake is situated about 128 km south-west of Jodhpur. It occupies an area of 83.2 sq km. The rain water leaches out the salts from the catchment area and carries them to subsoil in this depression.

About 50 km north-west of Sambhar lake is the Didwana lake. The depression is surrounded by sand hills on all sides except its western boundary. The beds of depression show the presence of black clay.

About 80 km north-east of Bikaner is located another salt depression near Lunkaransar where the salt is no longer being produced. All these depressions support several salt-loving species on the drying banks and in shallow water.

Rajasthan is well known for its artificial lakes which are the chief source of irrigation and drinking water. They are frequently cleared by way of weed removal. Very sparse vegetation, therefore, exists in such habitats. Important artificial lakes of the state are: Jaisamand, Udaisagar, Pichola Lake Fetehsagar in Udaipur district, Anasagar, Pushkar, Visalsagar and Faisagar in Ajmer district, Balsamand, Sardarsamad and Kailana in Jodhpur, Jaisamand in Alwar, Nakki talao at Mt. Abu, Gajner lake in Bikaner, Aklara Sagar and Ummed Sagar in Kota district. These lakes are of little significance from vegetation point of view. There are large numbers of tanks, ponds ditches and low lands, spread all over the state, which present variable emporia for aquatic and marshland plants.

GEOLOGY AND SOILS

GEOLOGY

In Rajasthan, the Aravalli range is considered the oldest folded range in the world which was peneplaned in Palaeozoic times and was subsequently re-uplifted in the Mesozoic era. It is composed of metamorphosed rocks of Aravalli, the Raialos and the Delhis. Banded Gneissic complex and Bundelkhand Gneiss, both pre-Aravalli formations, are concealed at great depth indicating that Aravalli and subsequent latter rock formations and structures have been built up over them.

Bundelkhand Gneiss is the oldest in India and extends from Eastern Rajasthan across Bundelkhand. This formation is mostly a normal granite in composition and varies from pink to reddish in colour, medium grained, non foliated and non porphyritic, with quartz, orthoclase and subordinate microcline and some ferro-magnesian minerals, mostly biotite. It is also traversed by veins of aplite, microgranite and quartz and dolerite dykes.

Banded Gneissic complex also belongs to pre-Aravalli rocks and in age to the Bundelkhand gneiss. It underlie the alluvial plains of Rajasthan and is best exposed in south Mewar where it has attained its great complexity with a clear erosion unconformity, accompanied by thick conglomerates

and great size of basic lava deposits. In the east of Udaipur, the gneiss is composed of biotite-schist and white or pink aplited and microgranite injected along the foliation, with intrusive bodies of all sizes of grey-foliated biotite granite. In north Mewar and plains of Ajmer, the gneisses are more heterogeneous with the rocks being dark shists and granulites, often garnetiferous, with intrusion of all sizes of dark coloured porphyritic biotite granite. In the central plains of Mewar and towards east up to Banswara occur bead gneiss in which feldspar phenocrysts are strung out along lines in the dark biotitic matrix.

In the plains along the foot hills of the Aravalli range is found another type of ancient gneiss which is composed of grey, rather fine-grained rock of granite composition and texture. The basal conglomerate of the Alwar series rests upon it.

Aravalli system :

Aravalli system has great thickness of Argillaceous rocks which have undergone metamorphic changes. The changes are clearly marked from east to west; in the east one finds shales and towards the west one passes through slates and phyllites to fine mica schists with garnet and magnetite. In some areas, alteration with acid granite has occurred resulting in the formation of composite gneisses. In south Alwar may be noted the northern exposures of the Aravallis. The beds of rocks occur as interrupted outcrop and extend south-west up to the plains of Gujarat. They also cover a large part of Mewar and Ajmer-Merwara interrupted by irregular outcrops of the pre-Aravalli gneisses. Other rocks of this system are arkose, grite and quartzites which rest upon Bundelkhand gneiss or the gneissic complex. Granitic material may also be noted with schists and gneisses. Argillaceous limestone is found near Bundi and eastern Mewar. A black massive limestone is common around Udaipur city. On the eastern side, the Aravallis are represented by brown and olive shales with ferruginous and clay concretions. On the western sides, the Aravallis are represented by slates and impure limestones frequently intruded by dolerites. Ranthambhor quartzites and sandstones occurring in Sawaimadhopur district belong to youngest part of Aravalli system.

Raialo series :

This series occurs between the Aravalli in the lower part and overlain

by the Delhi system. Generally white and crystalline limestone constitute this series. This series is found in widely separated areas such as Jodhpur, north of Udaipur, Nathdwara, Kankroli, Rajnagar etc. The famous Makrana marble which may be composed of white, coloured with pale grey, rose, pink and blue grey varieties of rocks are exposed from the sandy alluvial plains in a narrow ridge of about 80 km long near Makrana city. Near Ras, a much varied type of limestones which are coarse, white calcite marble, with diopside and white mica are exposed for about 80 km length.

Delhi system :

In eastern Rajasthan, the Purana rocks of Rajasthan have undergone more intense folding as well as greater amount of igneous intrusion. The best formations of these are developed in the main synclinorium of Ajmer Merwara and western Mewar, Alwar and Jaipur areas. In Ajmer, the synclinorium consists of two synclines with a long tongue of the pre-Aravalli gneiss between them. The north-western syncline is greatly affected by the igneous intrusions of Erinpura granite and of epidiorite. Towards south-west, beyond Ajmer, it increases to such an extent that one finds complete disappearance of sedimentary rocks in Jodhpur. The syncline becomes broader, additional folds appear and culminate in the Alwar series. Towards the south-west, the Erinpura granite increases. In the east of main synclinorium, there are several lineally arranged outliers in which only Alwar series, basement arkose grits and quartzites are present.

Malani series :

The maximum development of the Vindhyan occurred on the eastern flank of the Aravalli; while in western desertic region, it occurred in lesser form in detached outcrops. The rocks of this system are composed of a group of rhyotitic lavas including felsites. In western Rajasthan, two types of granites namely Jalor and Siwana granite are found.

Vindhyan series :

The Vindhyan system constitutes a vast sedimentary formation of sandstones, shales and limestones. They occupy two separate basins on both sides of Delhi synclinorium. The outcrop of western Rajasthan forms two areas joining near Jodhpur city. In eastern Rajasthan, the sedimentary material is deposited in a large basin extending from Karauli and Dholpur

in the north-east to Nimbahera and Suket in the south-west. The north-east and south-west outcrops are connected by narrow, disconnected patches extending from Sawaimadhapur to Bundi.

SOILS :

On the basis of their occurrence, the soils of Rajasthan may be divided into the following groups:

(a) *Desert soil* : The desert soil occupy an area from west of Aravallis up to the state's border with Pakistan in the west. This tract is covered by sand, hillocks and rock outcrops and is ill-watered and unproductive. The soils contain 90 to 95 per cent sand and 10 to 5 per cent clay, high percentage of soluble salts, high pH value, varying percentage of calcium carbonate and poor organic matter. In most of the aeolian sand, the CaO content varies from 1.0 to 1.5 per cent. In stabilised sandy areas, as near Jodhpur and Jaipur, it is noticed that CaO content decreases downwards resulting in CaCO₃ accumulation or Kankar bed formation. The Calcium content in the subsoil is nearly ten times that of the top soil. In most of desert soils nitrogen is low and this deficiency is balanced to some extent by nitrates. Thus, the phosphates and nitrates have made the desert sand fertile for agriculture.

(b) *Grey-brown desert soil* : This soil occurs in the districts of Barmer, Jalore, Jodhpur, Sirohi, Pali, Nagaur, Sikar and Jhunjhunu, all in the west of Aravallis. The soil is saline and alkaline with high pH value and high phosphate contents. They are calcareous in nature and nitrogen occurs in the form of nitrates.

(c) *Red and yellow soil* : The red and yellow soils usually occur together in the western parts of the districts of Udaipur, Bhilwara and Ajmer. They are poorer in carbonate and humus with the pH ranging from 5.5 to 8.5. These soils have good water holding capacity due to considerable percentage of silty loam and silty clay soils. In Ajmer district the sandy soil, shallow soil and dark medium heavy soil are also common.

(d) *Ferruginous red soil* : The central and southern parts of Udaipur district and the whole of Dungarpur district consist ferruginous red soil formed from ancient crystalline and metamorphic rocks. This soil has smaller content of lime, potash, iron oxide, phosphorous, nitrogen and humus.

(e) *Mixed red and black soil* : The eastern part of Udaipur, Chittorgarh, Dungarpur, Banswara and Bhilwara are covered with this soil. The pH is neutral to alkaline.

(f) *Medium black soil* : Kota, Bundi and Jhalawar districts are covered mainly with black soil and partly with heavy soil with grey brown to dark brown colour, medium heavy soil with grey brown colour and yellow and red light soils.

(g) *Alluvial soil* : Alluvial soil occupies the districts of Alwar, Bharatpur, Jaipur, Sawaimadhopur and central part of Ganganagar district. This soil is red-coloured, deficient in lime, phosphoric acid and humus. It varies from clayey to sandy loam in texture.

CLIMATE

The climate of the desertic zone in the west of Aravalli is characterised by extremes of temperature, severe drought accompanied by high wind velocity, low relative humidity, evaporation far exceeding precipitation and too scanty rainfall to support any appreciable vegetation. The climate in the east of Aravalli is almost semi-arid and comparatively milder. It supports comparatively dense, deciduous vegetation.

Temperature :

January is the coldest month in Rajasthan. The average mean temperature for this month ranges from 12°C to 17°C. At Mt. Abu, the temperature decreases to 7 to 8°C during this month. In the rear of some disturbances which traverse north India, cold waves occur and the temperature sometimes falls to 2 to 5°C below the freezing point, particularly in the north-western parts of the state. From mid February, the temperature adopts increasing tendency, more rapidly in western parts. From mid March hot weather is initiated which prevails up to June. During March the rise in temperature is somewhat uniform in the whole of Rajasthan. From April to June, diurnal range of temperature increases more, the days become hotter and the maximum daily temperature goes up to 32°C to 47°C. The mean monthly temperatures for the months of April to June in sandy arid plains (Marusthali) varies from 34°C to 40°C, in Deccan plateau from 34 to 36°C, in southern Aravalli range (Mt. Abu) from 28 to 32°C and in the remaining regions from 30 to 36°C. During the monsoon season from July to September the temperature shows slight decreasing trend and in the

month of October the maximum varies from 32 to 36°C and the minimum 17 to 21°C. During November-December, there is a gradual decrease in the temperature all over Rajasthan, reaching 12 to 17°C in the month of January.

It should, however, be noted that the differences between day and night temperatures at different stations in Rajasthan and fluctuations in the temperatures from January to December of a year and between maximum and minimum temperatures are so much that mean values convey a very inadequate picture of the true climatic conditions.

Rainfall:

The whole of the state continues to get heated till the onset of monsoon by the middle of June. The state receives the monsoon currents from the Bay of Bengal and Arabian Sea. More than ninety per cent of the rainfall is received from June to September. The general trend of isohyetal line during this period is from north-east to south-west. The south-western parts i.e. at Mt. Abu and its neighbourhood get the maximum rainfall i.e. 700-1250 mm.

In the Chappan plateau and southern parts of Bhorat and Deccan plateau the rainfall is 700-800 mm whereas in the north-western Bhorat plateau, north-eastern hilly tract, the Banas basin and the Vindhyan scarpland it is 500 to 600 mm. There is a rapid and marked decrease in rainfall from east to west of Aravalli making western Rajasthan the most arid part in India. The semi-arid transitional plain receives about 250-300 mm rainfall and the sandy arid plain (Marusthali), further west, receives less than 250 mm rainfall.

The variations in annual rainfall and the number of rainy days from year to year are appreciable. The month of July is the rainiest receiving 90 to 95 per cent rainfall. Five to ten per cent of the annual rainfall occurs in the form of local showers during winter season and thunder storms particularly during June-July. On an average, there are 30 to 40 rainy days in a year.

Relative humidity :

The relative humidity is minimum in the summer season, particularly in April and May when it ranges between 35 to 60 per cent in the morning hours and 10 to 30 per cent in the afternoon. The maximum humidity is noted during the rainy season, particularly mid July to mid August (90%).

During the winter season, particularly mid December to February, the relative humidity varies from 50-60% in the morning and 25 to 35 per cent in the afternoon. The relative humidity in the west of Aravalli is lesser than in the east of it.

Wind :

During post monsoon period and winters i.e. October to February the winds are very light and variable, with north westerly and northerly winds being more frequent. In the hot and rainy seasons, the winds usually move between south-west and west. During summers, dust storms are also very common, particularly in the western arid regions. Maximum dust storms occur in June in the arid regions and in May in south-east.

Hail storms are very rare and they generally occur from January-March. Fogs are comparatively more frequent, usually occurring between December to February.

GENERAL ASPECTS OF VEGETATION

Three physiographic regions may be recognised in Rajasthan for the study of flora and floral composition of the area, namely the western sandy desert, the eastern gravelly/rocky plateau with outliers of Aravallis and the main Aravalli range itself.

1. The western sandy desert :

The western arid and semi-arid region, commonly known as the Rajasthan desert or the Thar desert, covers a total area of 1,96,150 sq. km in the west of Aravalli range. Its geographical position and the topographic, climatic and edaphic characteristics have already been discussed in the preceding pages. The vegetation in arid regions is sparse consisting mainly of stunted, thorny or prickly shrubs and perennial herbs capable of drought resistance. Trees are few and scattered. The ephemerals come up during the rainy season, complete their life cycle before the advent of summer and the bulk of the area is once more transformed into open sandy plain, desolate and barren. Since the climate is more or less homogeneous, the vegetation can better be said to be edaphic controlled. We can study the vegetation of the desert under the following heads:

(a) *Sand-dunes and interdunal areas* : This is by far the most common habitat of this region. Sand-dunes of different types, magnitude and

orientation are encountered. They may be stabilised, partially stabilised or unstabilised and barren. The common trees and shrubs found on stabilised and unstabilised sand-dunes are: *Calligonum polygonoides*, *Clerodendrum phlomidis*, *Haloxylon salicornicum*, *Lycium barbarum* etc. On some of the dunes, trees like *Acacia senegal*, *Prosopis cineraria*, *Salvadora oleoides* etc. are also common. The other common inhabitants of sand-dunes include *Aerva javanica*, *Citrullus colocynthis*, *Crotalaria burhia*, *Dipterygium glaucum*, *Farsetia hamiltonii*, *Indigofera argentea*, *I. cordifolia*, *I. linifolia*, *Leptadenia pyrotechnica*, *Melhania denhamii*, *Sericostemma pauciflorum*, *Tephrosia falciformis*, *Tribulus longipetalus* etc. The common grasses and sedges which play a vital role in soil conservation are: *Aristida adscensionis*, *A. funiculata*, *Cenchrus biflorus*, *C. ciliaris*, *C. prieurii*, *C. setigerus*, *Cymbopogon jwarancusa*, *Dactyloctenium aegyptium*, *D. scindicum*, *Desmostachya bipinnata*, *Eragrostis* species, *Lasiurus indicus*, *Latipes senegalensis*, *Ochthochloa compressa*, *Panicum antidotale*, *P. turgidum*, *Sporobolus helvolus*, *Stipagrostis hirtigluma*, *Cyperus atkinsonii*, *C. conglomeratus* etc.

The interdunal gaps support more luxuriant vegetation due to greater availability of moisture. The common trees and shrubs are: *Acacia jacquemontii*, *A. senegal*, *Prosopis cineraria*, *Salvadora oleoides*, *Tecomella undulata*, *Calotropis procera*, *Capparis decidua*, *Ziziphus nummularia* etc. In addition, almost all the plants found on sand-dunes grow more profusely in the interdunal area.

At the foot of the isolated hills and rock outcrops, the windward sides of which obstruct the movement of sand, obstacle sand-dunes are often formed. On these dunes a mixture of characteristic elements of sand-dunes and rock outcrops like *Acacia senegal*, *Anogeissus pendula*, *Commiphora wightii*, *Maytenus emarginatus* etc. may be seen.

The unstabilised sand-dunes are least covered with plants. However, *Cyperus arenarius*, *Crotalaria burhia*, *Aerva javanica*, *Leptadenia pyrotechnica* etc. are some of the pioneer species to colonize these dunes. The very crest of such sand-dunes are often colonized by varying frequency of *Lasiurus indicus* and *Citrullus colocynthis* etc.

(b) *Sandy and hummocky plains* : Sandy and hummocky plains constitute the major part of the desert and plants growing in such habitats form some of the characteristic associations of the region. The common trees

and shrubs are: *Acacia senegal*, *Calligonum polygonoides*, *Calotropis procera*, *Capparis decidua*, *Maytenus emarginatus*, *Prosopis cineraria*, *Salvadora oleoides*, *S. persica*, *Tecomella undulata* and *Ziziphus nummularia*. In addition, under-shrubs and herbs like *Aerva javanica*, *Arnebia hispidissima*, *Boerhavia diffusa*, *B. elegans*, *Convolvulus microphyllus*, *Crotalaria burhia*, *Farsetia hamiltonii*, *Heliotropium strigosum*, *Indigofera cordifolia*, *Leptadenia pyrotechnica*, *Tephrosia purpurea* etc. are also common. The most common creepers are *Citrullus colocynthis*, *C. lanatus*, *Cucumis melo* and *C. prophetarum*, and of climbers mention may be made of *Coccinia grandis*, *Momordica dioica*, *Mukia maderaspatana* and *Pergularia daemia*. Most of these plants possess well developed root-system and occur in open clump formations with plenty of vacant spaces between them which are occupied by several ephemerals and grasses like the species of *Aristida* and *Cenchrus*, and *Dactyloctenium scindicum*, *Lasiurus indicus*, *Ochthochloa compressa*, *Panicum antidotale*, *Stipagrostis hirtigluma* etc. along with sedges like *Cyperus atkinsonii* and *C. conglomeratus*. The shifting dunes are often successful in over running the low vegetation.

(c) *Gravelly/rocky plains* : Gravel, which is formed by the action of wind, covers fairly large areas of the region. Some of the common plants of these habitats are: *Cleome vahliana*, *C. gracilis*, *Fagonia indica*, *Dactyloctenium aristatum*, *Indigofera linnaei*, *Heliotropium rariflorum*, *Leptadenia pyrotechnica*, *Blepharis sindica*, *Sericostemma pauciflorum*, *Bouchnera marubifolia*, *Salvia aegyptia* etc. Certain plants of gravel are prostrate and star like with the branches remaining appressed to the ground. e.g. *Euphorbia clarkeana*, *E. granulata*, *Indigofera cordifolia*, *I. hochstetteri*, *Mollugo cerviana*, *M. nudicaulis*, *Tribulus terrestris* etc. The common trees and shrubs of this habitat are: *Calotropis procera*, *Capparis decidua*, *Euphorbia caducifolia*, *Maytenus emarginatus*, *Prosopis cineraria*, *Salvadora oleoides*, *Ziziphus nummularia* etc. At certain spots, the gravel plains maintain characteristic grass-legume associations. The common grasses are: *Enneapogon brachystachyus*, *E. schimperanus*, *Melanocenchris abyssinica*, *M. jacquemontii*, *Oropetium thomaeum*, *Tragus roxburghii* etc.

The gravel plains are marked by deep valleys or shallow depressions, particularly near the foot of hills; the typical rock plants which become prominent along with some rammers in such habitats are: *Ephedra foliata*, *Asparagus racemosus* etc. The rocks in the area represent various geological

formations. The rocky plains maintain sparse vegetation without any true forests. *Anogeissus pendula*, *Asparagus racemosus*, *Balanites aegyptiaca*, *Corallocarpus epigaeus*, *Rivea hypocrateriformis* etc. are the common plants of these habitats.

(d) *Isolated hills and rock outcrops* : The region in the west of Aravalli consists isolated hills of low elevation and of various origin. These hills are usually bare at the top; occasionally, however, *Boswellia serrata*, *Rhus mysurensis* among woody plants and *Convolvulus stocksii* and *Viola cinerea* var. *stocksii* among herbaceous ones are found. The hill-slopes, however, maintain better vegetation due to the accumulation of sand and better water holding capacity. The common plants of these habitats are: *Acacia senegal*, *Anogeissus pendula*, *Capparis decidua*, *Commiphora wightii*, *Euphorbia caducifolia*, *Grewia tenax*, *Maytenus emarginatus*, *Ziziphus nummularia* etc.

Among climbers, *Abrus precatorius*, *Asparagus racemosus*, *Boerhavia verticillata*, *Rhynchosia minima*, *Rivea hypocrateriformis* are characteristic. The undergrowth is characterized by the presence of *Anticharis senegalensis*, *Barleria acanthoides*, *B. prionitis*, *Blepharis linaraefolia*, *Boerhavia diffusa*, *Cleome brachycarpa*, *Fagonia indica*, *Heliotropium bacciferum*, *Seetzenia lanata*, *Sida cordata* etc.

The vegetation is comparatively more dense at the foot of hills and nearby areas. *Acacia senegal* is the main jungle forming tree in such habitats. Other characteristic elements include *Blepharis sindica*, *Lipidagathis trinervis*, *Melhania denhamii*, *Monsonia senegalensis*, *Pavonia zeylanica*, *Schweinfurthia papilionacea*, *Seddera latifolia*, *Tephrosia purpurea*, *Tridax procumbens*, *Aristida adscensionis*, *Enneapogon brachystachyus*, *Melanocenchris jacquemontii*, *Oropetium thomaeum*, *Stipagrostis hirtigluma*, *S. pogonoptila*, *Tragus roxburghii* etc.

Lipidagathis bandraensis and *Corbichonia decumbens*, the typical lithophytes of this region, are found in crevices of rocks. *Commelina albescens* and *Lindenbergia indica* are some of the other species growing from the crevices of rocks.

(e) *Saline tracts* : There are large saline tracts spread throughout the desert. The common plants of this habitat are: *Cressa cretica*, *Haloxylon recurvum*, *H. salicornicum*, *Portulaca oleracea*, *Salsola baryosma*, *Sesuvium sesuvioides*, *Suaeda fruticosa*, *Tamarix indica*, *Trianthema triquetra*, *Zaleya govindea*, *Zygophyllum simplex* etc.

(f) *Aquatic and Marshland habitats* : The area maintains considerable number of fresh water, artificial, salt lakes and tanks with rocky substratum. These support a reasonable number of aquatic species like *Hydrilla verticillata*, *Lemna paucicostata*, *Najas graminea*, *N. welwitschii*, *Potamogeton crispus*, *P. pectinatus*, *Spirodela polyrhiza*, *Vallisneria spiralis*, *Wolffia* species etc. *Eichhornia crassipes* is also encountered in certain ponds and lakes.

(g) *Miscellaneous habitats* : The area has a number of old and historical buildings, forts, palaces etc. On the walls of such buildings, plants like *Lindenbergia indica*, *Ficus religiosa*, *Salvadora oleoides*, *Tephrosia strigosa*, *Vernonia cinerea* are frequent. *Cistanche tubulosa* is a common root-parasite particularly on *Capparis*, *Calotropis*, *Salvadora* and *Prosopis* species. *Ephedra foliata* is the only living gymnosperm found in this region.

Certain species escape from cultivation and imperfectly naturalise near habitations e.g. *Citrullus lanatus* var. *fistulosus*, *Lycopersicon esculentum*, *Momordica charantia* etc.

The area includes few biologically significant habitats like the Desert National Park and the Akal Fossil Wood Park. The Desert National Park, situated in Barmer and Jaisalmer districts, occupies an area of about 3000 sq km and represents all the characteristics of the desert ecosystem. It has been established to preserve the flora and fauna of the Thar desert and to restore the degraded natural ecosystem. It has good concentration of Chinkara, Black-Buck and Great Indian Bustard, the last being an endangered species.

The Akal Fossil wood park, located at Hirchindani in Jaisalmer district, has further enhanced the importance of the Thar desert by the discovery of fossil wood logs of the lower Jurassic age.

Saphari National Park, located at Kailana in Jodhpur district, is a recent effort being taken for the preservation of desert flora and fauna, including some of the rare and threatened plants and animals of W. Rajasthan.

(h) *Endemic and rare taxa* : The desertic zone due to its characteristic topography, geology, edaphic and climatic factors maintains a peculiar type of vegetation, not found elsewhere in India. About 16 taxa of angiosperms are endemic to the desert. They are: *Cenchrus rajasthanensis*, *Convolvulus*

blatteri, *Farestia macrantha*, *Pulicaria rajputanae*, *Ziziphus truncata*, *Abutilon bidentatum* var. *major*, *A. fruticosum* var. *chrysocarpa*, *Alysicarpus monilifer* var. *venosa*, *Barlaria prionitis* var. *diacantha*, *Cenchrus prieurii* var. *scabra*, *Cleome gynandra* var. *nana*, *Convolvulus auricomus* var. *ferruginosus*, *Ipomoea carica* var. *semine-glabra*, *Pavonia arabica* var. *glutinosa* and *P. arabica* var. *massuriensis*.

Most of these endemic taxa have very restricted distribution probably due to the greatly disturbed ecosystems in the desert and due to the limited range of adaptability of these taxa.

Besides these, the over exploitation of certain species for various uses in the desert pose a serious threat to them e.g. *Citrullus colocynthis*, *Commiphora wightii*, *Ephedra foliata*, *Tecomella undulata* etc.

The other rare taxa found in Rajasthan are: *Ammannia desertorum*, *Glossonema varians*, *Heliotropium rariflorum*, *Lineum indicum*, *Moringa concanensis*, *Seddera latifolia*, *Sesuvium sesuvioides*, *Tephrosia falciformis* and *Tribulus rajasthanensis*.

2. Aravalli Range :

The second physiographic region of interest is the Aravalli range which runs diagonally across the state extending from Champaner in Gujarat in the south-west to near Delhi in the north-east for a distance of about 692 km. Within Rajasthan, the range runs from Khed Brahma in the south-west to Khetri in the north-east for a length of about 550 km. The elevation of the Aravalli range gradually rises in the south-west direction and so also the vegetation pattern and floral composition changes due to the changes in climatic and edaphic factors. On Khetri hills (792 m) the vegetation is scrubby and in degraded stage. The top of the hills are practically barren while on the slopes, where some sand and moisture accumulate, thick growth of plants such as *Acacia leucophloea*, *A. senegal*, *Balanites aegyptiaca*, *Capparis decidua*, *Euphorbia nivulia*, *Grewia tenax*, *Justicia adhatoda*, *Securinega leucopyrus* etc. are noticed. On Harshnath hills (913 m), the floral composition up to 600 m is similar to that of Khetri hills; but above 600 m, plants like species of *Calotropis*, *Clerodendrum*, *Justicia* etc. disappear and their places are taken by elements like *Dichrostachys cinerea*, *Euphorbia neriiifolia*, *Triumfetta rhomboidea* etc. Trees like *Anogeissus latifolia*, *A. pendula*, *balanites aegyptiaca*, *Prosopis cinerarea*, *Wrightia*

arborea etc. which are stunted at lower elevations become more and more prominent.

Further south-westwards at Kho (920 m), Raghunathgarh (1055 m) and Todgarh in Ajmer district the scrub vegetation merges to some extent with the deciduous type. The floral composition of these hills include *Anogeissus pendula*, *Acacia leucophloea*, *Bauhinia racemosa*, *Boswellia serrata*, *Commiphora wightii*, *Dichrostachys cinerea*, *Mimosa hamata*, *Prosopis cineraria*, *Rhus mysorensis*, *Securinega leucopyrus*, *Sterculia urens* etc.

From Bijapur forest range (1100 m) in Pali district to further south-westwards, the hills are covered over with mixed deciduous type of forests dominated by *Anogeissus pendula*. The other common associates at Bijapur are *Aegle marmelos*, *Anogeissus latifolia*, *Bauhinia racemosa*, *Boswellia serrata*, *Butea monosperma*, *Cassia fistula*, *Diospyros melanoxylon*, *Mitragyna parvifolia*, *Wrightia tinctoria* etc.

Mt. Abu (1727 m) at the south-western border of the state is the highest peak not only of the Aravallis but also between western Himalayas and Nilgiri hills. The vegetation here falls into fairly distinct elevational zones though they intermingle to certain extent. The chief components up to 1300 m are the same as between Bijapur and Mt. Abu with only a little change in the frequency and abundance. But above 1300 m, the vegetation gradually changes to subtropical evergreen type with species like *Boswellia serrata*, *Carvia callosa*, *Crateva nurvala*, *Flacourtia indica*, *Girardinia zeylenica*, *Jasminum humile*, *Lannea coromandelica*, *Mallotus philippensis*, *Mangifera indica*, *Rosa brunoni*, *R. involucrata*, *Sterculia urens*, *Syzygium cumini* etc. At certain places *Albizia* spp., *Erythrina* spp., *Emblica officinalis*, *Kydia calycina*, *Trema orientalis* etc. are also found at higher elevations. Several species of ferns and fern-allies also occur at Mt. Abu.

The ground cover comprising of *Acanthospermum hispidum*, *Blainvillea acmella*, *Sclerocarpus africanus*, species of *Alysicarpus*, *Cassia* and *Desmodium*, *Borreria articularis*, *B. pusilla*, many grasses etc. become very dense at lower elevations at Mt. Abu. In the north-eastern direction from Bijapur, right up to Khetri hills, not only the density of the above mentioned taxa decreases but species like *Boerhavia diffusa*, *Borreria articularis*, *Dactyloctenium aegyptium*, *Evolvulus alsinoides*, *Glossocardia bosvallea* and species of some ferns like *Actinopteris*, *Adiantum* etc. become more common.

Endemic and Threatened plants : Mt. Abu maintains a characteristic vegetation due to the relatively high altitude coupled with the climatic and edaphic factors. The endemic taxa of Mt. Abu are: *Bonnaya bracteoides*, *Dicliptera abuensis*, *Oldenlandia clausa*, *Strobilanthes hallbergii* and *Veronica anagallis* var. *bracteosa*. These taxa were described by Blatter and Hallberg between 1918-1931 with the type specimens deposited in Blatter Herbarium, Bombay (BLAT). Since then many botanists have explored Mt. Abu, but none could collect these taxa; probably they have become extinct.

3. The area in the east of Aravalli :

The area situated in the east of Aravalli range constitutes the third physiographic region. From Ajmer onwards several parallel outliers of Aravallis become conspicuous and begin to spread to the south and south-east. This area may be subdivided into the following physiographic units for a better understanding of the flora and floral composition.

(a) *Bhorat plateau* : The eastern part of Sirohi, major part of Udaipur and the entire Dungarpur district fall under 'Bhorat Plateau'. The highest section of the outliers of the Aravallis lies to the north-west of Udaipur between Kumbalgarh and Gogunda. The average elevation of this plateau is 1225 m above m.s.l. The vegetation on the hills is of mixed deciduous type, showing three altitudinal zonation with the higher elevations dominated by *Boswellia serrata*, associated with *Anogeissus latifolia*, *Lannea coromandelica*, *Sterculia urens* etc. In the middle zone *Anogeissus pendula* is dominant and it is associated with *Albizia odoratissima*, *Diospyros melanoxylon*, *Holoptelea integrifolia*, *Wrightia tinctoria* etc. The lower elevations are dominated by *Cassia auriculata*, associated with *Annona squamosa*, *Butea monosperma*, *Dichrostachys cinerea*, *Diospyros cordifolia* etc. Shrubs and undershrubs are usually not affected by elevation, the common ones being *Capparis sepiaria*, *Dyerophytum indicum*, *Grewia flavescens*, *Justicia adhatoda*, *Spermadictyon suaveolens*, *Woodfordia fruticosa* etc.

(b) *Banas basin* : The eastern part of Udaipur, western Chittorgarh, Bhilwara, western Ajmer, Tonk, Jaipur, western Sawaimadhopur and southern part of Alwar district constitute 'Banas Basin'. The maximum height of hills is about 582 m near Deogarh. The forests located here are of the mixed deciduous type dominated by *Anogeissus pendula*, associated with *Acacia senegal*, *Bauhinia racemosa*, *Boswellia serrata*, *Capparis sepiaria*, *Cassia fistula*, *Dichrostachys cinerea*, *Diospyros melanoxylon*,

Lannea coromandelica, *Wrightia tinctoria* etc. There is no significant elevational effect on the vegetation of Banas basin except that *Boswellia serrata* becomes more abundant at the summit of the hills and *Butea monosperma* and *Cassia auriculata* on the outskirts. *Sterculia urens* is usually found at the top or on higher slopes. The vegetation is comparatively denser in the valleys of the hills.

(c) *Chappan plateau* : South-eastern part of Udaipur, southern Chittorgarh and Banswara district constitute "Chappan plateau" The average height of the plateau is 350 m and the outliers hardly exceed 700 m above m.s.l. The forests are of deciduous type, dominated mainly by *Tectona grandis*. The altitude does not have much effect on the zonation of vegetation except that on higher slopes teak is replaced by species like *Bauhinia racemosa*, *Boswellia serrata*, *Dalbergia latifolia*, *Emblica officinalis*, *Lannea coromandelica*, *Sterculia urens* etc. The vegetation is richer on the gentle slopes, where additional associates of teak like *Adina cordifolia*, *Aegle marmelos*, *Albizia odoratissima*, *Diospyros melanoxylon*, *Hymenodictyon excelsum*, *Lagerstroemia parviflora*, *Madhuca longifolia*, *Mitragyna parvifolia*, *Terminalia arjuna*, *Wrightia tinctoria* occur. *Dendrocalamus strictus* grows in isolated patches. The steep slopes with big boulders of rocks support *Euphorbia nerifolia*, *E. nivulia* etc. At the foot of the hills *Nyctanthes arbor-tristis* is abundant. On the outskirts, dry teak forests are reduced to scrubs with many stemmed, crooked branchy teak stocks amidst *Acacia chundra*, *A. leucophloea*, *Butea monosperma*, *Holarrhena pubescens* etc.

(d) *Deccan plateau* : The western part of Deccan plateau extends to the south-eastern part of Rajasthan over Kota, Bundi and Jhalawar districts with the Vindhyan and Aravalli outliers. The forests here are of mixed deciduous type, showing altitudinal zonation of the vegetation to the extent that *Adina*, *Aegle*, *Boswellia*, *Buchanania lanzen*, *Cassia fistula*, *Dendrocalamus*, *Diospyros*, *Lagerstroemia*, *Lannea*, *Sterculia* etc. are more abundant in the middle zone, while *Acacia leucophloea*, *Butea monosperma* etc. are abundant at the foot or outskirts. *Anogeissus pendula* is the dominant species of these forests extending right from the base to the top of the hills.

A natural belt of teak is found in the flat terrain along Parbati river from Atru to Kishanganj in Kota district. In the east of Kishanganj, the terrain becomes hilly and the forests mixed deciduous of *Anogeissus*

pendula type. There are three peripheral zones of vegetation in this flat terrain. The inner part is of pure *Tectona grandis*, with isolated trees of *Diospyros melanoxylon* and *Hardwickia binata* and naked ground floor. In the peripheral region, the destruction of the forest has resulted in scrub woodlands consisting of *Acacia catechu*, *A. nilotica* subsp. *indica*, *A. leucophloea*, *Balanites aegyptiaca*, *Butea monosperma*, *Diospyros melanoxylon* etc. Shrubs and undershrubs are also abundant in the marginal zone. Separating the two, there is a thick belt of *Acacia catechu*, *A. nilotica* and *Ziziphus mauritiana* associated with teak.

A subtropical evergreen forest named "Sitabari" situated near Kelwara village in Kota district, and considered sacred supports species like *Ampelocissus latifolia*, *Bombax ceiba*, *Carissa congesta*, *Cayratia trifolia*, *Cissus repanda*, *Cordia dichotoma*, *Ficus virens*, *Hiptage benghalensis*, *Ixora arborea*, *Mangifera indica*, *Pueraria tuberosa*, *Schleichera oleosa*, *Syzygium cumini*, *Terminalia arjuna*, *Vanda tassellata* etc. Many ferns, aquatic and shade loving spermatophytes grow in this forest fed by a perennial stream.

(e) *Vindhyan scarpland* : The Vindhyan scarpland having an average elevation between 350-580 m above m.s.l. covers the area between Banas and Chambal rivers and includes Bharatpur, Dholpur and Sawai Madhopur districts. In Dholpur and Bharatpur districts, most of the area is either under cultivation or is in the form of ravines and useless. The hillocks are more or less naked with degraded and stunted trees and shrubs. In the protected forests, however, the trees attain considerable height, the common ones being *Acacia leucophloea*, *A. nilotica*, *Anogeissus pendula*, *Balanites aegyptiaca*, *Kirganelia reticulata*, *Maytenus emarginatus*, *Prosopis juliflora*, *Salvadora oleoides*, *S. persica* etc. In addition, *Dichrostachys cinerea*, *Sterculia urens* etc. are also found.

Keoladeo Ghana Bird National Park occupying an area of about 29 sq km and located near Bharatpur is also a protected forest which is comparatively denser than elsewhere. The area is an extensive marshland and it was once the hunting preserve of the princely family of Bharatpur. Besides the taxa already noted above, *Adina cordifolia*, *Azadirachta indica*, *Diospyros montana*, *Mitragyna parvifolia*, *Pithecellobium dulce*, *Phoenix sylvestris*, *Ziziphus mauritiana* etc. also occur in this park where thousands of migratory birds from Afghanistan, Central Asia, Tibet, Siberia, China etc. come and make their nests. *Clerodendrum phlomidis*, *Justicia adhatoda*,

Ziziphus nummularia etc. together with many climbers further make the habitat suitable for wild animals like pythons, porcupines, nilgai, spotted deer, hyenas, sambar and wild boar.

The vegetation of wastelands is identical to other regions except that *Tamarix aphylla* and *Alhagi maurorum* are very common throughout the area. It is interesting to note that thick populations of *Carissa spinarum* are encountered near Sikandra village along the foot of the hills (Bayana-Bharatpur). The area also maintains many aquatic and marshland plants, including algal flora.

(f) *North-eastern hilly region* : North-eastern hilly region (Alwar district) is traversed in the north and north-east to south and south-east by a number of parallel outliers of Aravallis rising up to 800 m. This region is open towards north-west and south-west with flat plains at 300-400 m above m.s.l. The hill slopes are excessively stony and the vegetation shows three distinct elevation zones, dominated by *Boswellia serrata*, associated with *Crateva nurvala*, *Euphorbia nerifolia*, *Holoptelea integrifolia*, *Mallotus philippensis*, *Terminalia bellerica* etc. at higher elevations. The middle zone is dominated by *Anogeissus pendula*, associated with *Commiphora wightii*, *Lannea coromandelica*, *Wrightia tinctoria* etc. In the basal zone *Acacia nilotica*, *Dichrostachys cinerea*, *Butea monosperma*, *Tecomella undulata* etc. grow almost in equal proportions. In the cool and shady valley *Colebrookea oppositifolia*, *Dendrocalamus strictus*, *Mitragyna parvifolia*, *Wrightia arborea* etc. grow in abundance.

The ruthless destruction of vegetation in various ways has resulted in the naked hills with big boulders of rocks throughout eastern Rajasthan. The vegetation in such habitats is very sparse, stunted and bushy with plants like spiny Euphorbias and Acacias, *Diospyros cordifolia*, *D. montana* etc.

(g) *Wasteland vegetation in the east of Aravalli* : The vegetation of wastelands is almost identical in all the physiographic divisions in the east of Aravalli. It is semi-xerophytic with sparse tree layer. The common trees are: *Acacia leucophloea*, *A. nilotica*, *Aegle marmelos*, *Azadirachta indica*, *Balanites aegyptiaca*, *Butea monosperma*, *Cordia dichotoma*, *Dolichandrone falcata*, *Ficus benghalensis*, *F. religiosa*, *Mangifera indica*, *Phoenix sylvestris*, *Pithecellobium dulce*, *Prosopis cineraria*, *Salvadora persica*, *Ziziphus mauritiana* etc. The progressive regeneration of most of the trees, both by seeds and coppice, is negligible due to great biotic pressure on them.

Prosopis juliflora is the only species which shows highest survival percentage under adverse climatic and biotic conditions.

The wasteland habitats are more favourable for shrubs and undershrubs which form a comparatively dense layer. The most common shrubs are: *Abutilon indicum*, *Acacia farnesiana*, *A. jacquemontii*, *Calotropis procera*, *Capparis decidua*, *C. sepiaria*, *C. zeylanica*, *Clerodendrum phlomidis*, *Dichrostachys cinerea*, *Ficus palmata*, *Kirganelia reticulata*, *Lantana camara*, *Leptadenia pyrotechnica*, *Mimosa hamata*, *Opuntia elatior*, *Solanum incanum*, *Ziziphus nummularia* etc. These shrubs usually grow in clumps with trees and in vacant spaces.

A large number of undershrubs also grow in the wastelands, the most common ones are: *Cassia auriculata*, *C. occidentalis*, *Desmodium gangeticum*, *Malvastrum coromadelianum*, *Pavonia zeylanica*, *Pupalia lappacea*, *Sida alba*, *S. cordifolia*, *S. ovata*, *Triumfetta pentandra*, *T. rotundifolia*, *Urena lobata*, *Xanthium strumarium* etc.

The most common climbers are: *Abrus precatorius*, *Argyreia sericea*, *Cissampelos pareira*, *Cocculus hirsutus*, *Cryptostegia grandiflora*, *Leptadenia reticulata*, *Marsdenia tenacissima*, *Mucuna pruriens*, *Pergularia daemia*, *Rivea hypocrateriformis*, *Teramnus labialis*, *Wattakaka volubilis* etc. They usually grow among the trees and shrubs, particularly on the boundaries of fields and gardens.

Besides these, a large number of annual and perennial herbs are encountered in the wastelands. With the advent of the winter season a considerable number of compositaceous meadow herbs, in association with *Acalypha ciliata*, *Achyranthes aspera*, *Argemone mexicana*, *Leucas cephalotes*, *Nepeta hindostana*, *Solanum nigrum* etc. come into bloom. The most common compositaceous herbs are: *Ageratum conyzoides*, *Echinops echinatus*, *Eclipta alba*, *Gnaphalium polycaulon*, *Lagascea mollis*, *Launaea procumbens*, *Pulicaria angustifolia*, *Sonchus oleraceus* and *Sphaeranthus indicus*; the last mentioned species often forms dense mats at certain places.

Decreasing moisture content, increasing temperature and high velocity winds during March and April result in the disappearance of most meadow herbs excepting those growing in somewhat moist habitats. The dry meadow herbs appearing during summer months are very few e.g. *Alhagi maurorum*, *Chrozophora rotleri*, *Solanum surrattense*, *Tridax procumbens* and *Dipcadi serotinum* which possesses underground bulbs and become visible above the ground only during the summers.

During the rainy season, the area presents a glorious appearance of a green carpet of semi-xerophytic and meadow herbs which help in increasing the humus content of the soil and extend the vegetation to the barren areas. The life-cycle of most of the herbs comes to close before the winter sets in. The rainy season herbs are dominated by leguminous plants like species of *Alysicarpus*, *Cassia*, *Crotalaria*, *Indigofera*, *Psoralea*, *Tephrosia*, *Vigna* etc. The common associates of the above are: *Aristolochia bracteolata*, *Borreria articularis*, *Cieome gynandra*, *C. viscosa*, *Convolvulus prostratus*, *Evolvulus alsinoides*, *Glossocardia bosvallea*, *Merremia tridentata*, *Polygala erioptera*, *Tridax procumbens* and several grasses among which the species of *Aristida*, *Cenchrus*, *Chloris*, *Eragrostis*, *Tragus*, *Urochloa* etc. are more common.

On the boundaries of fields, gardens and orchards, *Antigonon leptopus*, *Canavalia ensiformis*, *Cardiospermum halicacabum*, *Coccinia grandis*, *Dioscorea bulbifera*, *Momordica dioica*, *Mukia maderaspatana* etc. besides reducing wind velocity also act as an obstacle in the path of moving sand particles.

A few sciophytic humus and shade loving herbs fairly distributed in the gardens, orchards and other similar habitats are: *Baliospermum montanum*, *Biophytum sensitivum*, *Chenopodium album*, *Corchorus olitorius*, *Euphorbia hirta*, *Hybanthus enneaspermus*, *Lindernia crustacea*, *Oldenlandia corymbosa*, *Oxalis corniculata*, *Phyllanthus fraternus*, *Physalis minima*, *Solanum nigrum* etc.

The neglected corners of fields and gardens which escape ploughing and have lower percentage of nitrates, humus and low water holding capacity are most suitable for the growth of lime loving species like *Chenopodium album*, *Desmostachya bipinnata*, *Echinops echinatus*, *Euphorbia hirta*, *Perotis indica*, *Saccharum spontaneum*, *Vetiveria zizanioides* etc.

Parks and play grounds are most suitable localities for many grasses which form dense mental and act as an effecient soil-binder e.g. *Bothriochloa pertusa*, *Cynodon dactylon*, *Dichanthium annulatum*, *Imperata cylindrica*, *Iseilema laxum*, *Tragus roxburghii* etc.

Inhabiting semi-demolished walls of ancient buildings and monuments, there are well recognisable associations of meadow herbs like *Bidens biternata*, *Euphorbia hirta*, *Glossocardia bosvallea*, *Haplanthodes verticillata*, *Indoneesiella echioides*, *Lindenbergia indica*, *Tridax procumbens*