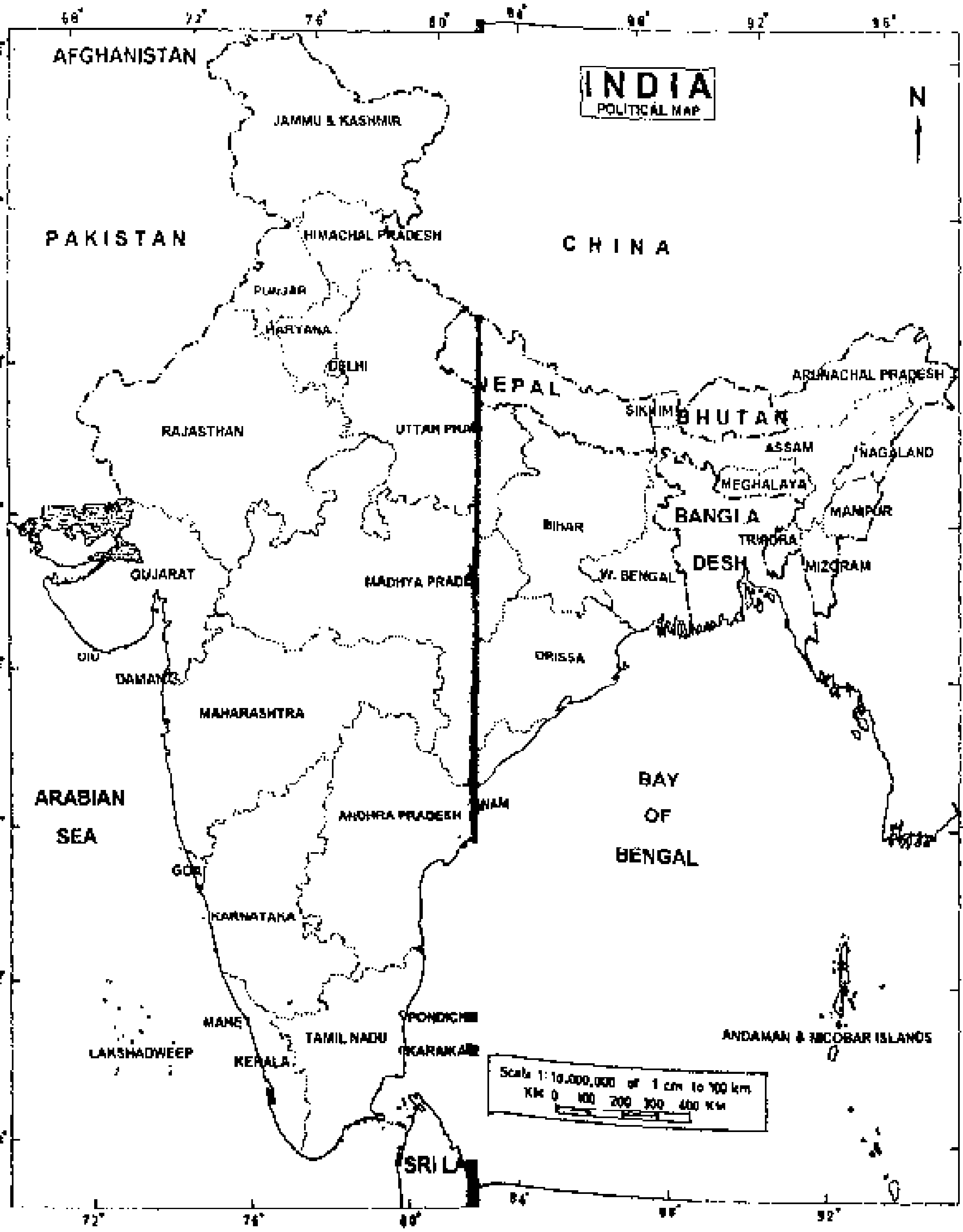
FLORA OF INDIA

INTRODUCTORY VOLUME

PART II

BOTANICAL SURVEY OF INDIA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CHINA
JAMMU & KASHMIR
HIMACHAL PRADESH
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BHUTAN
ARUNACHAL PRADESH
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BANGLA DESH
MANIPUR
TRIPURA
MIZORAM
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ANDHRA PRADESH
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KARAIKAL
ANDAMAN & NICOBAR ISLANDS
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Scale 1:10,000,000 or 1 cm to 100 km
Km 0 100 200 300 400 Km

FLORA OF INDIA

Introductory volume
(Part II)

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6. AFFINITIES - PALAEOBOTANICAL AND GEOLOGICAL EVIDENCES, RELATIONSHIP WITH ADJACENT REGIONS, PAST AND RECENT PLANT MIGRATION

(B.D. Sharma)

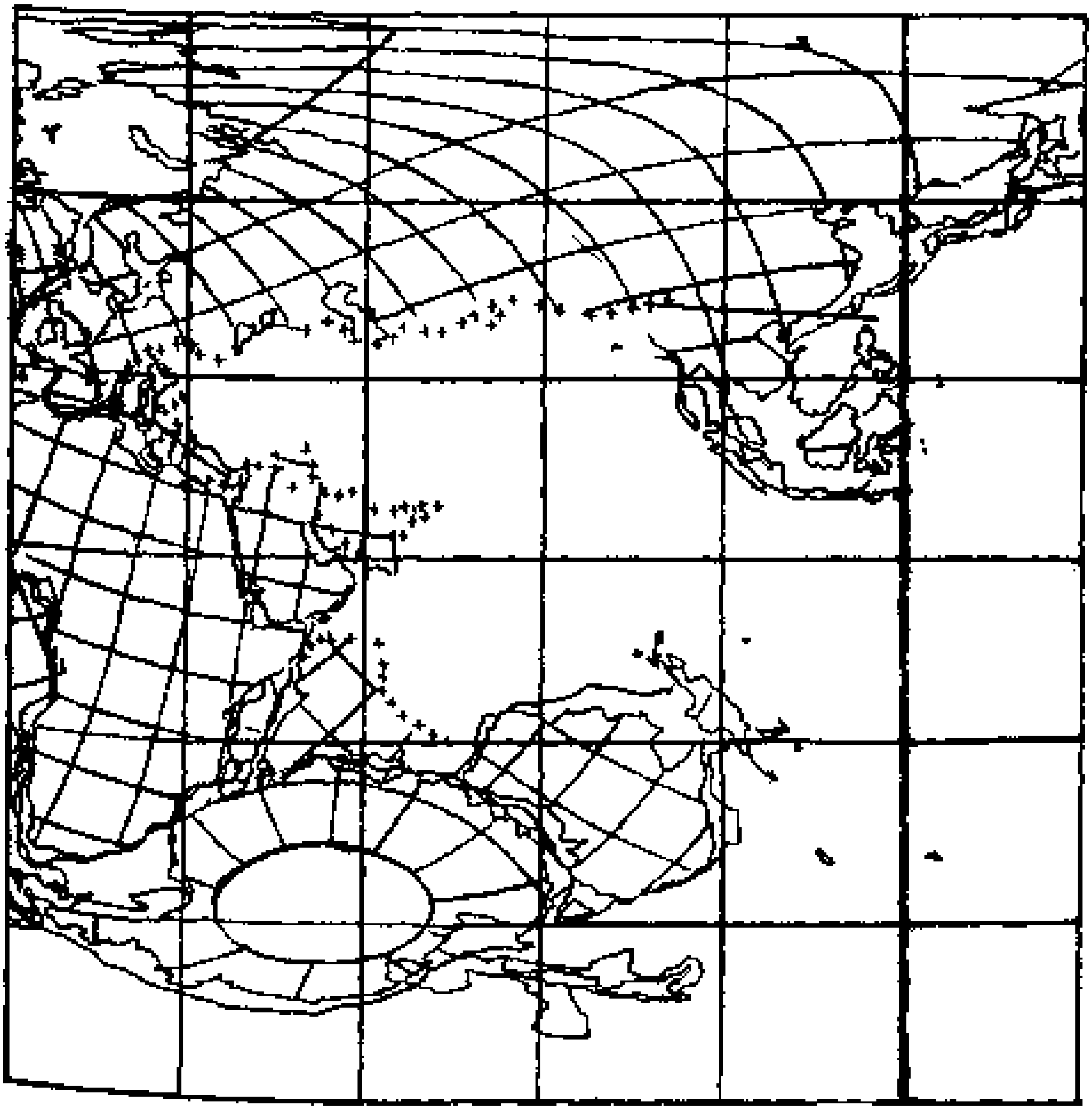
INTRODUCTION

The planet Earth is *ca* 4.6 billion years old. The scientists are not sure when or in what form life first appeared on the Earth. During the Cambrian period primitive plants resembling algae of modern days appeared. The Odovician period witnessed part of the seabeds overgrown with algae which provided food for the sea animals. The plant life became more varied in structure and included primitive vascular plants like ferns and mosses in Silurian period. During Devonian period land plants which included horsetails and clubmosses flourished extensively. The plant life continued to flourish during warm damp Carboniferous period. Huge clubmosses, horsetails and tree ferns soon grew into impenetrable forests. The Permian period witnessed disappearance of old type plants. The ferns were succeeded by coniferous trees. The vegetation only grew in places where there was enough moisture. Gymnosperms and conifers were widely distributed. The luxuriant vegetation included many species of gymnosperms during Jurassic period. The flowering plants which originated in mid Jurassic developed and flourished during Cretaceous period. During Palaeocene and Eocene period flowering plants, including deciduous plants, became dominant. Oligocene and Miocene period was dominated by deciduous trees and conifers. The Pliocene and Pleistocene period fossil records exhibit progressive development of flowering plants. The Holocene period is characteristic of equable climatic condition of the present times. Life on land and in the sea were as it is today.

Some 300 million years ago the then India occupied high latitudes and lay quite close to the South Pole (Fig. 1; Map 1-6). The Continental Drift Theory postulates that Peninsular India formed part of the Gondwanaland and it got detached from it 75 m Y.B.P. ago and started drifting towards northern direction. During the course of northward passage the Indian Plate was subjected to different climatic stresses and volcanic eruptions causing flow of Deccan lavas, leading to the impoverishment of its flora. Extinction took the toll of most groups of the

ERA	PERIOD/ SUBPERIOD		EPOCH		MILLION YEARS BEFORE PRESENT (Ma)
CENOZOIC	QUATERNARY		Holocene		0.01
			Pleistocene		1.64
	TERTIARY	NEOGENE	Pliocene	upper	3.4
				lower	5.2
			Miocene	upper	10.4
				middle	16.3
				lower	23.3
		PALAEOGENE	Oligocene	upper	29.3
				lower	35.4
			Eocene	upper	38.6
				middle	50.0
				lower	56.5
			Palaeocene	upper	60.5
				lower	65.0
MESOZOIC	CRETACEOUS	UPPER	Senonian		74.0
					83.0
					86.6
					88.5
			Gallic		90.4
					97.0
		LOWER			112.0
					124.5
					131.8
			Neocomian		135.0
					140.7
					145.6

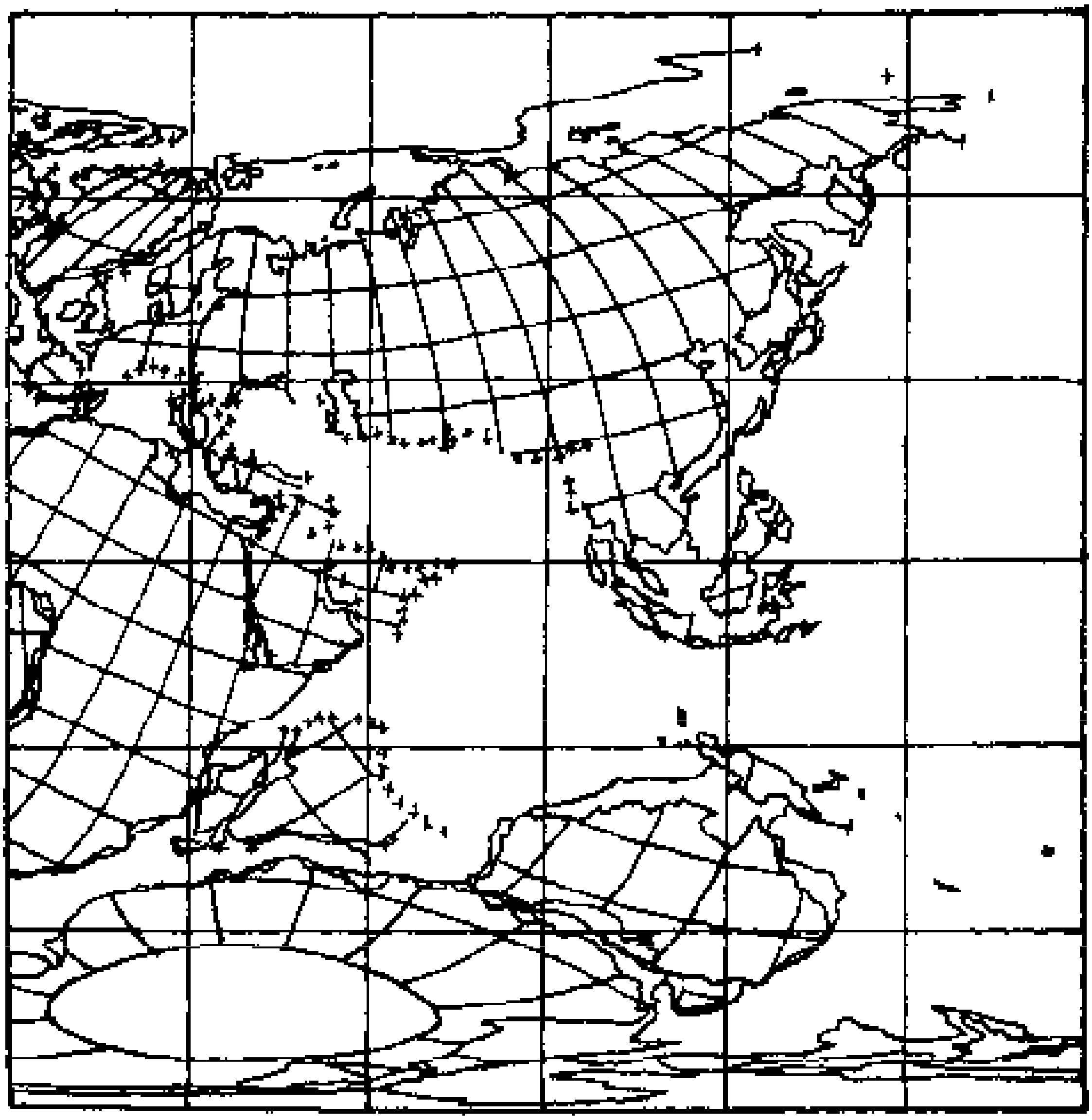
Fig. 1. A Partial time-scale (Cretaceous-Present)



Map 1. Palaeocontinental map of the latest Triassic (200 m y; after Smith & Briden, 1979).

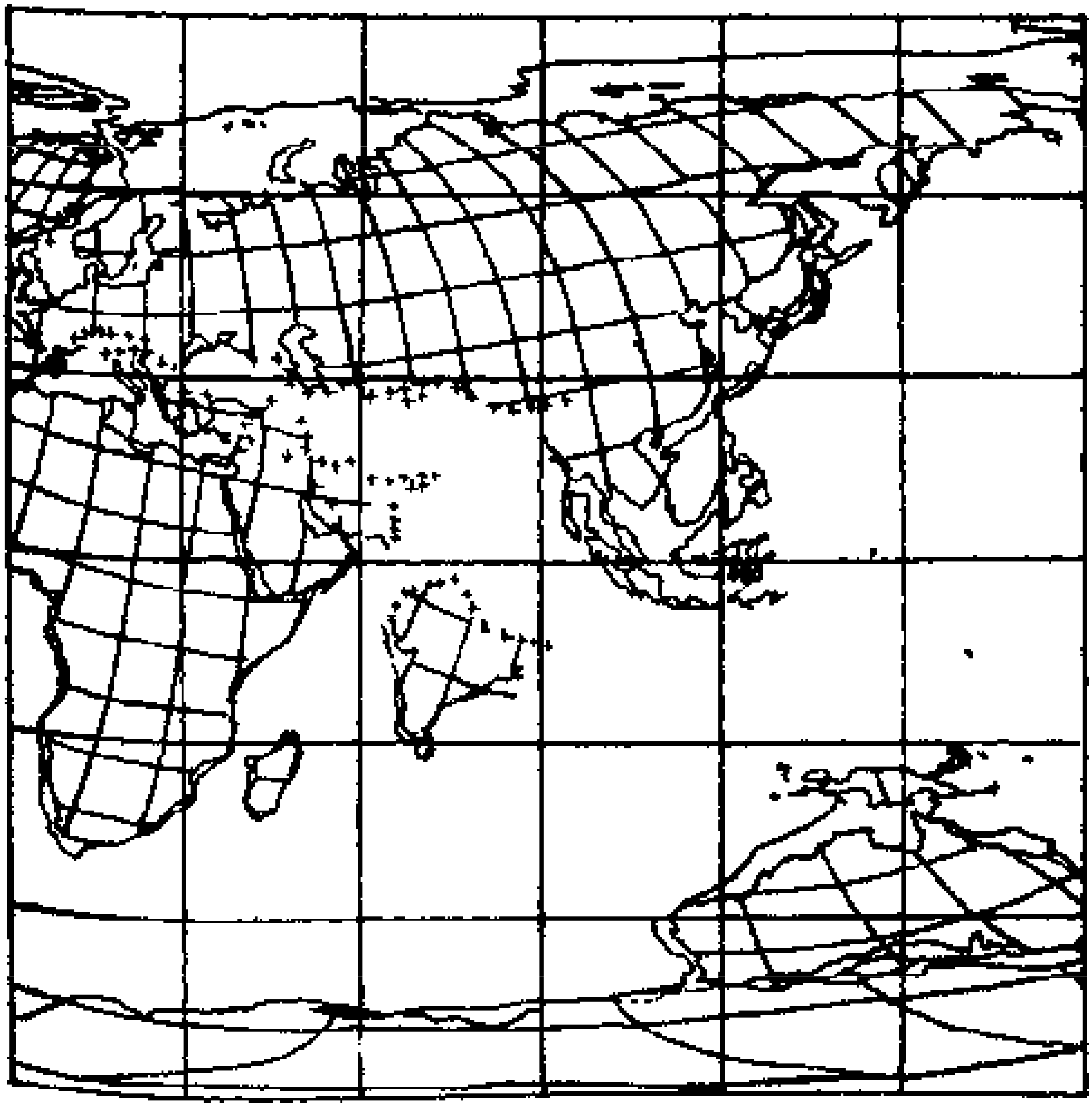
Gondwanic floristic stock during the time of northward movement. As such, the history of the flora of Peninsular India is that of floristic impoverishment due to the flow of Deccan lavas during Cretaceous-Eocene period and spreading aridity during the Neogene-Quaternary times. The present day flora of Peninsular India is thus an extant relictual and was apparently supplemented by later day migrations and speciations. This movement continued traversing about 5900 km to crash against Laurasia in the northern tropical latitudes during the Late Cretaceous.

The continued movement of Indian Plate towards north resulted in crumpling of sediments and progressive shallowing and narrowing of the Tethys. As a consequence of this, east-west basins with intervening highlands were formed between 37-53 million years ago. The last major phase of the northern movement of India occurred around 15 million years ago. The crash of Indian Plate against southern part of Laurasia resulted in the upliftment of Himalayas.



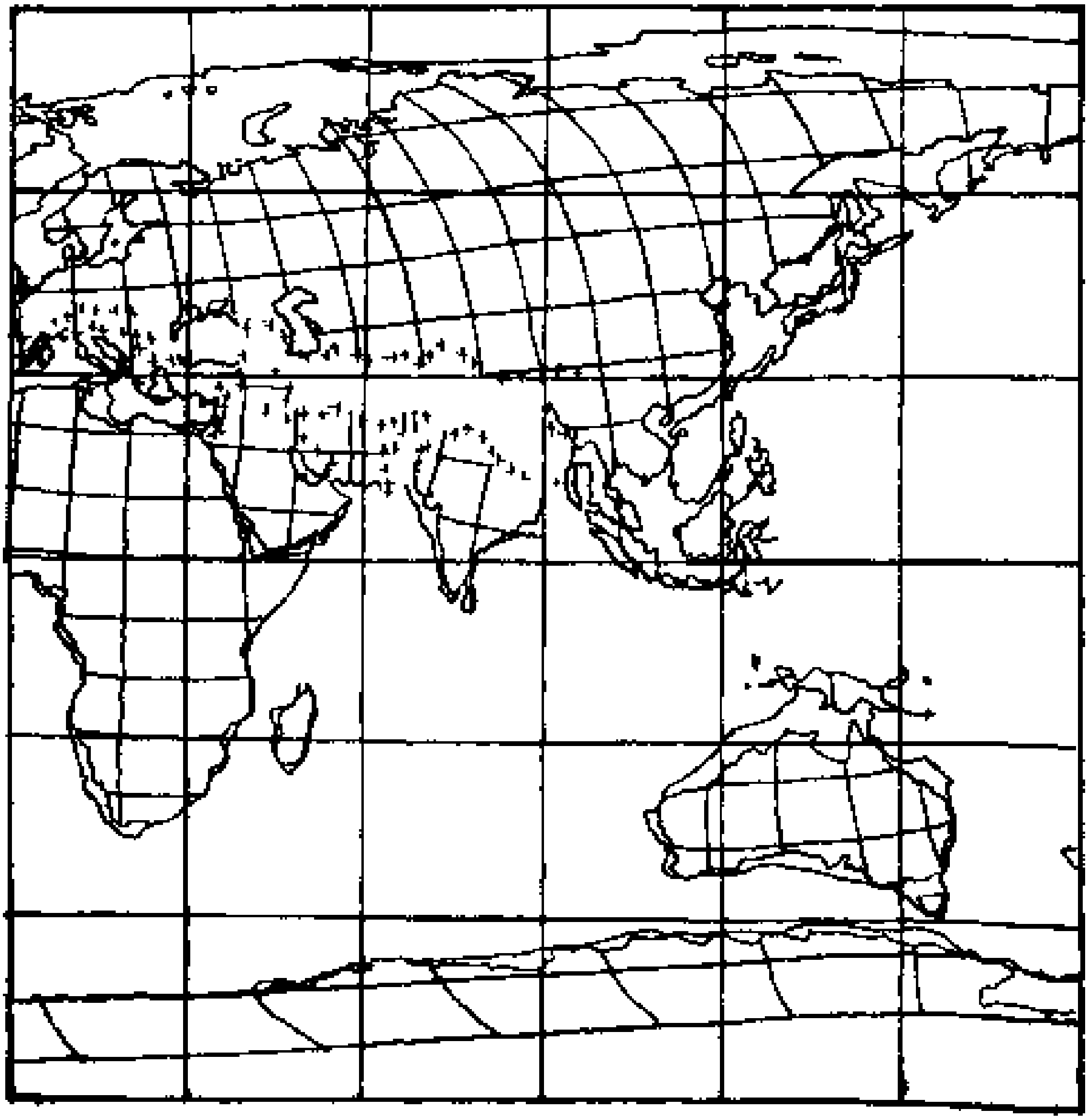
Map 2. Palaeocontinental map of the Early Cretaceous (120 m y; after Smith & Briden, 1979).

The closing of Tethys sea and opening of the Indian Ocean brought about new climatic pattern of trade winds and monsoon regimes. The upliftment of Himalayas lead to chain of events resulting in formation of land and river systems. These geomorphological changes resulted in extinction of vulnerable groups, evolution of floras, migration of floras through corridors provided by the mountain systems and adaptive radiation of species complexes in conducive ecological niche.

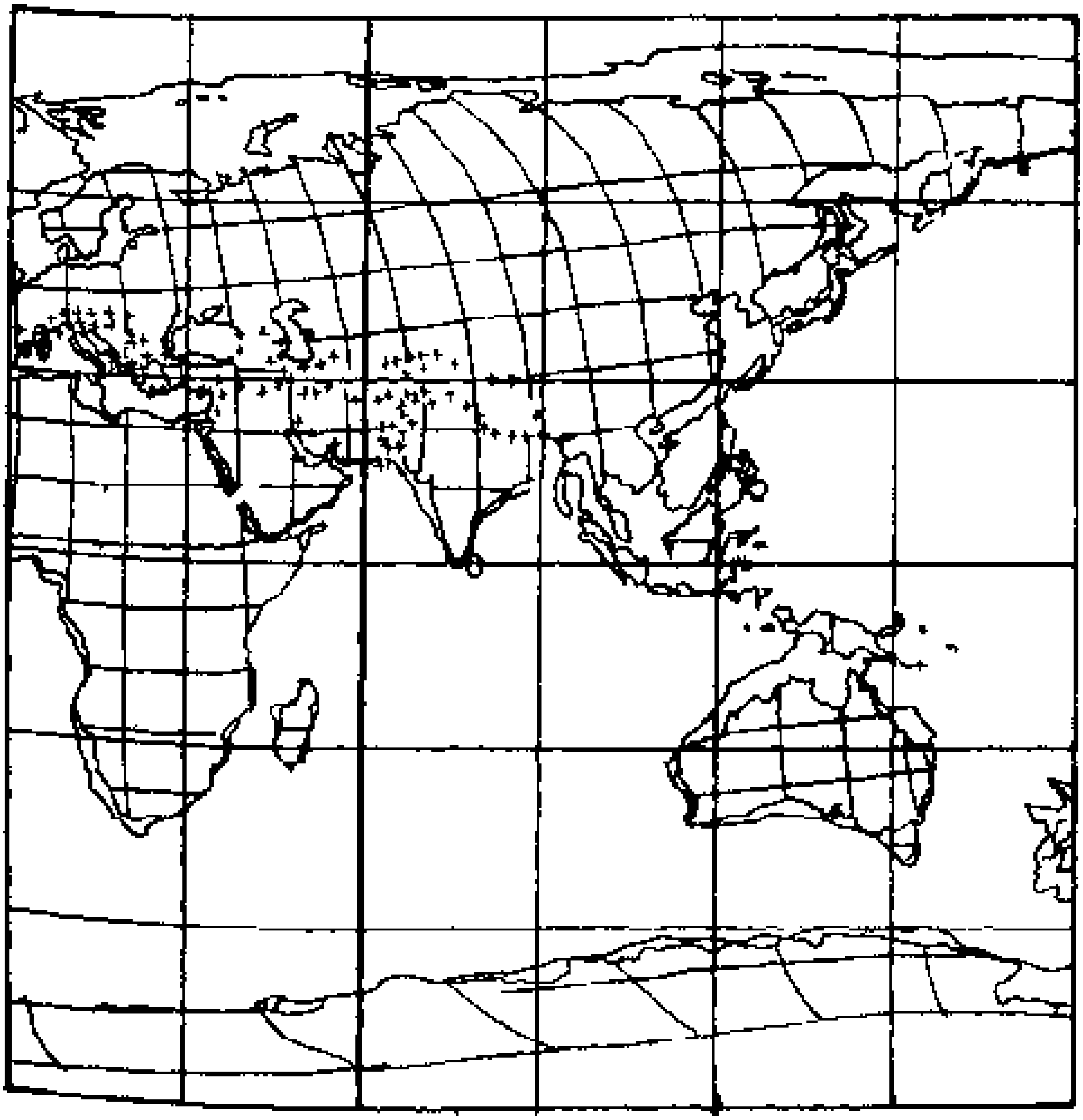


Map 3. Palaeocontinental map of the Palaeocene (60 m y; after Smith & Briden, 1979).

Lakhanpal (1988) states "As a result of orogenic movements, there was progressive shallowing and narrowing of Tethys during late Cretaceous, culminating in the splitting of the sea into two or more longitudinal basins in Eocene. By the end of the Oligocene the sea water has completely evacuated the region, giving way to fresh water or subaerial facies. As a result of vigorous elevation during Middle Miocene, a foredeep was created along the southern side of the rising Himalayas, into which the Siwalik molassic sediments were deposited. Some furrows also developed on Tibetan side, in which the Kargil molasse and other sediments of Ladakh-Karakoram areas were laid down. From Late Pliocene to Pleistocene the molassic sediments were uplifted and the continued elevation even after Pleiostocene resulted in the development of the present day structure. By the end of Palaeogene the ground was literally prepared for the development of the Himalayan land floras. Its major components were established during the Neogene and final details acquired in the Quaternary period"



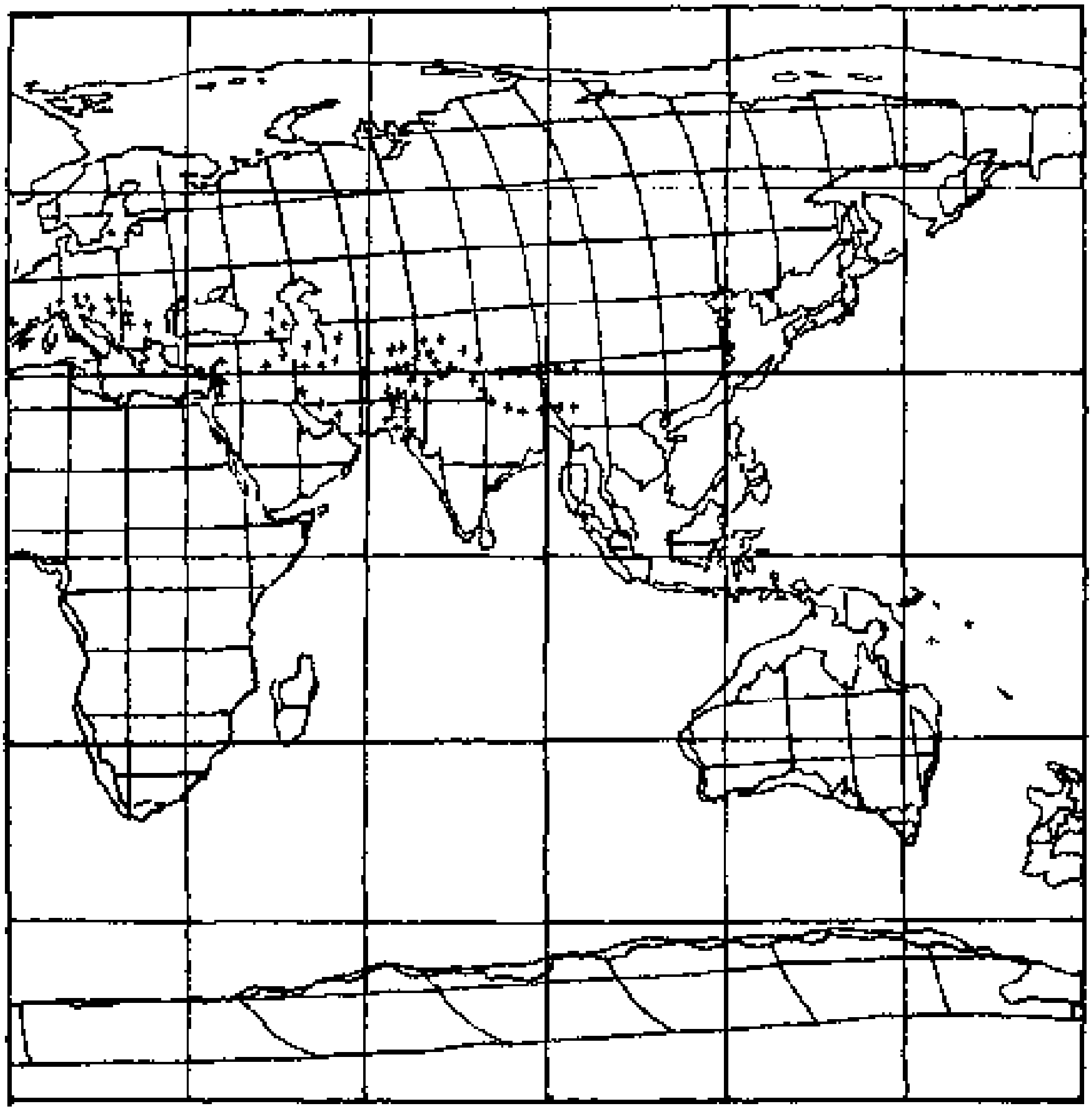
Map 4. Palaeocontinental map of the Late Eocene (40 m y: after Smith & Briden, 1979).



Map 5. Palaeocontinental map of the Early Miocene (20 m y; after Smith & Briden, 1979).

I. TERTIARY FLORA OF INDIA

Geologically India is divided into three units (1) Peninsular, (2) Extra-Peninsular and (3) Indo-Gangetic Plain. The Tertiary Flora of India can be conveniently divided into two groups Palaeogene and Neogene. The Palaeogene flora is found in Peninsular India while Neogene occurs in both the Peninsular and extra-Peninsular region. They are predominently tropical floras, made up of genera now confined to the old world. A notable feature of the Indian Palaeogene is the occurrence of a few Southern hemisphere taxa which may recall the pre-Cenozoic relationship between India and Gondwana continents to the south (Lakhanpal, 1970).



Map 6. Palaeocontinental map of the Late Miocene (10 m y; after Smith & Briden, 1979).

(a) Palaeogene vegetation of Peninsular India

During the Palaeogene period the Indian Plate got separated from the main landmass of the Gondwana, but not yet joined the Asian Plate. This was the time when angiosperms of the Indian subcontinent witness their appreciable spread and diversification. The fossil flora is represented by the elements belonging to marine, estuarine, fresh water and terrestrial habitat with both evergreen and deciduous forms. A majority of the taxa reported from Palaeogene localities find their place in the present day flora of the region. The fossil plants thus form the ancestral stock of some of the present day taxa.

The presence of African, Madagascarian, Australian and South American elements in the Palaeogene flora of Indian subcontinent is indicative of India's past connection with these Gondwanaland countries.

(i) Deccan Intertrappean Flora :

Mahabale (1966), in his presidential address to the Botany Section of the Indian Science Congress, presents comprehensive and lucid account of Deccan Intertrappean Flora and its comparison with the present day flora of the region. The plant fossils preserved in the sediments deposited between successive lava flows, the flora comprises woods, leaves, flowers, fruits and other organs representing all major groups of Plant Kingdom. Bande (1992) has reviewed and presented a comprehensive account of the Palaeogene vegetation of Peninsular India based on the megafossils. He has dealt with these elements in the following four assemblages.

(i) Rajamundry assemblage
(ii) Nagpur-Chhindwara assemblage
(iii) Bombay-Malabar-Worli Hill assemblage
(iv) Mandla assemblage

(i) *Rajamundry Assemblage* :

This assemblage is dominated by estuarine algal element and 13 species of charophytic gyrogonites. Some of the important groups are

Helimeda, Dissocladella, Terquemella, Acetabularia, Neomeris, Holosporella and *Acicularia.*

In addition to the above, three gymnospermous fossil woods belonging to Taxaceae and Podocarpaceae, viz. *Taxaceoxylon kateruense, Mesembrioxylon fusiforme* and *M. dudukurense* are also reported. Two palm taxa, viz. *Palmoxylon* *sundaram* and *Rhizopalmoxylon sundaram* showing affinities to genus *Cocos* have been described. Another fossil taxon *Sonneratioxylon dudukurense* is also reported. These elements suggest a mangrove habitat.

(ii) *Nagpur-Chhindwara Assemblage :*

Algae : Some of the important members of this assemblage are

(a) *Fresh water Algae : Spirogyrites, Oedogonites, Westielopsis, Ulothrix* like filament, *Chara sausari, Platychara raoi, P. Sahnii* and *Microchara* sp.

(b) *Marine Algae : Peyssonnelia antiqua, Distichoplax raoi, Solenospora* sp.

Fungi : Shuklania, Diplodia, Tetracosporium, Palaeosordaria, Perisporacites.

Bryophytes : Shuklanites deccani (anthocerotaceous capsule), *Riccia chitaleyii* (thallus similar to *Riccia*).

Pteridophytes : The important genera reported are : *Azolla, Rodeites, Marsilea* and *Salvinia*. A strobilus resembling *Selaginella* is also reported.

Gymnosperms : Mostly cones have been reported : *Takliostrobus alatus* and *Indostrobus bifidolepis :* show resemblance to Abitineae and also to Podocarpaceae. *Pityostrobus crassitesta :* resembles Abietineae. *Mohgaonstrobus shanii :* shows affinity with modern Araucariaceae.

Harrisostrobus intertrappea : uncertain affinity. A cycadian ovule is also reported.

Angiosperms :

(a) *Monocots :* Wood, fruits, petioles and roots of palm are of frequent occurrence.

Palmoxylon (50 spp.), *P. livistonoides* shows affinity with extant genus *Livistona*. *Palmocaulon hyphaeneoides* showing similarity with the living genus *Hyphaena*.

Other important Monocot family is Musaceae. Fossil fruit and pseudostem has been assigned to *Musa*. The leaf *Musophyllum* is assigned to Musaceae.

Cyclanthodendron sahnii having affinities with South American family Cyclanthaceae is also reported.

(b) *Dicots* : There is rich dicot assemblage of flowers, fruits and woods. The flower of *Sahnianthus parijai* and fruit of *Enigmocarpon parijai* have affinities with *Sonneratia apetala* and *S. acida*. The other noteworthy flower and fruits are *Sahnipushpam*, *Chitalepushpam*, *Harrisocarpon* and *Sahniocarpum*.

Fossil woods are mostly known from Keria and Mahurzari. The most common species being *Ailanthoxylon indicum*. The other known genera are *Simarouboxylon*, *Boswellioxylon*, *Bridelioxylon*, *Mallotoxylon*, *Tetramelioxylon* etc. from Keria and *Grewioxylon*, *Elaeocarpoxylon*, *Leeoxylon*, *Barringtonioxylon* etc. from Mahurzari. *Aeschynomenoxylon* is comparable to extant genus *Aeschynomene*. A peduncle having affinities with Nymphaeaceae is also reported.

The intertrappeans near Nawargaon contain rich floral assemblage. The fossils include 5 species of *Palmoxylon*. *Palmoxylon livistonoides* shows affinities with extant genus *Livistona* and *Palmocaulon hyphaeneoides* resembles extant genus *Hyphaene*.

The fossil wood discovered show affinities with the extant genera such as *Evodia*, *Amoora*, *Sonneratia*, *Ardisia*, *Heterophragma*, *Gmelina*, *Phyllanthus*, *Aristolochia* etc.

(iii) *Bombay-Malabar-Worli Hills Assemblage* : The fossil wood bamboo, leaflets comparable to *Acacia* and seeds similar to *Artabotrys* have been reported alongwith fossil wood of Podocarpaceae.

(iv) *Mandla Assemblage :*

(a) *Monocots :* (exclusively woods of palms) : The taxa reported from the assemblage is comparable with present day elements such as *Arenga, Licuala, Chrysalidocarpus, Hyphaene* and a fruit comparable with *Hyphaene indica.*

(b) *Dicots : Polyathia, Homalium, Hydnocarpus, Garcinia, Sterculia, Grewia, Elaeocarpus-Echinocarpus, Atlantia-Limonia, Bursera, Canarium, Gomphandra, Heynea, Aglaia, Walsura, Dracontomelum, Ailanthus, Lophopetalum, Artocarpus, Syzygium, Eucalyptus, Melaleuca Tristania, Barringtonia, Sonneratia* and *Drypetes.*

Bande (1992) discusses further the doubts raised by Borkar (1987) regarding presence of mangroves, coastal and marine taxa in the Deccan Intertrappean flora around Nagpur-Chhindwara and Mandla. He concludes his argument on this issue in the following words "It should be clear that the objections raised by Borkar against the presence of *Nipa, Sonneratia, Cocos, Distichoplax* and *Peyssonnelia* in the Deccan intertrappeans are not tenable. Occurrence of coastal and marine environment around Nagpur during Deccan Intertrappean sedimentation is also supported by palaeontological evidence (Sahni, 1983, 1984; Bhattacharya *et al.*, 1990)"

Eocene Flora of Kutch :

Lakhanpal *et al.* (1984) presented comprehensive review on the Eocene Flora. The flora comprises

Algae (3 species), *Lithothamnium* sp. cf. *L. validum, L.* sp. cf. *L. hofilli* and *Lithophyllum* sp.

The leaf impressions reported from Panandhro assemblage have been assigned to *Terminalia panandhroensis, Syzygium kachchense, Lagerstroemia patelii, Cinnamomum eokachchensis, Ficus kachchensis* and *Pandanus eocenicus.* Lakhanpal (1984) reported three species of *Dicotylophyllum* viz., *Dicotylophyllum cordatum, D. panandhroensis* and *D. quadrinervatum.* Recently, Guleria (1991) described carbonised woods of *Terminalia calamansanai* and *Sonneratia apetela* from the Rajpardi lignite mines (Bharuch District, Gujarat).

Eocene plant fossils from Fuller's earth deposits :

The assemblage belongs to Middle Eocene in age and comprises leaf and fruit-impressions belonging to *Mesua* cf. *M. ferrea*, *Garcinia* and *Calophyllum* (Lakhanpal & Bose, 1951) and a fruit of *Cocos* (Kaul, 1951). Lakhanpal (1964) later on assigned these leaves to *Mesua tertiara* and *Garcinia barooahii* respectively.

Eocene plants from Meghalaya :

Bhattacharyya (1967) described fossils of *Nipa* and *Calophyllum* from Lower to Middle Eocene beds near Cherrapunji and Laitrayngew in Meghalaya. Lakhanpal (1954, 1955) reported the following leaf impressions from Middle Eocene beds near Damalgiri in Garo hills, Assam

Nelumbium sp. comparable with extant genus *Nelumbium*

Trema garoensis comparable with *Trema orientalis*

Neolitsia sahnii comparable with *Neolitsia zeylanica*

Grewia foxii comparable with *Grewia tiliaefolia*

Bombacites orientalis compares with *Eriodendron anfractuosum/ Bombax* sp.

Bose and Sah (1964) reported a palm leaf *Sabalites* from near Laitryngew near Shillong. Bande (1972) suggests that it should be referred to genus *Phoenicites* Brongniart.

Bhattacharya (1979, 1983, 1985) has described a number of angiosperm leaf, flower and fruit impressions from

(i) West Daranggiri
   -- *Nelumbo* shows affinity with *Nelumbo nucifera*.

(ii) Rongrenggiri and Nangalbibra

Fossil plants	Compares with modern taxa
Nipa sahnii	*Nipa*
Poacites sp.	
Nelumbo nangalensis	*Nelumbo*
Litsea sp.	*Litsea*
Phoebe sublanceolata	*Phoebe*
Artocarpus garoensis	*Artocarpus*
Triumfetta rhomboideocarpa	*Triumfetta*
Heteropanax sp.	
Osmanthus eocenicus	*Osmanthus*
Ligustrum turaensis	*Ligustrum*
Antholithes oleaceaeformis	
A. campanulatum	

(iii) Garo Hills

Fossil plants	Compares with modern taxa
Leguminoceous fruits	
Leguminocarpon desmodioides	*Desmodium triquetrum*
L. derrisoides	*Derris cuneifolia*
L. millettiodes	*Millettia rubiginosa*
L. pongamioides	*Pongamia pinnata*
L. albizioides	*Albizia lucida*

Based on the Palaeogene fossil palnt evidence gathered from the different localities of Penisular India Lakhanpal (1970), Lakhanpal *et al.* (1984), Prakash (1973), Bande and Prakash (1983), Bande *et al.* (1988) and Bande and Chandra (1990) made efforts to reconstruct palaeoclimate and phytogeography of the area.

The occurrence of estuarine algae and *Cocos* in the Intertrappean beds of Rajahmundry is indicative of existence of sea shore which was little more inland than the present shore line (Bande, 1992).

The Nagpur-Chhindwara assemblage is suggestive of typical tropical climate and broadly five ecological facies are decipherable, viz.

(i) Marine	:	As is indicated by the presence of *Distichoplax*, *Peyssonnelia* and Solenoporaceae.
(ii) Mangrove	:	Suggested by the occurrence of *Sonneratia* and *Nipa*
(iii) Coastal	:	Indicated by *Cocos*

(iv) Fresh water lakes, ponds, streams, marshes : suggested by occurrence of fresh water algae, water ferns, aquatic angiosperms *Barringtonia*, *Syzygium*, *Aeschynomene*.

(v) Terrestrial and Upland : Indicated by Araucariaceae, Podocarpaceae and other arborescent angiosperms.

Araucariaceae and Podocarpaceae show wide range of altitudinal distribution from high altitude to sea level (Florin, 1963). Most of modern comparable taxa are distributed in evergreen to semi-evergreen forests of Western Ghats and north-east India and some of the elements in dry deciduous forests. It is, therefore, deduced that the depositional places were located at the mouth of the river and in the vicinity of the sea.

The Mandla assemblage exclusively comprises angiosperms, dominated by arborescent species. The components when compared with extant taxa are suggestive of evergreen to semi-evergreen vegetation. Bande and Chandra (1990), based on the habit and habitat of modern taxa, concluded that "forest was constituted by water loving forms like *Syzygium*, *Drypetes*, *Barringtonia*, low trees and shrubs like *Garcinia*, *Gomphandra*, *Grewia*, *Heynea*, *Atalantia* *Limonia*, *Tristania*, *Polyalthia* etc., moderate to large sized trees like *Bischofia*, *Bursera*, *Dracontomelum*, *Hydnocarpus* and *Walsurea* and some very large trees like *Artocarpus*, *Canarium*, *Lophopetalum* and *Sterculia* with their crowns projecting up in the sky through the main forest canopy. The palm genera like *Chrysalidocarpus*, *Licuala* and *Arenga* must have constituted the understorey but *Hyphaene* must have occupied some open area. Presence of *Sonneratia* indicates brackish water conditions, most probably at some distance from the main forests".

Bande and Prakash (1982) based on the analysis of fossil components of Nagpur Chhindwara & Mandla assemblage envisaged "central India had a climate similar to the present day climate of Western Ghats. It has been postulated that the area enjoyed a humid tropical climate with an annual rainfall over 2000 mm, an uniform temperature throughout the year and long duration of rainy season. The factors responsible for the occurrence of such a type of climate were:

(i) almost equatorial position of the area during that period.

(ii) presence of sea in near vicinity and

(iii) probable absence of Western Ghats as main barriers in the path of the southwest monsoon currents.

The northward drift of the Indian Plate, the withdrawal of sea and uplifting of the Western Ghats in the post-trappean times resulted in the establishment of the present day climate and tropical dry deciduous to moist deciduous vegetation in central India against a tropical wet evergreen to semi-evergreen forest of the past"

Lakhanpal *et al.* (1984) have analysed the Panandhro assemblage belonging to the Lower Eocene and attempted to decipher the palaeo-environment around the basin. They stated that presence of marine algae is suggestive of transgression of sea in the Kutch area during the deposition of their sediments. The occurrence of angiosperm species, which are comparable to modern taxa, is indicative of moist evergreen to deciduous vegetation around Panandhro. The littoral and swampy components like *Lagerstroemia speciosa*, *Syzygium* sp. and *Pandanus tectorius* are indicative of marshes around this locality.

The Middle Miocene Flora of Kapurdi (Rajasthan) is typically tropical in character. The occurrence of *Mesua* cf. *M. ferrea*, *Garcinia* and *Calophyllum* indicates a moist tropical climate with evergreen forest around Kapurdi. Presence of *Cocos* suggests that shore line was not far away from the locality during Middle Miocene.

Fossil plants described from near Damalgiri in the north-east are indicative of presence of evergreen to semi-evergreen vegetation and a tropical to subtropical climate around this locality in Middle Miocene. *Trema orientalis* and *Neolitsea* *zeylanica*, identified from these deposits, are small to middle sized evergreen trees. *Grewia tiliaefolia* is distributed in east tropical Africa and peninsular and northeastern parts of India. *Eriodendron* occurs in America but *E. anfractuosum* is moderate-sized deciduous tree occurring in Burma, Andaman, Malaya Peninsula and the Archipelago, western parts of Indian Peninsula and tropical America. *Bombax malabaricum* another comparable form is well distributed in tropical Himalaya and throughout the warmer forests of India to Burma and Sri Lanka and also Java and Sumatra. *Bombax insigne* another species of the genus, is a common tree of mixed deciduous forests extending into evergreen semi-evergreen forests. It is essentially a tropical tree occurring in Burma, Andaman, Chittagong, Malaya Peninsula and Western Ghats of India (Lakhanpal, 1954).

Occurrence of *Nipa* in the Lower to Middle Eocene beds around Cherrapunji and Garo Hills indicates an estuarine condition in both these areas. Presence of *Nelumbo* suggests fresh water lakes or ponds. The occurrence of *Calophyllum*, *Artocarpus*, *Litsea* sp., *Phoebe*, *Ligustrum* and *Osmanthus*, all of which are tropical to subtropical in habitat, suggests a depositional site, especially around Rongrengiri and Nangalbibra in Garo Hills very similar to that around Mohgaonkala during Deccan Intertrappean sedimentation. It is interesting to note that atleast four families, viz. Palmae, Guttiferae, Nymphaeaceae and Moraceae and two genera *Nipa* and *Artocarpus* are common in Deccan Intertrappean flora of central Indian and Lower to Middle Eocene assemblage of Meghalaya.

Bande (1992) summarises the palaeoclimate as "An overview of the palaeogene flora of India broadly suggests that wet evergreen to semi-evergreen forests and tropical climate in Central India, prevalent during early Palaeogene, i.e. during Deccan Intertrappean sediments, continued to prevail in the west as well as north-east India at least till Middle Miocene. It was only in the post-Palaeogene period, after joining of the Indian Plate with the Asian Plate that the Indian subcontinent started acquiring its present day topography resulting in the onsetting of the current vegetational and climate pattern of this sub-continent"

(ii) Palaeo-Phytogeography and Plant Migration

The Palaeogene represent a period when Indian Plate had already broken away from rest of the continents of the Gondwanaland but had not yet joined the Asian Plate. It is, therefore, obvious to expect the existence of some of taxa of the

Palaeogene Peninsular India having affinities with those presently confined to the other countries belonging to Gondwanaland of the past. An analysis of the fossil plants reported from the Palaeogene period of Peninsular India does support this assumption. A few examples from these components are :

Indian fossil plants	Showing resemblance	Native of
Rodeites	*Regnellidium* (Water fern)	Brazil
Cyclanthodendron	*Cyclanthus*	Tropical America
Simarouboxylon	*Simarouba*	do
Hyphaene (fruit and also petiole)	*Hyphaene* (2 species in India)	41 species occur in Tropical & sub-tropical areas of Africa & Arabia.
Chrysalidocarpus		Madagascar
Eucalyptus		Australia
Tristania Melaleuca		do-

Bande (1992) while discussing the phytogeography and plant migration during the Palaeogene period observes "It is essential to rethink regarding position of India in relation to Australia in the past. Further, if view proposed by some that before the Gondwana break-up Australia and India were in juxtaposition to each other is accepted, then what was the time of separation of India and Australia?. Even after the separation took place, were these two landmasses inter - connected through some land bridges till as late as the Palaeogene? Can it be presumed that during the Palaeogene the present day tropical Africa, Madagascar, India and Australia enjoyed a similar type of climate permitting the existence of at least some common plant taxa on this? It should be interesting to note that at least a few Indian Palaeogene families like Myrtaceae, Lauraceae, Sterculiaceae, etc. have been recorded from the Palaeogene deposits of Antarctica also (Birkenmajer & Zastawniak, 1986)".

The Indian flora acquired its composition after the Indian Plate joined with Asian Plate and establishment of land connection between India and South-East Asia (Bande & Prakash, 1986). An analysis of Palaeogene flora of India and Palaeogene vis-a-vis Palaeogene as well as Neogene flora of South-East Asia will show migration of various elements between these two landmasses.

Some of the genera which appear to have migrated from India to South-East Asia during the Neogene are *Sterculia, Grewia, Polyalthia, Gomphandra, Lophopetalum, Syzygium* and *Sonneratia*. Similarly the most significant floral components which were added to the Indian flora from South-East Asia during the post-Palaeogene period are Dipterocapaceae and several genera of Leguminosae.

The Palaeogene flora of Peninsular India constituted the parental stock for the present day flora of India. This stock is replenished with the elements from South-East Aisa, Asia, Africa and also Europe during post-Palaeogene period. The intermingling of these elements and some other factors have resulted in giving the present shape to Flora of Indian subcontinent.

(b) Neogene vegetation of Peninsular India :

Guleria (1992) summarises the Neogene vegetation of the Peninsular India in the following words "during Neogene period the whole of Peninsular India was covered by luxuriant tropical evergreen to deciduous forests. Occurrence of Dipterocarpaceae from East to West and North to South alongwith other common elements suggests a more or less uniform warm tropical climate throughout the Peninsula. A gradual decrease in rainfall during Neogene due to northward shift of the Indian Peninsula from equator and growing continentality caused by the rise of Himalayan mountains is decipherable. Further decrease in rainfall towards the end of Neogene is evidenced by the complete eradication of dipterocarps and the appearance of dry or desertic conditions towards the end of Pliocene in western

(Gujarat and Rajasthan) and south-eastern (Cuddalore) part of the Peninsula is noticeable. Large scale migration and admixture of floras took place between the Indian Peninsula, South-East Asia and Africa due to land connections by the Neogene. Wide spread occurrence of Dipterocarpaceae and dominance of legumes together with Sapotaceae, Ebenaceae and Rosaceae etc. distinguishes the Neogene flora of Peninsular India from the Palaeogene".

Lakhanpal (1970) while discussing tertiary floras of India states "A notable feature of the Indian Palaeogene is the occurrence of a few southern hemisphere forms like *Podocarpus*, *Araucariaceae*, *Proteaceae* and *Casuarina*. Podocarpaceae and Araucariaceae were characteristic during Mesozoic era and continued into the Cenozoic. Podocarps gradually decreased through the Tertiary and only two species have survived, *Podocarpus wallichianus* in Southern India and *P. neriifolius* in Eastern India. On the other hand araucarians are completely absent from the living flora of India and there is no record even in Neogene." A comparison of the Palaeogene and Neogene floras of India by Lakhanpal (l.c.) shows that the following new families have appeared in the Neogene time ; Parkeriaceae, Gleicheniaceae, Abietineae, Anonaceae, Dipterocarpaceae, Sterculiaceae, Rhamnaceae, Rosaceae, Alangiaceae, Compositae, Ericaceae, Sapotaceae, Ebenaceae, Verbenaceae, Moraceae, Fagaceae, Juglandaceae. Leguminosae, which was meagrely represented before, became abundant in Neogene period. Dipterocarpaceae, with centre of origin in Western Malaysia, spread eastward to the Philippines area and northward through Myanmar to India. From India the Diptocarpus spread westward into Africa probably via Arabia. The sudden abundance of Leguminosae in Neogene of Malaysia, India and Africa suggests that member of this family also migrated side by side with Dipterocarpaceae.

Neogene flora of Peninsular India can be broadly divided into five groups.

1. *Western India Neogene Flora :*

   i) Gujarat flora (Kutch and Saurashtra basins)
   ii) Rajasthan flora (Jaisalmer and Bikaner basins)
   iii) Konkan flora
   iv) Kerala coast flora (Kerala Lakshadweep basins)

2. *East Coast Neogene Flora :*
   i) Rajahmundry flora (Krishna-Godavari basins)
   ii) Neyveli lignite flora
   iii) Cuddalore series flora

3. *North East Neogene Flora* (Assam-Arakan basins)

4. *Bengal and Bihar Neogene Flora*

5. *Central India Neogene Flora*

1. *Western India Neogene Flora*

(i) *Gujarat (Kutch and Saurashtra basins) :* The fossil localities lie adjacent to the Tropic of Cancer and hence fall in the tropical region. The fossil assemblage comprises four genera of calcareous red algae *(Aethesolithon, Archaeoporolithon, Lithophyllum* and *Mesophyllum)* indicating marine habitat, transgression and regression of the sea in Kutch during Miocene; and a gymnosperm *(Podocarpoxylon)*, three monocots and over 25 dicot genera. The higher plant fossils comprise petrified woods, impressions of leaf, fruits and seeds and are comparable with the following modern genera :

Afzelia-Intsia, Albizia, Bauhinia, Barringtonia, Cassia, Ceriops, Chlorophora, Cinnamomum, Cynometra, Dialium, Dipterocarpus, Euphorbia, Ficus, Gluta, Isoberlinia, Lagerstroemia, Milletia, Milletia-Pongamia, Murraya, Podocarpus, Pterospermum, Schleichera, Sonneratia, Sterculia and *Terminalia*. At present only *Bauhinia, Cassia, Ceriops, Ficus* and *Sterculia* are represented in flora of Kutch. The floristic analysis presented by Guleria (1992) clearly shows that Kutch had been the meeting ground of eastern elements, viz., *Cinnamomum, Dipterocarpus, Euphorbia, Gluta, Murraya, Pterospermum, Schleichera* etc. and western elements particularly African, viz., *Isoberlinia, Chlorophora* etc. This could be possible due to establishment of land connections between Malaya, India, Arabia and East Africa during Neogene. The presence of *Ceriops, Sonneratia, Barringtonia* and *Lagerstroemia* indicates the existence of littoral and riverine or swampy conditions. Presence of other elements indicates luxuriant vegetation and warm condition with plenty of rainfall during Neogene in contrast to present day xeric condition.

(ii) *Rajasthan (Jaisalmer and Bikaner Basins)* : Guleria, 1984b, 1986, 1990a, 1990b, 1991, 1992 reported 25 genera of petrified woods. Except for two gymnosperms *Araucaria-Agathis* and *Podocarpus* all other fossils belong to dicot genera. The fossil wood recorded are comparable with the modern taxa such as *Afzelia-Intsia*, *Anisoptera*, *Baphia*, *Bauhinia*, *Dialium*, *Dipterocarpus*, *Copaifera-Detarium-Sindora*, *Cordia*, *Cynometra*, *Entandrophragma*, *Erythrophleum*, *Khaya*, *Lagerstroemia*, *Mangifera*, *Millettia-Pongamia*, *Ormosia*, *Ougeinia*, *Pterocarpus*, *Sterculia*, *Terminalia*, *Tetrapleura* and *Ziziphus*.

The presence of evergreen elements such as *Araucaria- Agathis*, *Podocarpus*, *Anisoptera* and *Dipterocarpus* indicates luxuriant vegetation and tropical humid climate. However, the majority of genera belong to deciduous type. It indicates a trend towards shift in the rainfall. The occurrence of African elements in Rajasthan further supports this view. Nerverthelèss, the rainfall seems adequate for fairly thick forest cover during Pliocene in contrast to the desertic conditions encountered in the area today. As stated by Guleria (1992), the occurrence of typical African genera such as *Baphia*, *Entandrophragma*, *Erythrophleum*, *Khaya* and *Tetrapleura* are phytogeographically significant since they are basically confined to tropical Africa and Madagascar. They indicate migration of plants from East Africa to western part of India. They have not moved further to eastern or southern India. These have not been recorded from other Neogene deposits. These elements perished from the Jaisalmer and Bikaner region due to progressive increase in aridity.

The desertic conditions in Rajasthan are result of post-Pliocene climate changes as also has been inferred in Kutch. The probable means of migration of African taxa are high velocity of winds, birds and animals. The possible routes could be :

(i) Egypt to northern Arabia to Persia to Baluchistan and Sind to Western India.

(ii) Ethiopia to southern Arabia to Persia to Baluchistan and Sind to Western India.

(iii) *Konkan Flora :* The fossils in form of compression or mummified leaf remains or carbonised fruits have been reported from the lignite beds of Ratnagiri District by Kulkarni and Phadtare, 1980; Dalvi & Kulkarni, 1982; Phadtare & Kulkarni, 1984; Shinde & Kulkarni, 1989. These elements are comparable with the present day genera such as *Alangium, Diospyros, Dracontomelum, Eugeissona, Garcinia, Nothopegia, Nipa* and *Nyssa* and ranges from deciduous to evergreen trees. The occurrence of *Nipa* is indicative of estuarine condition which even now exists at Ratnagiri allowing the growth of mangroves.

Nipa no longer occurs in Ratnagiri. *Garcinia, Diospyros, Nothopegia* are presently found in Western Ghats. *Nyssa* is confined to Sikkim, North Bengal and Assam extending further to Malayan region. *Eugeissona* and *Dracontomelum* are typical Malaysian genera; the latter genus also occurs in damp places along streams and river of Andaman and Nicobar Islands. The assemblage indicates a warm humid palaeoclimate.

(iv) *Kerala Coast Flora* (Kerala-Lakshadweep Basin) : The Neogene flora comprises carbonised woods deposits of Kerala coast. The floral components are distributed over 15 families and 20 genera as reported for by Awasthi and Ahuja (1982), Awasthi and Panjwani (1984), Awasthi and Srivastava (1989, 1990, 1992). These taxa are comparable with the present day genera such as *Anisophyllea, Anisoptera, Calophyllum, Canarium, Careya, Cassia, Cynometra, Diospyros-Maba, Dryobalanops, Fagara-Acronychia, Gluta, Gonostylus, Hopea, Hydnocarpus, Leea, Litsea-Cinnamomum, Payena-Palaquium, Shorea, Swintonia* and *Terminalia.* Most of these elements still occur in Tropical Evergreen forests found in Western Ghats. The presence of *Anisoptera, Dryobalanops, Gonystylus, Swintonia*, which are rain forest trees suggest high rainfall and excessive humid condition at the time of deposition. Their absence today is suggestive of shift in the amount of rainfall in the Western Ghats since Neogene.

East-Coast Neogene Flora :

(i) *Rajahmundry Flora* (Krishna-Godavari Basins). A large number of fossil taxa have been described by various palaeobotanists (see Guleria, 1992). However, there is a confusion regarding the establishment of the age of the Rajamundry deposits. In absence of the index fossils of Neogene, the Rajamundry cannot be regarded as belonging to Miocene or Neogene period.

(ii) *Cuddalore Series flora* (Cauvery Basin) : The Neogene flora of Cuddalore series of South Arcot district, Tamil Nadu, has been thoroughly investigated. It consists of petrified woods. The flora has been critically reviewed by Ramanujam (1968), Lakhanpal (1970, 1973) and Awasthi; (1974b). The fossil flora consists of 78 species belonging 48 genera. The flora is predominently angiospermous and dominated by dicots. Monocots are represented by 3 species of palm. Gymnosperms are represented by 5 species of Podocarpaceae and one of Taxodiaceae. The fossils are comparable with modern elements such as :

Podocarpus, Livistona, Xanthophyllum flavescens, Callophyllum wightianum, C. inophyllum, C. tomentosa, Mesua ferrea, Dipterocarpus indicus, D. tuberculatus, Dryobalanops oblongifolia, Anisoptera, Shorea, Hopea, Sterculia-Firmiana, Ailanthus, Euphoria longana, Mangifera altissima, Gluta, Millettia pendula, Pongamia glabra, Erythrophloem?, Pterogyne?, Pterocarpus, Peltophorum, Cynometra, Tamarindus?, Afzelia-Intsia, Bauhinia, Acacia, Sindora supa, S. siamensis, S. velutina, Albizia amara, Cassia javanica, Pericopsis mooniana, Parinarium corymbosum, Terminalia, Anogeissus, Barringtonia angusta, Careya arborea, Lagerstroemia flos-reginae, L. lanceolata, Sonneratia apetala, Duabanga grandiflora, D. moluccana, Chrysophyllum roxburghii, Diospyros-Maba, Diospyros assimilis, Alangium javanicum, A. meyeri, Holoptelea integrifolia Castanopsis, etc.

The presence of Moist Evergreen elements, viz., *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Calophyllum, Mesua, Gluta, Cynometra, Afzelia-Intsia, Alangium, Duabanga, Sonneratia* and *Podocarpus* alongwith other deciduous trees suggests the existence of luxuriant forests and high precipitation during Mio-Pliocene. Most of these elements are presently confined to Western Ghats and Assam region.

The absence of these taxa in the present day flora of Cuddalore indicates drastic change in climate which has become drier since Mio-Oligocene time. The occurrence of number of Indo-Malayan components is quite significant.

(iii) Neyveli lignite flora :

The known megafossils of the lignite are based on the carbonised woods, dispersed xylinoid and non-xylinoid tissues. The fossil taxa, comparable with the following extant taxa :

Phoenix, Dracaena, Calophyllum/Mesua, Dipterocarpus, Hopea plagata, Shorea robusta, Sterculia, Grewia microcos, Gluta, Bouea burmanica, Cassia/Acacia, Bauhinia foveolata, B. malabarica, B. racemosa, B. retusa, Parinari indicum, P. travancoricum, Altingia excelsa, Carallia lucida, Terminalia, Lagerstroemia indicum, Careya, Randia uliginosa, Bassia-Mimusops, Diospyros-Maba, Diospyros assimilis, Melodinus monogynus, Cryptostegia grandiflora, Litsea, Cordia myxa, Excoecaria agallocha.

The existence of these fossils is suggestive of humid tropical condition during the formation of lignite.

3. *North-east Neogene Flora* (Assam-Arakan Basin)

The fossil flora comprises predominently dicotyledonous woods, a fruit of *Nipa* and a few dicot leaves. Till date 45 genera spreaded over 20 families have been reported. Some of the important taxa are *Adenanthera, Afzelia-Intsia, Albizia, Anisoptera, Antiaris, Artocarpus, Bauhinia, Barringtonia,* *Bischofia, Bursera-Garuga, Calophyllum, Careya, Cassia, Cinnamomum-Dehasia, Cynometra, Diospyros, Dipterocarpus, Duabanga, Elaeocarpus, Gymnosporia, Echinocarpus, Garuga, Gluta, Heritiera, Holigarna, Kayea, Kingiodendron, Koompassia, Lagerstroemia, Lannea-Odina, Madhuca, Mangifera, Mallotus, Millettia, Nipa, Ougeinia, Phoebe, Phyllanthus, Pometia, Sindora-Capaifera-Detarium, Shorea, Sterculia, Swintonia, Terminalia* and *Vitex*.

All these taxa are indicative of warm tropical rain forests conditions during Neogene. Most of these taxa still grow in the area. It shows that the vegetation and climate had not changed much since the Neogene. The presence of *Nipa* in Garo Hills, *Afzelia-Intsia* in Cachar hills is suggestive of existence of coastal condition in the area during Neogene. Obviously, the sea had receded to its present position since Neogene.

The presence of taxa like *Anisoptera, Dipterocarpus, Koompassia, Pometia* indicates migration of Indo-Malayan elements in the flora.

4. *Bengal and Bihar Neogene Flora :*

A. *West Bengal* (Bengal Basin)

The Neogene exposure of Midnapur, Bankura, Birbhum and Bardhaman districts of West Bengal have provided rich fossil assemblage. The flora consists of 26 genera belonging to 10 families of fossil woods. A palm and an araucarian wood had also been reported. The fossil woods are comparable with the modern taxa such as *Afzelia-Intsia, Anisoptera, Agathis-Araucaria, Calophyllum, Canarium, Cassia, Cynometra, Dipterocarpus, Mangifera, Dracontomelum, Gluta, Kayea, Koompassia, Laurinoxylon, Shorea.*

The fossil flora is indicative of warm tropical climate.

B. *Bihar*

Most of the fossils recovered from Chhota Nagpur (Bihar) comprise leaf impressions, though some flower and fruit impressions have been found. Number of fossil woods are very limited. These elements have been identified as follows : *Shorea robusta, Sterculia villosa, Pterogata elata, Grewia tiliaefolia, Evodia meliaefolia, Murraya paniculata, Garuga pinnata, Spondias pinnata, Mangifera indica, Erythrina suberosa, Millettia auriculata, Ougenia oojeinense, Bauhinia* sp. cf. *B. purpurea, Hopeoxylon speciosu'n, Combretum decandrum, Terminalia tomentosa, Mitragyna parviflora, Schleichra oleosa, Madhuca indica, Lagerstroemia* sp. cf. *L. parviflora, Diospyros montana, Vitex negundo* var. *incisa, Alstonia scholaris, Cryptolepis buchanani, Mallotus philippensis, Ficus foveolata, F. glaberrima, F. tomentosa, Dillenia* sp. and some fruits of *Ziziphus xylopyrus, Z. mauritiana, Dalbergia sissoo.*

It is worth noticing that Gymnosperms are absent and so also *Dipterocarpus* and *Anisoptera* which were widely distributed upto Pliocene in India as reported from Kutch and Rajasthan. Amongst Dipterocarpaceae only *Shorea robusta* is represented which grows relatively in drier parts. This flora is continuing till today.

5. *Central Indian Neogene Flora :*

The angiospermous fossils (leaf impressions) pertaining to Mio-Pliocene period belonging to Katni Formation of Madhya Pradesh area reported by Yadekar and Pitchai Muthu (1988). These fossils comprise leaf impressions and are comparable with the modern taxa such as *Millettia* sp., *Lagerstroemia indica, Ficus infectoria* and *Rumex acetosella.*

(c) Neogene vegetation of other regions :

The information is very scanty and does not throw any light on the palaeoclimate.

1. *Andaman and Nicobar Islands Neogene Flora :*

Gee (1926) was the first to report the occurrence of fossil red algae *Lithothamnion* which is now recognised as *Archaeolithothamnium*. Other members of the assemblage are *Aethesolithon, Lithothamanium* and

Neosolenopora. No other Megafossils have been reported from this area. It is difficult to throw light on the past flora and climate of the Islands. A carbonised lauraceons wood from the Eocene of Baratang Island has also been reported.

Guleria (1992) who reinvestigated the Neogene vegetation of Peninsular India concludes as follows "The Neogene vegetation of Peninsular India is mainly represented by dicotyledonous woods which are widely distributed throughout the peninsula. Palms are infrequent and gymnosperms rare.

During Neogene entire peninsula was covered by rich vegetation since the climate must have been more or less uniform on account of situation of the Indian peninsula in the tropical zone.

All the floras from different basins show very close similarity in their composition as most of the genera are common. The wide distribution of tropical rain forest family Dipterocarpaceae from East to West and North to South alongwith other genera clearly indicates a more or less uniform tropical moist climate throughout the Peninsular India during the Neogene.

Aridity could have gradually increased towards the close of Neogene due to the growing continentality caused by the rise of Himalayan mountains and disappearance of the Tethys sea in the North. This resulted in the complete eradication of dipterocarps from Kutch, Rajasthan, Cuddolore and their recession from the western Himalayan foothills to north eastern India.

There were large scale migrations and admixture of floras over Malaysia, India, Arabia and Africa during Neogene due to establishment of land connections by Early Miocene. This was most probably the time when dipterocarps migrated into India, colonised the Peninsula and spread westwards to Africa via Rajasthan, Kutch and Arabia. Like wise some genera did migrate into India from Africa as seen particularly in the flora of Kutch and Rajasthan.

The presence of some families and genera such as Dipterocarpaceae, Ebenaceae, Rhamnaceae, Sapotaceae, *Afzelia-Intsia*, *Gluta*, *Swintonia* alongwith the dominance of legumes distinguishes the Neogene flora from the Palaeogene flora of India".

2. *Siwalik Succession :*

Awasthi (1992) presented a comprehensive review of palaeobotanical records from Neogene Himalaya and attempted to reconstruct the vegetation pattern and interpret the palaeoclimate prevailing in the region during Siwalik period. The recovery of palynofossil from Kasauli and Dagshai formation is indicative of presence of subtropical to temperate vegetation in the upper regions of the newly uplifted Himalayas. However, in contrast a rich assemblage of the megafossils from the Siwaliks is indicative of widespread occurrence of tropical to evergreen to moist deciduous mixed forests in the lowland sub-Himalayan zone during Middle Miocene-Pliocene. Awasthi (1992) further states "The assemblage is dominated by wet-evergreen dipterocarps and associated taxa, most of which are known to have entered the Indian subcontinent from South-East Asia during Miocene and subsequently spread all over and finally reached the lower slopes of sub-Himalaya. This has resulted increase in the diversity of tropical vegetation"

The post-Pliocene orogeny of Himalaya brought great changes in the topography and climate which adversely affected the vegetation pattern of the region. The Eearly and Middle Siwalik tropical evergreen forests whose chief components are *Anisoptera, Dipterocarpus, Hopea, Shorea,* (other than *Shorea robusta*), *Polyalthia, Calophyllum, Aphanamixis, Dysoxylum, Gluta, Dracontomelum, Mangifera, Swintonia, Cynometra, Koompassia, Ormosia, Pongamia, Sindora, Duabanga, Diospyros* spp., *Myristica* etc. started dwindling towards the end of Middle Siwalik and subsequently disappeared from the western and central sectors, though a few taxa like *Mangifera, Litsea, Cinnamomum, Bauhinia, Dalbergia, Ficus,* etc. continued to adjust to the new climatic conditions. Extinction of tropical evergreen taxa and further rise of Himalaya gave way to proliferation and diversification of tropical and subtropical moist deciduous to dry deciduous temperate vegetation in the lower and higher slopes, respectively as is also evidenced from palynological records.

The following three major sedimentary zones have been identified in the Himalayan orogenic belt :

1. The sub-Himalayan zone
2. The lesser Himalayan zone
3. The Tethys Himalayan zone

The sub-Himalayan zone represents the Siwalik rocks of Neogene age. These extend from Potwar Plateau in the west to Arunachal Pradesh in east, cover a distance of *ca* 2400 km in length. These are generally 20-25 km in width. These are formed by accumulation of alluvial detritus into long narrow foredeep derived from the rising Himalayas during Middle Miocene to Lower Pleistocene. The foredeep was formed as a sequel to the collision of Indian Plate with Laurasia and complete evacuation of Tethys sea during Oligocene. During the final phase of the rise of Himalaya in Pleistocene-Recent, the Siwalik sediments were also upheaved, folded and faulted forming a continuous mountain range of relatively low height ranging from 1000 to 1200 m above m.s.l.

A large number of fossiliferous localities from Palandri in the West to Pasighat in the East (Arunachal Pradesh) have been explored by various workers. The information generated by these explorations and investigation of mega-fossils has helped a lot in deciphering palaeoecology and palaeogeography of the region.

The Siwaliks

(a) Lower/Middle Siwalik (Middle/Upper Miocene) :

Grasses (*Poacites sivalicus* Sahni) occurred in Poonch region of the Jammu & Kashmir State.

The vegetational complex in the Kalka region in Himachal Pradesh (the foothills of Kasauli, Koshalia river in the Nahan formation and Nalagarh : Prakash, 1972, Table 3, 1979; Awasthi, 1982) comprised :

Albizinium eolebbekianum
Caryoxylon pondicherriense
Cassinium borooahii
C. prefistulai
Cynometroxylon indicum
Dicotylophyllum sp.
Dipterocarpoxylon nalagarhense
D. premacrocarpum
D. sivalicus
Dracontoxylon palaeomangiferum
Dryoxylon nahanai
Millettioxylon pongamiensis
Pahudioxylon indicum

In the Dehra Dun region in Uttar Pradesh (from Mohand Kundian, Balugoloa, Hardwar, Kalagarh and Tanakpur : Prakash, 1972, Table 3, 1979; Awasthi, 1992), the vegetational complex was :

Anisopteroxylon jawalamukhi
A. kalagarhensis
Bauhinioxylon indicum
Berchemia baluguloensis
Cassinium barooahii
Cynometroxylon indicum
C. sivalicus
Dipterocarpoxylon parabaudii
D. sp.
Dipterocarpus sp.
Diospyros embryopterisites
Ebenoxylon miocenium
Fissistigma senii
Glutoxylon kalagarhense
Lagerstroemia sp.
Meliaceaephyllum mahagonites
Pahudioxylon indicum
Parinarioxylon kalagarhense
Persea punyagiriensis
Polyalthioxylon indicum
Sterculioxylon kalagarhense
Terminalia sp.
Ziziphus sivalicus

It is believed (Prakash, 1979) that some of these plant fossils show proximity to the following extant taxa.

Afzelia bipindensis
A. martabanica
Albizzia lebbeck
Anisoptera scaphula
Berchemia floribunda
Careya arborea
Cassia fistula
C. siamea
Cynometra cauliflora
C. polyandra
C. ramiflora
Dalbergia sissoo
Diospyros kurzii
Dipterocarpus baudii
D. dyeri
D. indicus
D. macrocarpus
Dracontomelum mangiferum
Ficus cunea
Fissistigma wallichii
Millettia prainii
Polyalthia simiarum
Smilax macrophylla
S. roxburghiana
Ziziphus incurva

The Upper Siwaliks (*Pliocene*)

During the Tatrot Formation the higher plant life comprised ***Boraginocarpus lakhanpalii*** (Mathur, 1974) and *Litsea bhatiai* Mathur, the latter resembling modern *Neolitsea pallens* (D. Don) Momiyama and Hara.

Palmoxylon wadiai and *P. jamuense* together with grasses (Poacites) comprised the vegetation in Jammu region (Sahni, 1964; Mathur, 1978).

On the India/Nepal border at Bhikhnathoree in West Champaran District the vegetational complex was : *Ziziphus mauritiana* and species of *Mangifera, Bauhinia, Indigofera, Dalbergia, Litsea, Cinnamomum, Ficus, Gardenia, Toona, Aphanamyxis, Kydia* and members of *Leguminosae* (Lakhanpal & Awasthi, 1983).

Awasthi (1992) published Siwalik floristic compositions in tabular form from number of assemblages which are reproduced below. The data comprises family/fossil taxa, comparable extant species, broad distribution of comparable extant species and forest type.

SIWALIK FLORISTIC TABLES

(Awasthi, 1992 with deletion of author's name)

Table-1. Balugoloa Assemblage (Himachal Pradesh)

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
SMILACACEAE			
Smilax sp.	*Smilax roxburghiana* *S. macrophylla* *S. prolifera*	---	---
ANNONACEAE			
Fissistigma senii	*Fissistigma bicolor*	Northeast India	Evergreen
F. siwalika	*F. rubiginosum*	Assam, Bangladesh, Myanmar, Thailand Borneo	Evergreen
DIPTEROCARPACEAE			
Dipterocarpus siwalicus	*Dipterocarpus tuberculatus*	Northeast India, Andaman Islands, Myanmar, Malaya	Evergreen
RHAMNACEAE			
Berchemia balugoloensis	*Berchemia floribunda*	Sub-Himalayan region, North-east India	Evergreen

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
Ziziphus siwalicus	*Ziziphus incurva*, *Z. xylopyrus*	India, Myanmar	Moist deciduous to dry deciduous
FABACEAE			
Dalbergia (fruit)	*Dalbergia sissoo*	Greater part of India	Deciduous
COMBRETACEAE			
Terminalia balugoloensis	*Terminalia alata* var. *nepalensis*	Sub-Himalayan tracts, Punjab eastwards to Myanmar	Deciduous
LYTHRACEAE			
Lagerstroemia sp.	*Lagerstroemia indica*	---	---
MORACEAE			
Ficus precunea	*Ficus cunea*	Himalayan foot-hills, Assam region, Bangladesh	Evergreen

Table-2. Nalagarh Assemblage

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
DIPTEROCARPACEAE			
Dipterocarpoxylon siwalicus	*D. indicum*	Western Ghats	Evergreen
	D. turbinatus *D. gracilis*	Northeast India, Andaman Islands, Malaya Peninsula	
D. nalagarhense	*D. dyeri*	Malaya Peninsula	Evergreen
D. premacrocarpum	*D. macrocarpus*	Northeast India, Myanmar	Evergreen
MELIACEAE			
Aglaia nahanensis	*Aglaia edulis*	Northeastern India, Bangladesh, Myanmar, Malay Peninsula	Evergreen

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
ANACARDIACEAE			
Dracontomelumoxylon mangiferumoides	*Dracontomelum mangiferum*	Andaman and Nicobar islands, Malaya Peninsula	Evergreen
FABACEAE			
Acrocarpus siwalicus	*Acrocarpus fraxinifolius*	India, Myanmar	Moist deciduous
Adenantheroxylon	*Adenanthera pavonina*	Indo-Malayan region	Moist deciduous
Albizinium eolebbekianum	*Albizia lebbek*	Himalayan foot-hills	Deciduous
Cassinium prefistulai	*Cassia fistula*	India, Myanmar	Deciduous
Cynometroxylon boldenii	*Cynometra polyandra*	Northeast India, Myanmar, Malaya	Evergreen
Koompassioxylon elegans	*Koompassia malaccensis*	Malayan region	Evergreen
Millettioxylon pongamiensis	*Pongamia pinnata*	India, Myanmar, South-east Asia, North Australia, China	Evergreen
Ormosioxylon bengalensis	*Ormosia robusta*	India, Bangladesh, Myanmar	Evergreen
LECYTHIDACEAE			
Careyoxylon pondicherriense	*Careya arborea*	India, Myanmar	Moist deciduous

Table-3. Kalagarh Assemblage

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
ARECACEAE			
Palmoxylon wadiai	Palm in general	---	---
ANNONACEAE			
Polyalthioxylon indicum	*Polyalthia* spp.	Indo-Malayan	Evergreen

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
DIPTEROCARPACEAE			
Anisopteroxylon kalagarhense	*Anisoptera scaphula*	Myanmar, Thailand Malaya Peninsula	Evergreen
A. oblongoides	*A. oblonga*	Myanmar, Malay Peninsula	Semi-evergreen to deciduous
Dipterocarpoxylon kalagarhense	*Dipterocarpus obtusifolius*	Myanmar, Thailand, Malay Peninsula	Evergreen
D. parabaudii	*D. baudii*	Myanmar, Cambodia, Thailand, Malay Peninsula	Evergreen
D. surangeii	*D. tuberculatus*	Bangladesh, Myanmar, Thailand	Evergreen
D. nungarhense	*D. tuberculatus*	- do -	---
Shoreoxylon ornatum	*Shorea* spp.	Indo-Malayan region	Evergreen
Vaterioxylon kalagarhense	---	---	---
V. miocenicum	---	---	---
Shoreoxylon siwalicus	*Shorea minor*	Malaysia	Evergreen
Hopenium prenutanoides	*Hopea nutan*	Malay Peninsula	Evergreen
H. kalagarhensis	*H. sulcata*	Myanmar, Malaya	Evergreen
STERCULIACEAE			
Sterculioxylon kalagarhensis	*Sterculia coccinia* *S. oblonga* *S. rhinopetala*	Northeast India to Malayan region	Evergreen
ANACARDIACEAE			
Dracontomelumoxylon mangiferumoides	*Dracontomelum mangiferum*	Andaman islands	Evergreen
Glutoxylon kalagarhensis	*Gluta* spp.	Myanmar, Malaya	Evergreen
FABACEAE			
Bauhinium palaeomalabaricum	*Bauhinia malabarica*	India, Myanmar	Moist deciduous
B. miocenicum	*Bauhinia retusa*	Chota Nagpur, Eastern and Western Ghats	Moist deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
Cynometroxylon boldenii	*Cynometra polyandra*	Northeast India	Evergreen
Millettioxylon kalagarhensis	---	---	---
Hopeoxylon eosiamensis	*Sindora siamea*	Malay Peninsula	Evergreen
Ormosioxylon bengalensis	*Ormosia robusta*	Northeast India, Bangladesh, Myanmar	Evergreen
ROSACEAE			
Parinarioxylon splendinum	Affinities doubtful	---	---
COMBRETACEAE			
Terminalioxylon palaeomanii	*Terminalia manii*	Andaman and Nicobar Islands	Dry to moist deciduous
T. siwalicus	*T. paniculata*	Western Ghats	Deciduous
SONNERATIACEAE			
Duabangoxylon indicum	*Duabanga* spp.	Northeast Indian region	Evergreen
EBENACEAE			
Ebenoxylon siwalicus	*Diospyros brandisiana*	Myanmar	Evergreen
E. kalagarhensis	*D. malabarica*	Indo-Malayan region	Evergreen
LAURACEAE			
Laurinoxylon siwalicus	Lauraceous genera	---	---

Table-4. Poornagiri (Tanakpur) Assemblage (Awasthi, MS)

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
STERCULIACEAE			
Sterculia	*Sterculia urens*	India, Myanmar	Dry deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
FABACEAE			
Ormosia	*Ormosia robusta*	Nepal, North-east India, Bangladesh Myanmar	Evergreen
COMBRETACEAE			
Terminalia	*Terminalia chebula*	India	Deciduous
MYRTACEAE			
Syzygium	*Syzygium cumini*	India, Myanmar	Evergreen to deciduous
BORAGINACEAE			
Cordia	*Cordia myxa*	India, Myanmar, South East Asia	Deciduous
EBENACEAE			
Diospyros	*Diospyros ebenum* *D. sylvatica*	India, Sri Lanka	Moist deciduous
LAURACEAE			
Persea	*Persea* spp.	Indo-Malayan	Evergreen
Cryptocarya	*C. griffithiana*	Indo-Malayan	Deciduous
MORACEAE			
Artocarpus	*Artocarpus integrifolius*	India, Myanmar	Evergreen

Table-5. Bhikhanathoree Assemblage

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
MALVACEAE			
Urena palaeolobata	*Urena lobata*	Tropical to sub-tropical region	Deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
MELIACEAE			
Aphanamixis bhikhnathoriensis	*Aphanamixis polystachya*	Indo-Malayan	Evergreen
Toona siwalika	*Toona ciliata*	Indo-Malayan, Australia	Evergreen to deciduous
RHAMNACEAE			
Ziziphus champarensis	*Ziziphus mauritiana*	Tropical to subtropical region of the world	Moist to dry deciduous
ANACARDIACEAE			
Mangifera someshwarica	*Mangifera indica*	Indo-Malayan	Evergreen to deciduous
FABACEAE			
Indigofera prepulchella	*Indigofera pulchella*	India	Semi-evergreen to dry deciduous
Dalbergia sp.	*Dalbergia sissoo* *Dalbergia latifolia*	India	Dry deciduous
Derris champarensis	*Derris scandens*	Indo-Malayan	Semi-evergreen to dry deciduous
Pongamia siwalika	*Pongamia pinnata*	India, Southeast Asia, North Australia	Semi-evergreen to dry deciduous
Cassia antiqua	*Cassia glauca*	Indo-Malayan	Evergreen
Bauhinia siwalika	*Bauhinia* spp. (*B. diptera*, *B. tomentosa*, *B. corymbosa*)	Indo-Malayan	Deciduous
MYRTACEAE			
Syzygium palaeobracteatum	*Syzygium bracteatum*	Northeast India, Orissa	Evergreen
RUBIACEAE			
Gardenia palaeoturgida	*Gardenia turgida*	Northern India	Moist deciduous
MYRSINACEAE			
Ardisia antiqua	*Ardisia solanacea*	India, Myanmar, Sri Lanka	Moist deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
CONVOLVULACEAE			
Ipomoea erio-carpoides	*Ipomoea eriocarpa*	India, Myanmar, Sri Lanka	Moist deciduous
LAURACEAE			
Phoebe champa-rensis	*Phoebe lanceolata*	India, Myanmar Sri Lanka	Evergreen
Cinnamomum palaeotamala	*Cinnamomum tamala*	India, Myanmar	Evergreen to Moist deciduous
Litsea prenitida	*Litsea nitida*	Eastern Himalaya, Assam, Bangladesh	Semi evergreen
MORACEAE			
Ficus champarense	*Ficus* spp.		

Table-6. Koilabas Assemblage

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
DILLENIACEAE			
Dillenia palaeoindica	*Dillenia indica*	India, Myanmar	Moist evergreen
FLACOURTIACEAE			
Ryparosa prekunstleri	*Ryparosa kunstleri*	Malaya	Evergreen
CLUSIACEAE			
Mesua tertiara	Affinities doubtful	---	---
DIPTEROCARPACEAE			
Dipterocarpus siwalicus	*Dipterocarpus tuberculatus*	Northeast India, Myanmar, Southeast Asia	Evergreen to moist deciduous
MELIACEAE			
Chloroxylon palaeoswietenia	*Chloroxylon swietenia*	India, Sri Lanka	Deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
FABACEAE			
Albizia siwalika	*Albizia gamblei*	Northeast India	Moist deciduous
Cassia nepalensis	*Cassia hirsuta*	Central India	---
Dalbergia miosericea	*Dalbergia sericea*	Sub-Himalayan region, Madagascar	Deciduous
Millettia siwalica	*Millettia ovalifolia*	Jammu to Sikkim Upper Myanmar	Moist deciduous
Millettia koilabasensis	*Millettia macrostachya*	Upper Myanmar	---
Ormosia robustoides	*Ormosia robusta*	Northeast India, Myanmar	Evergreen
COMBRETACEAE			
Anogeissus eosericea	*Anogeisus sericea*	Central India	Deciduous
Calycopteris floribundoides	*Calycopteris floribunda*	Western Peninsula, Northeast India, Myanmar	Deciduous
Terminalia koilabasensis	*Terminalia angustifolia*	Malaya	Evergreen
Terminalia siwalica	*T. pyrifolia*	Myanmar	—
Terminalia sp.	*Terminalia arjuna*	Throughout India, Myanmar	Deciduous
RUBIACEAE			
Randia miowallichii	*Randia wallichii*	Northeast India to Myanmar, Andaman Islands	Evergreen
APOCYNACEAE			
Tabernaemontana precoronaria	*Tabernaemontana coronaria*	Sub-Himalayan region, Sri Lanka, Myanmar	Evergreen
SOLANACEAE			
Datura miocenica	*Datura fastuosa*	Tropical region	---
VERBENACEAE			
Vitex prenegundo	*Vitex negundo*	India, Sri Lanka, China	Deciduous

Family/Fossil Taxa	Comparable extant species	Distribution of comparable extant species	Forest type indicated
Vitex siwalicus	*Vitex pubescens*	India, Myanmar	Evergreen
LAURACEAE			
Cinnamomum mioinunctum	*Cinnamomum inunctum*	Myanmar, Malaya	Evergreen to moist deciduous
MORACEAE			
Ficus precunea	*Ficus cunea*	Sub-Himalaya region, Assam, Myanmar	Deciduous
Ficus retusoides	*Ficus retusa*	Indo-Malayan	Evergreen
Ficus nepalensis	*Ficus glaberrima*	Indo-Malayan	Evergreen

Table-7. Surai Khola Assemblage

Stratigraphic Sequence	Family/Fossil taxa	Comparable extant species	Distribution	Forest type indicated
Surai Khola beds	MARANTACEAE			
	Clinogyne ovatus	*Clinogyne grandis*	Indo-Malayan region	Moist deciduous
	FLACOURTIACEAE			
	Flacourtia nepalensis	*Flacourtia ramnotchii*	India, Myanmar, Sri Lanka	Deciduous
	FABACEAE			
	Milletia miocubitii	*Milletia cubitii*	Malayan region	Moist deciduous
	Bauhinia nepalensis	*Bauhinia malabarica* *B. variegata*	India, Myanmar	Evergreen to deciduous
	EBENACEAE			
	Diospyros miokaki	*Diospyros kaki*	India, Myanmar, China, Japan	Moist deciduous
	EUPHORBIACEAE			
	Breynia prerhamnoides	*Breynia rhamnoides*	Indo-Malayan region	Moist deciduous

Stratigraphic Sequence	Family/Fossil taxa	Comparable extant species	Distribution	Forest type indicated
Kaila Khola	ARECACEAE			
	Caryota siwalika	*Caryota urens*	Indo-Malayan region	Evergreen to moist deciduous
	ANACARDIACEAE			
	Mangifera someshwarica	*Mangifera Indica*	India, South-East Asia	Evergreen
	Gluta siwalika	*Gluta renghas*	Myanmar, Malaysia	Evergreen
	Swintonia miocenica	*Swintonia floribunda*	Bangladesh, Myanmar	Evergreen
	FABACEAE			
	Entada palaeo-scandens	*Entada scandens*	Indo-Malayan region	Moist deciduous to evergreen
	COMBRETACEAE			
	Terminalia palaeochebula	*Terminalia chebula*	India, Myanmar, Sri Lanka	Moist deciduous
	Terminalia panandhroensis	*Terminalia coriacea*	India, Myanmar	Deciduous
Chor Khola beds	MYRISTICACEAE			
	Myristica palaeoglomerata	*Myristica glomerata*	Malay Peninsula	Evergreen
	POACEAE			
	Bambusa siwalika	*Bambusa tulda*	India, Myanmar	Moist deciduous
	FABACEAE			
	Millettia palaeoracemosa	*Millettia racemosa*	India, Myanmar	Deciduous
	Entada palaeo-scandens (Leaf)	*Entada scandens*	India, Myanmar	Moist deciduous to semi-evergreen
	EUPHORBIACEAE			
	Excoecaria palaeocrenulata	*Excoecaria crenulata*	Southern India	Evergreen
	CLUSIACEAE			
	Calophyllum suraikholaensis	*Calophyllum polyanthum*	Sikkim and Khasi Hills	Evergreen

Stratigraphic Sequence	Family/Fossil taxa	Comparable extant species	Distribution	Forest type indicated
	DIPTEROCARPACEAE			
	Dipterocarpus siwalicus	*Dipterocarpus tuberculatus*	Northeast India to South-East Asia	Evergreen
Patm Khola beds and Bankas beds	DIPTEROCARPACEAE			
	Dipterocarpus siwalicus	*Dipterocarpus tuberculatus*	Northeast India to South east Asia	Evergreen
	D. turbinatus	---	---	---
	ANNONACEAE			
	Polyalthia simiarum	*Polyalthia simiarum*	Northeast India, Myanmar	Evergreen
	FABACEAE			
	Cynometra siwalika	*Cynometra polyandra*	Khasi and Cachar Hills, Malay Peninsula	Evergreen

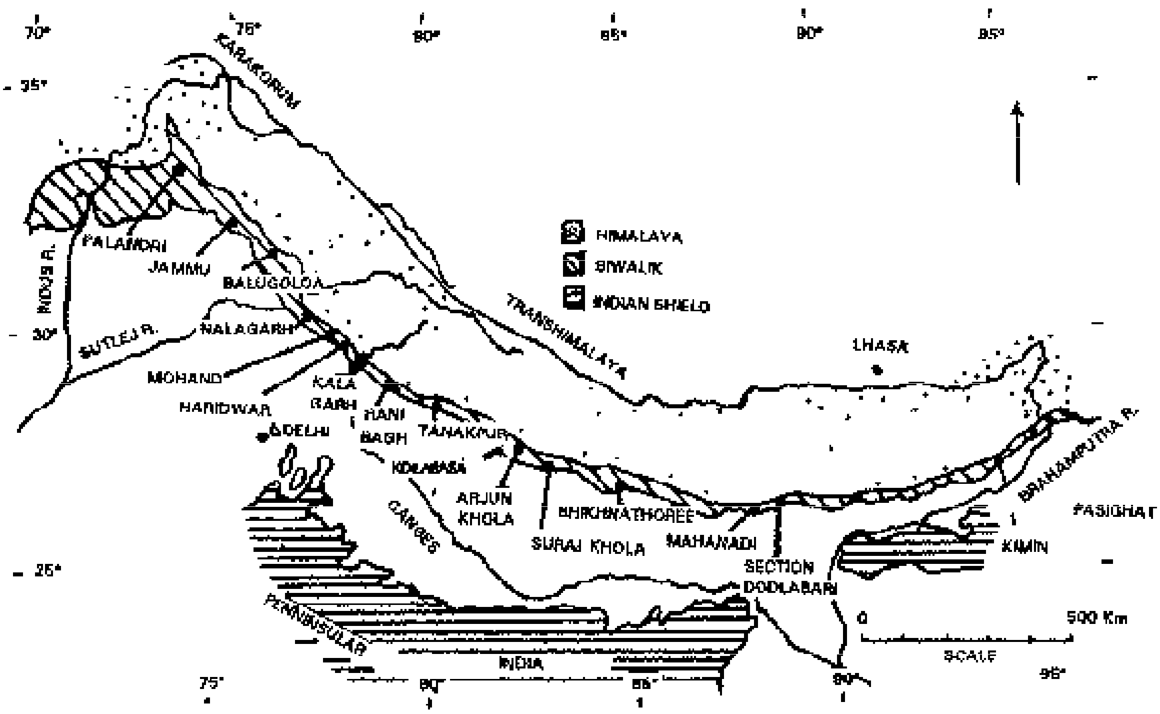
Siwalik flora includes the following assemblages from number of exposures located in the foot-hills covering an area between Jammu in the west and Arunachal Pradesh in the east (Map 7).

Jammu :

Sahni (1931) was first to report two petrified woods as *Palmoxylon jammuense* and *P. wadiai* from near Jammu. However, the exact stratigraphical position of deposits in not known. The only other known fossil plant from Jammu area is *Poacite siwalicus*, a grass-like monocot leaf.

Himachal Pradesh :

Two important localities, viz. Balugoloa near Jawalamuki in Kangra District and other Nalagarh in Solan District have been investigated by various palaeobotanists (Awasthi, 1992). The taxa recovered are listed in the table.



Map 7. Extent of the rocks of Siwalik Group (after Awasthi, 1992)

Uttar Pradesh :

From Mohand in Saharanpur District to Tanakpur at Nainital there are number of Siwalik exposures of Lower and Middle Siwalik which contain great variety of woods and leaves. The fossil taxa published from Kalagarh area, Pauri, District Garhwal and Poornagiri Hills, near Tanakpur, Nainital District are given in the Table.

Bihar-Nepal Border :

Fossil taxa published from Bhikhnathoree, West Champaran are given in Table.

Nepal :

The Nepalese Siwalik deposits published from Koilabas and Surai Khola are given in Table so as to understand complete picture from east to west.

Bengal and Arunachal Pradesh :

Some stray reports on megafossil from foothills of Bengal and Arunachal Pradesh have been published. Pathak (1969) documented a few fragmentary leaves such as *Castanopsis tribuloides, Cinnamomum tamala, Machilus villosa, Litsea polyantha, Bridelia stipularis, B. verrucosa, Mallotus philippensis* and *Rhododendron lepidotum* from the Middle Siwalik sediments of Mahanadi Section in the foot-hills of Darjeeling District. Awasthi (1982), however, doubts the generic and specific identification.

Singh and Prakash (1980) have reported leaves of *Ziziphus* and *Dioscorea* from Pasighat, District Siang (Arunachal Pradesh). Choudhury (1970) reported dicotyledonous leaves of uncertain affinities from the area. Awasthi (unpublished) has collected semisilicified and semicarbonised woods from Upper Subansiri (Subansiri district, Arunachal Pradesh) which are comparable with the extant genera such as *Shorea; Euphorbia, Gluta, Albizia, Afzelia-Intsia, Cynometra, Cassia* and *Sindora*. These are mostly evergreen genera.

The small American elements comprising *Adenocaulon, Oxybaphus, Podophyllum, Meconopsis* Sect. *Stylopodium, Liquidamber, Gnetum, Lardizabala, Monotropa uniflora, Brassenia* and *Mitreola paniculata* perhaps also arrived through the North-east (Vishnu-Mittre, 1969).

3. *Temperate flora and Himalaya :*

After the final withdrawal of the Tethys during Oligocene, the further Himalayan orogeny created conditions favourable for the migration from mainland Asia of temperate plants during the Middle Miocene.

Latitudinally, nearly half of the India lying north of the Tropic of Cancer should have been out of the realm of tropical zone, had not the lofty Himalayas extending all along the northern boundary of the Indian subcontinent shielded from the cooler influence of the northern lanes, resulting in the prevalence of a more or less tropical monsoon climate almost throughout this region. Paradoxically, this very mountain which initially guarded India from temperate climate of the adjacent parts of Asia, itself provided in its rising altitude a favourable ground for the growth of temperate plants (Lakhanpal, 1988).

Broadly speaking the vegetation of Himalayas can be roughly divided into three zones, (i) Subtropical from base of the mountains upto 1200 m, (ii) Temperate from 1200 to *ca* 3600 m., (iii) Alpine higher altitudes upto 4500m.

The subtropical vegetation is an extention from Indian side. However, the temperate vegetation in the next zone could have come from the adjoining northeastern, northern and northwestern regions when the Himalayas had attained sufficient elevation to provide an environment cool enough for temperate plants to grow. Phytogeographically it is important to find temperate elements entered the Himalayan flora and the palaeobotanical evidence thereof.

The occurrence of temperate components in the geological history of the Himalayan flora was amply revealed by the palynological studies conducted on the Lower and Middle Siwalik beds by Banerjee (1968), Lukose (1969), Nandi (1972, 1975), Mathur (1973), Singh and Saxena (1981), Saxena and Singh (1982 a & b) and a few others. According to Lukose (1969), Nandi (1975), Ghose (1977), Ranga Rao *et al.* (1981) most of the pteridophytes and angiosperms represented in the pollen contents of the Siwaliks belong to humid tropical or subtropical environments, most gymnosperms and some angiosperms are temperate. For example *Abies, Picea, Pinus, Tsuga, Alnus, Betula, Carya* and *Juglans*, to which some of the pollen grains have been assigned, are all temperate plants. These forms are very low in frequency in the Lower Siwalik, they become more frequent in the Middle and Upper Siwalik beds. Based on these finding these palynologists believe that the climate of the Siwalik country was humid tropical to start with but gradually became colder as reflected by the increasing frequency of temperate elements in the upper sediments.

However, there is no evidence of occurrence of temperate mega-fossils from Siwalik sediments. In the prevailing tropical monsoon type of climate in the Siwalik region there is no possibility of occurrence of temperate elements such as *Abies, Picea, Tsuga* and *Betula* etc. unless there was an altitude of about 2000 m. Lakhanpal (1970) gives a plausible explanation that the Siwalik basin was surrounded by tropical plants whose remains became entomed in the sediments being deposited there. Along with them were preserved the pollen grains of temperate gymnosperms and angiosperms that grew on the higher mountains situated in the north. These pollen grains were either air borne or floated down in the river into the Siwalik basin. This hypothesis was corroborated a few year later by the finding of palm impressions from Liya formation of Ladakh at an altitude of 5400 m above m.s.l. This leaf resembled very much with genus *Trachycarpus* and is described as *Trachycarpus ladakhensis* by Lakhanpal *et al.* (1984). The Liyan Formation belongs to Miocene period. *Trachycarpus maritima* and *T. fortunei* grow in the hills of Khasi and Manipur hills at an altitude of *ca.* 1250 m and belong to warm temperate reigon. *Trachycarpus takil* grows at about 2200-2450 m in Kumaon (Himalaya) and is covered annually by snow is definitely a temperate species. This unquestionably constitute forest temperate megafossils finding from the Indian Tertiary.

By the Miocene period and with the rise of Himalayas, the land connections were established between Indian and mainland of Asia on the north side. It was probably the time when northern temperate elements entered the Himalayan Flora. A petrified wood collected by Thakur and Virdi in 1978 from Kargil Formation (= Liyan Formation) has been assigned to temperate genus *Prunus* (Rosaceae) and named it *Prunus wadiai*.

The uplift of the Himalayas took place in different phases and during the initial one or two phases ending in the Oligocene there was progressive shallowing of the Tethys, resulting in complete evacuation of sea water and establishment of fresh water or subaerial facies. The next phase Dharamshala or Siramurian Orogean culminated in the Middle Miocene and was the strongest of the

Himalayan orogenic movement. This created favourable climate for migration of temperate plants from mainland of Asia.

Palaeoclimate and Floral Evolution

Awasthi (1992) based on review of Neogene of Himalaya concludes "the Himalayan foothills tropical forests with overwhelming majority of evergreen elements existed during Middle Miocene-Pliocene. The flora includes sizeable number of evergreen taxa of South-East Asia distribution, e.g. *Anisoptera, Gluta, Koompassia, Sindora, Swintonia* and some species of *Dipterocarpus* and *Hopea*."

The rise of Himalayas resulted in conversion of areas into land with number of water basins. As a sequal to this the foothills all along Himalayas became more warm and humid with high precipitation. The Indian Plate has already joined with Eurasia and leading to formation of land connections between Indian and neighbouring countries. Through these land connections the influx of numerous tropical moist evergreen to semi-evergreen taxa from Southeast Asia has taken place. The lead is taken by the dipterocarps through Burma and reached the Himalayan as evidenced by fossil records.

On the higher slopes Sino-Japanese elements such as *Trachycarpus, Prunus* and *Populus* support the different floral pattern. The tropical forests mostly comprise taxa of Malayan and South-eastern distribution whereas subtropical and temperate forests had sizeable Sino-Japanese and Russian elements.

The luxuriant evergreen forest started dwindling towards the end of Middle Siwaliks or beginning of Uppr Siwaliks (Awasthi, 1992). Ultimately, these forests were replaced by deciduous elements such as *Clinogyne, Flacourtia, Millettia, Bauhinia, Breynia* etc.

The Early Pleistocene Period witnessed the last phase of Himalayan uplift, progressive change of warm humid to drier and cooler climate. This change in climate has adverse effect, particularly on the dipterocarp community which has a luxuriant growth. Almost all the members disappeared from the Western and Central sectors of the Himalayan foothills. *Dipterocarpus* and *Shorea* are the sole survivor which has restricted distribution in Assam and Arunachal Pradesh.

Shorea robusta is only dipterocarp which occurs in Western and Central sectors of Himalayan foothills.

II. QUATERNARY VEGETATION/FLORA OF INDIA

The Quaternary Period comprises two epochs, Pleistocene and Holocene and covers a time period from 1.64 m.y.B.P. to 0.01 m.y.B.P. and thereafter to present day respectively. The Pliocene orogeny has induced drastic changes in floristics. Similarly, the geological events in the early Pleistocene resulted in the migration and establishment of central Asian (Chinese and Euro-Siberian) taxa, particularly in Himalayas. The pulsating climate and varying ecological niche provided ideal situation for extention and expansion of other floristic belts and evolution of Himalayan taxa from the migrant floristic components.

A rich data on Quaternary megafossils and microfossils is now available which reveals interesting information on the floristics and palaeoclimate. Vishnu-Mittre (1984) has published a comprehensive review paper on floristic changes in Himalaya (southern slopes) and Siwaliks from Mid Tertiary to recent times. Gupta and Sharma (1982) presented a critical review on the Quaternary palynostratigraphy in India providing important information on Kashmir, Ladakh, Himachal Pradesh, Kumaon Himalaya, Eastern Himalaya (Darjeeling and Sikkim), Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, Southern India, Eastern India (Bengal, Assam).

Gupta (1992) while discussing changing pattern of vegetation in the intermontane basins of Kashmir states "Palynological and Palaeobotanical investigations carried over a large number of exposures have revealed that there is no unanimity in vegetation all through the Karewa deposits, instead a variety of vegetation types has been recorded in time and space indicating their development under different circumstances. The vegetation met here varies from typical subtropic to desertic alpine type. The climate has not been static for a long period rather reciprocity in climate has been recorded which has been deciphered from vegetal signature left by the nature".

The post-glacial sediments investigated from the lake basins in the valley have revealed vegetational development reflecting on three-fold climatic evolution.

The fossil plant investigation from Pir Panjal dates back to 1864 when Godwin-Austin reported the occurrence of fossil leaves belonging to the modern species of plants in clay deposits at Gojpathri near Nilnag and at Liddarmarg, southwest of Gulmarg.

The existence of Karewa deposits, as far as Pir Panjal range, shows beyond doubt that the ancient Karewa Lake(s) must have greatly exceeded the present width of the Kashmir valley. Godwin-Austin referred Karewa deposits to Pleistocene.

PLEISTOCENE

Palaeobotany of Karewa

MEGAFOSSILS :

Mega-plant remains from Karewa were first reported by Godwin-Austin (1864). Middlemiss (1911) collected a number of fossil leaves, fruits etc. from Liddarmarg which were identified as *Quercus glauca, Buxus semipervirens, Alnus* sp. The assemblage is indicative of sub-tropical forests and corresponds to the present forests growing between the altitude of 1165-1670 m.

Quality and quantity wise the Lower Karewa deposits toward Pir Panjal have yeilded rich plant megafossils. Puri (1948) who carried out intensive and extensive studies on Karewa has identified three distinct floristic assemblages, viz. :

(1) *Laredura Flora :*

This locality lies 12 km south-west of Baramula town. Puri (l.c.) clubbed *ca* equivalent fossiliferous sites such as Nichahom and Nagbal. The floristic components of Laredura is indicative of both warm temperate and subtropical form and comprises fossil leaves of *Quercus dilatata, Q. incana, Ulmus, Alnus, Cedrus, Pinus roxburghii, Aesculus indica, Acer caesium.* Presently their modern equivalent do not exist in the valley. They are restricted to the lower elevation between 1165-2000 m a.s.l.

(2) *Ningle Nullah Flora*

The locality lies at an altitude of 3200 m.s.l. and is approachable from Gulmarg. Butapathri and Gofipathri are two identical localites situated *ca* at the same altitude. The floristic components comprise temperate forms such as willows, poplars, cherries, walnuts, maples, elms, spruce, silver fir, blue pine, deodar etc. The modern equivalent of these elements still exist on the northern slopes of Pir Panjal in Kashmir valley between altitude of 2300-3300 m.s.l.

(3) *Liddermarg Flora*

The locality lies at an elevation of 3500 m a.s.l. The fossiliferous components are indicative of tropcial zone. These are *Quercus incana*, *Machilus* sp., *Acer oblongum*, *Pittosporum eriocarpum*, *Berchemia* sp., *Mallotus* sp., *Leea* sp., *Myrsine* sp. and *Ficus cunea*. This kind of flora does not exist in the valley today. It is rather confined to sub-Himalayan rain forests.

Table-8. Plant fossils remains from Karewa, Kashmir
(Leaf impressions except few cases)

Taxa	Climatic signal
(1) LAREDURA FLORA	
Euphorbiaceae	
Mallotus philippensis	Subtropical
Hippocastanaceae	
Aesculus indica	Temperate
Myrsinaceae	
Myrsine sp.	Subtropical
Oleaceae	
Olea grandulifera	Subtropical
**Fraxinus* sp.	Warm temperate
Ulmaceae	
Ulmus wallichiana	Warm temperate
U. laevigata	Cool temperate
U. campestris	---
Juglandaceae	
Engelhardtia colebrookiana	Subtropical
Lythraceae	
Woodfordia fruticosa	Subtropical
Salicaceae	
Salix elegans	Temperate
Fagaceae	
Quercus semecarpifolia	Cool Temperate
Q. dilatata	Sub-tropical
Q. ilex	Sub-tropical

Taxa	Climatic signal
Betulaceae	
Betula utilis	Cool Temperate
B. alnoides	Cool Temperate
Alnus nitida	Sub-tropical
Corylaceae	
Corylus ferox	Warm temperate
Aceraceae	
**Acer villosum*	Temperate
A. caesium	Temperate
Berberidaceae	
Berberis lycium	Subtropical
Aralliaceae	
Hedra nepalensis	Temperate
Papilionaceae	
Desmodium nutans	Temperate
D. latifolium	Sub-tropical
D. tiliaefolium	Sub-tropical
Indigofera hepeptelea	Sub-tropical
Anacardiaceae	
Rhus punjabensis	Sub-tropical
R. succedenea	Sub-tropical
Lannea coromandelica	Temperate
Rosaceae	
Prunus cerasiodes	
Pyrus pashia	
Rosa webbiana	Sub-tropical
R. macrophylla	Sub-tropical
Spiraea sp.	Temperate
Cotoneaster bacillaris	Temperate
Rubus fruticosa	Temperate
Ranunculaceae	
'*Ranunculus* sp.	Temperate
**Clematis* sp.	Temperate
(2) NINGLE NULLAH FLORA	
Hippocastanaceae	
Aesculus indica	Cool temperate
Ulmaceae	
Ulmus laevigata	Warm temperate Cool temperate
Salicaceae	
Salix wallichiana	Cool temperate
S. elegans	Warm temperate
Populus ciliatus	Warm temperate
P. balsamifera	Warm temperate

Taxa	Climatic signal
Betulaceae	
Betula utilis	Cold temperate Sub-alpine
Alnus nepalensis	Warm temperate Cold temperate
Aceraceae	
Acer pictum	Cold temperate
A. pentapomicum	Cold temperate
A. villosum	Cold temperate
Cornaceae	
Cornus macrophylla	Warm temperate
Marlea begoniaefolia	Cold temperate
Oleaceae	
Fraxinus excelsior	Warm temperate Cool temperate
Rosaceae	
Prunus cornuta	Warm temperate
Pyrus malus	Cool temperate
Cotoneaster nummularia	Warm temperate
C. microphylla	Cool temperate
(3) LIDDARMARG FLORA	
Fagaceae	
Quercus incana	Sub-tropical
Q. glauca	Warm temperate
Urticaceae	
Ficus cunea	Tropical
Euphorbiaceae	
Mallotus philippensis	Tropical
Lauraceae	
Litsea lanuginosa	Subtropical
Cinnamomum tamala	Subtropical
Machilus odoratissima	Subtropical
M. duthie	Subtropical
Phoebe lanceolata	Subtropical
Buxaceae	
Buxus wallichiana	Subtropical to Warm temperate
B. papillosa	Subtropical to Warm temperate
Rutaceae	
Skimmia laureola	Tropical to Subtropical
Toddalia sp.	Tropical to Subtropical
Rhamnaceae	
Rhamnus virgatus	Tropical

Taxa	Climatic signal
R. triquetra	Tropical
Berchemia floribunda	Tropical
Myrsinaceae	
Myrsine africana	Tropical-Subtropical
M. semiserrata	Tropical-Subtropical
Rubiaceae	
Wendlandia exceria	Tropical
Rosaceae	
Pyrus communis	Subtropical-temperate
Cotoneaster bacillaris	Subtropical-temperate
Spiraea sp.	Subtropical temperate
Berberidaceae	
Berberis lycium	Subtropical
Cornaceae	
Dendrobenthamia capitata	Subtropical
Papillionaceae	
Desmodium podocarpum	Subtropical
D. laxiflorum	Subtropical
Asteraceae	
Inula cappa	Tropical
Araceae	
Acorus sp.	Tropical
Cyperaceae	
Scirpus sp.	Tropical
Cyperus sp.	Tropical

*Fruit; **Leaf & Fruit

MICROFOSSIL

Palynology of Karewa :

The Kashmir valley presents a complete sequence of Pleistocene and Holocene deposits in Karewa and lakes and swamps. The palaeopalynological data obtained from these deposits throws light on the palaeofloristics and palaeiclimate. The palynological studies carried out by Nair (1960) from Lower and Upper Karewa reflected on the palaeogeography and migration of plants. The investigation further revealed that plant components such as *Alnus, Carpinus, Pinus roxburghii* and *Quercus* though present in the deposits are conspicuous by their absence in Kashmir valley today, although presently they exist on the southern slopes of Pir Panjal mountains.

Palynology of Lakes and Swamps in Kashmir :

The palynological data obtained from some lakes and swamps represent postglacial and Holocene time span, whereas other represent a part of Holocene Period. Haigam (Vishnu-Mittre and Sharma, 1966), Baba Rishi and Yus Maidan (Sharma & Vishnu Mitre, 1969), Burman and Walanwar (Singh, 1964) profiles are not yet dated radiometrically. However, the evidence from vegetational development indicates that the Haigam Lake represents complete Holocene sequence, whereas other lakes are shallow and represent either middle or upper part of the Holocene Period.

The postglacial pollen deposits suggest three fold vegetation development viz., pine-quercetum mixtum-pine. This spectrum of vegetation development reveals three-fold climate oscillation viz., cool-warm-cool coinciding with world-wide scheme of postglacial climatic changes put forward by von Post (1946).

The combined studies of Lithostratigraphy, Palynostratigraphy, Fission track, Palaeomagentic and 14c dating provides a long sequence of changing pattern of vegetation and climatic oscillation. The results can be summarised as follow.

Between 4.0 to 3.8 Ma	More or less uniform vegetation prevailed comprising Chirpine, Oak-elder-spruce-walnut-Poaceae with minor variation at the top where spruce replaced Chirpine. The water plants improved.
Between 3.8 to 3.7 Ma	No pollen record available.
Between 3.7 to 2.6 Ma	The cylicity of vegetational development was quite evident. The vegetation between 3.7-3.5 Ma was mostly dominated by spruce forest,

	indicative of cool/cold temperate climate. Thereafter, a catastrophy in the vegetation took place resulting in the establishment of subtropical and dry climate. Colonization of pure Chirpine forest took place, however, this type of forest did not last long. The shift in vegetation is marked by onset of warm temperate type of climate. The climatic cycle of subtropical and warm temperature alternating with each other could be worked out upto *ca* 2.8 Ma. Thereafter, temperate climatic regime was set-in. Slow and gradual deterioration in temperature continued till 2.6 Ma where cool temperate and dry climate developed encouraging the establishment of blue pine-silver fir-spurce forests.
Between 2.6-2.4 Ma	No pollen record.
Between 2.4 to 2.2 Ma	There existed typical temperate climate in the beginning which successively became cool and ultimately cold temperate climate was established towards the top.

	It was marked by establishment of silver fir-spruce-cypresses forests.
Between 0.72 to 0.6 Ma	The vegetation was represented by alpine scrub with prepondrance of Rosaceae (Dryas) Chenopodiaceae, Asteraceae, Apiaceae, Poaceae etc. This grade of vegetation forming meadows is generally found in alpine desert area above the tree-line zone and could be equated to present day vegetal scenario of Ladakh.

The glacial conditions must have prevailed during this period.

Between 0.6 to 0.3 Ma	The glaciation influence began to sink and late glacial conditions switched on ceding pace to establish spruce-Silver fir-blue pine forests typifying the existence of subalpine climate.
Between 0.3 to 0.2 Ma	No pollen record.
Between 20,000 to 15000 yr B.P.	Postglacial period began. The palynological data obtained from the investigation of lakes and swamps revealed plentiful record of post-glacial events.

The post-glacial vegetation all through the Kashmir valley is marked by a three-fold development viz., pine-quercetum mixtum- pine in chronological order. The climate was cool-warm-cool.

The climate remained changing all through the basinal development in the valley since four million years.

Pliocene to Lower Pleistocene :

The floristic alteration of 3.5 m.y. B.P. in the Kashmir Valley comprised a sedge/grass steppes interrupted by *Pinus roxburghii/Alnus/Juglans/Quercus* forests (Vishnu-Mittre, l.c.). Thereafter until 2.47 m.y. B.P. Vishnu-Mittre (l.c.) reconstructed six pollen spectra from the part of Hirpur Section Loc. III between I and II conglomerates (Dodia *et al.* 1982a).

Conglomerate-II
2.47 m.y.

Poaceae/Quercus/Engelhardtia
Poaceae/Chenoamaranths/Quercus/Alnus
Pinus roxburghii
Larix/Quercus/Engelhardtia/Poaceae
Pinus roxburghii
Careya/Quercus/Poaceae

3.41 m.y. B.P.

Conglomerate-I

The vicinity of Wazpan, witnessed Chenoamaranths/grass/*Artemisia* steppes. The site has been dated to the upper part of Lower Karewa (Gupta *et al.* 1982b).

Pollen investigations of Hirpur Loc.III (Gupta *et al.*, 1982b) shows *Pinus roxburghii*, *Juglans* and *Viburnum* in the intervening sand layers; *Pinus wallichiana*, *Abies*, *Picea*, *Cedrus* and *Betula* in the intervening mud layers and *Larix*, *Cedrus*, *Juglans* and *Engelhardtia* in the intervening lignite layers in the 180 m long section. In this strange pattern of the course of vegetational development, contrary to the normal course of vegetational development in the Himalaya, 15 climatic oscillations viz., four tropical dry, one tropical wet, one subtropical, four warm temperate and five cold and dry temperate have been inferred from 15 pollen zones for the Pliocene to which the section is dated.

The supporting and additional floristic evidence from the Hirpur formation, is known from the fossil woods largely from the sandy layers and foliar impressions from the mud layers (Awasthi and Guleria, 1982a, 1982b) and comprises :

Abies cf. *A. pindrow, Acer villosum, A.* sp., *Aesculus indica, Cupressus torulosa, Fraxinus excelsior, Juglans regia, Nelumbo* sp., *Pinus wallichiana, Populus* sp. cf. *euphratica, Potamogeton* sp., *Pteridium aquilinum, Rosa macrophylla, Salix wallichiana, S.* sp., *Trapa* sp., *Ulmus wallichiana, Viburnum cotinifolium.* Both *Larix* and *Pinus roxburghii* are absent in the megafossils.

Vishnu-Mittre (1984) provided detailed information on Southern slope of Himalaya.

The pollen analysis of other Lower Karewa exposures, like Sedau, Laredura, Nichahom, Raithan, Botapathri (Vishnu-Mittre, 1993), have been litho-stratigraphically correlated and are believed to belong to Early Pleistocene (De Terra & Patterson, 1939) or possibly Pliocene/Early Pleistocene, are :

Open forest of *Juglans/Ulmus/Picea*
Picea/Quercus/Cedrus woods
Grass/Chenoamaranths/*Artemisia* steppes and decline of pine.
Pinus wallichiana mixed-oakwoods
Migration and expansion of *Pinus wallichiana* into grass/Sedge/Chenoamoranths steppes
Quercus-Alnus-Cedrus.

The floristic complex comprised the following taxa known from foliar impressions described by R.R. Stewart and G.S. Puri and discussed and listed by Vishnu-Mittre (1965).

ANGIOSPERMS

Acer caesium
A. pentapomicum
A. villosum
A. pictum
A. oblongum
A. sp. cf. *acuminatum*
A. sp.
Acorus sp.
Aesculus indica
Alangium chinense
Alnus nepalensis
A. nitida
A. sp.
Artemisia sp.
Berberis ceratophylla
B. lycium
Berchemia floribunda
Betula alnoides
B. utilis
Buxus papillosa
B. wallichiana
Carpinus sp.
Catanopsis sp.
Cerotophyllum sp.
Cinnamonum tamala
Clematis montana
C. sp.
Cornus capitata
C. macrophylla
Cotoneaster bacillaris
C. microphylla
C. mummularia
C. sp.
Cyperus sp.
Desmodium gangeticum
D. latifolium
D. laxiflorum
D. nutans
D. podocarpum
Engelhardtia colebrookiana
Ficus cunea
Fraxinus excelsior
Hedera nepalensis
Indigofera hebepetala
I. sp.
Inula cappa
Jasminum sp.
Juglans regia
Lannea grandis
Litsea elongata
L. lanuginosa
L. sp.
Machilus duthei
M. odoratissima
Mallotus philippensis
Meliosma africana
M. semiserrata
M. sp.
Myriophyllum sp.
Nelumbo nucifera

Olea sp.
Parrotia jacquemontiana
Persicaria sp.
Phoebe lanceolata
Pittosporum eriocarpum
Populus alba
P. ciliata
P. nigra var. *fastigata*
P. sp.
Prunus cerasifera
P. cornuta
P. jacqumontii
Pyrus aucuparia
P. communis
P. foliosa
P. pashia
Quercus dilatata
Q. glauca
Q. ilex
Q. incana
Q. semicarpifolia
Rhamnus purpurea
Rhus cotinus
R. punjabensis
R. succedanea
Rosa macrophylla
R. webbiana appr. *R. beggariana*
Salix denticulata
S. elegans
S. gulacea (S. wallichana)
S. sp.
Scirpus sp.
Skimmia laureola
Spiraea canescens
Syringa emodi
Toddalia sp.
Trapa bispinosa
T. natans
Typha sp.
Ulmus campestris
U. pumila (U. parvifolia)
U. villosa (U. laevigata)
U. wallichiana
U. sp.
Viburnum mullaha (V. stellulatum)
Wendlandia fruticosa

GYMNOSPERMS

Abies pindrow (A. webbiana)
Cedrus sp. *(deodara)*
Juniperus sp.
Picea smithiana
Pinus wallichiana
Taxus sp.

PTERIDOPHYTES

Adiantum
Dryopteris sp. cf. *felix-mas*
Selaginella sp.

During the Pliocene/Early Pleistocene, Kashmir Valley experienced the arrival and expansion of *Pinus wallichiana* after the decline of *Cedrus*/Oak woods, and arrival of *Picea* and the formation of *Picea/Cedrus*/oak woods after the decline of pine forests. This floristic sequence was governed by three warm temperate and three cool oscillations of climate.

Last Glaciation (Pre 40,000 to 10,000 radio carbon Y.B.P.)

Within the Himalayan region itself, in certain areas where drier climate had prevailed, the loessic deposits intercalated by palaeosols are further manifestations of climatic fluctuation during the last glaciations. The floristic change during the last Glaciation comprised alternations of steppes and juniper in the trans-Himalayan region of Ladakh, of steppes and alpine birch in the alpine region of Toshmaidan Kashmir Valley, and of steppes and oak woods in the subtropical region of Kathmandu Valley.

HOLOCENE

The Holocene is believed to have been a period of progressively increasing warmth after the last glaciation. The release of water from the ice caused a progressive rise in sea level which, during the climatic optimum in the mid-Holocene had flooded the coastal area. A general trend in floristic change in the alpine region above the tree limits comprised alternation between steppes and *Ephedra* or birch/oak/*Abies* as observed at Mari (3313 m) and Baltal during the last 7500 radio carbon years (Bhattacharyya, 1982; Vishnu-Mittre *et al.*, 1983) However, a distinct increase in juniper at 10,000 y. B.P. took place in Ladakh, and the pine/birch woods were constituted between 10,000 to 9500 y. B.P. at Toshmaidan in Kashmir Valley (Vishnu-Mittre *et al.*, op.cit.). In the temperate and subtropical Western Himalaya, a prominent trend has been from conifers/oak mixed woods/conifers since the last 8000 to 7000 y. B.P. with the exception that the oak/*Pinus roxburghii* woods showing an increase of pine have continued in the subtropical region of Kumaon (Naukutchiya Tal profile : Vishnu-Mittre *et al.*, 1983; Gupta, 1977; Sat Tal profile : Gupta and Khandelwal, 1982). The undated abrupt decline of oakwoods and their replacement by Pinus in Kashmir Valley (Haigam pollen diagram : Vishnu-Mittre and Sharma, 1966) may have occurred before 4000 y. B.P., since pine forests have occurred in the valley in the subsequent millennia (Ancher lake and Hokar Sar pollen profiles : Dodia *et al.*, 1982 b).

In Himachal Pradesh, the oakwoods which were predominant over 4000 y. B.P. became replaced by *Cedrus deodara* forests about 1250 y. B.P. (Khajiar pollen profile : Sharma & Singh, 1974a; Vishnu-Mittre 1974; Vishnu-Mittre *et al.*, 1983) and by *Pinus roxburghii* forest elsewhere by 900 and then 600 y. B.P. (Rewalsar and Parasram pollen profiles : Sharma & Singh, 1974 b; Vishnu-Mittre, 1974; Vishnu-Mittre *et al.*, 1983).

The data on the changes of the level of sea and the land from the Indian coastal region reveal that the sea level was nearly 160 m lower than high water level (HWL) between 10,400 to 9,100 y. B.P.; at the same time juniper increased in the steppes at Ladakh and pine-birch invaded the steppes at Toshmaidan in Kashmir Valley. Submergence along Kerala coast is recorded 8000 y.B.P., possibly then or later than oaks invaded the *Pinus roxburghii* forests in the Kumaon region of the Western Himalaya, when the sea level rose about 2-3 m, 7000 y. B.P. and continued until 4500 y. B.P. It is about this time that the oakwoods predominated in the temperate and the subtropical region of the Western Himalaya. Thereafter, sea level fluctuated between 1-3 m especially after 3000 y.B.P. when *Abies*/birch/pine forest was established at Toshmaidan in Kashmir Valley and conifers (pine/*Cedrus* forests) became dominant in temperate and subtropical region of Western Himalaya. The oak woods had either disappeared locally in certain areas (Kashmir Valley) or had been relegated to subsidiary status, surviving in sheltered belts within the conifer forests.

Man has played an important role in Holocene period in changing the floristic pattern.

Gupta and Sharma (1982) constructed pollen diagrams based on the information available from the deposits in Ladakh, Kashmir Valley, Himachal Pradesh, Kumaon, Rajasthan, Uttar Pradesh, Maharashtra, Gujarat, Assam, Bengal and Nilgiri. Sharma (1993) also presented synoptic analysis of palynological data on Himalayan lacustrine sediments covering Kashmir, Ladakh, Himachal Pradesh, Kumaon, Nepal, Darjeeling and Sikkim.

(i) *Kashmir :*

The pollen analysis data from the lower and upper Karewa deposits (Nair, 1960) revealed existence of *Alnus, Carpinus, Pinus roxburghii* and *Quercus* which were present in Karewa deposits are conspicuous by their absence in the Kashmir Valley today, although their equivalent species do occur on the southern slopes of Pir Panjal mountains. *Larix griffithiana* which was one of the components of the Karewa flora migrated to the Central and Eastern Himalayas (Sharma & Gupta, l.c.).

Broadly speaking the pollen analytical data from Toshmaidan (Singh, 1964) and Haigam Lake (Vishnu-Mittre & Sharma, 1966) three-fold vegetational succession i.e. Conifers-Quercetum-Mixtum-Conifer which is indicative of cool-warm-cool climatic condition.

(ii) *Ladakh :*

The information obtained from the pollen analytical data from the Tsokar Lake provides vegetational history from 30,000 to 9,000 years B.P. It is indicative of cold and dry climate during the last 30,000 years. The *Juniperus* community expanded during the amelioration of the climate.

(iii) *Himachal Pradesh :*

Sharma (1993) States "Comparative evaluation of the pollen diagram for lake sediments from different climatic or altitude zones in Himachal Pradesh reveal that palaeovegetation pattern in the Himachal Sector does not differ much from place to place. Rather there is concordance of subtropical and temperate zones in the late Holocene period. Furthermore, the older Oak-pine forest around Khajiar Lake in the temperate zone was gradually replaced by temperate-zone forests of deodar 1200 year ago. Similarly, around Rewalsar and Parasram Lake in the subtropical zone the oak-pine mixed forests growing 4000 year B.P. were replaced by pine forest around 1400 years B.P. At Marhi *Betula* ("Bhojpatra") was the chief arboreal of the high altitude open forests, together with Cyperaceae grasses forming the ground cover vegetation during the early Holocene, pointing to cool moist climate in the region. It was above 8000 years B.P. that oak and fir invaded the region, culminating in the growth of forests of *Quercus-Abies-Betula*. Thus there was change to a warm-moist climate, which reverted to cool-moist climate as is reflected by the preponderance of Cyperaceae-*Betula*."

(iv) *Kumaon Himalaya :*

The Holocene deposits of subtropical belt of Kumaon Himalaya reflect three-fold climatic fluctuation i.e. period of increasing warmth, period of optimum warmth and period of decreasing warmth which was corroborated by the existence of pine forests in the beginning, supercession of pine forests by broad-leaved oak forests during mid-Holocene and finally reverting to predominating pine forests.

(v) *Eastern Himalayas :*

(a) *Darjeeling :* The pollen analytical profile from Lake Mirik reveals vegetational history covering the last Glacial Maximuam and Holocene period (Sharma & Chauhan, 1988a; Sharma & Chauhan, 1988). The studies indicate conditions around 20,000 years B.P. Around mid Holocene these grasslands were replaced by mixed broad-leaved forests dominated by *Quercus, Alnus, Betula* and *Corylus* as climate turned comparatively more moist.

(b) *Sikkim :* The pollen analytical data from the lake deposit from Khechipiri reveals existence of mixed broad-leaved forests around 2500 years B.P. The mixed broad-leaved forests are indicative of warm and moist climate. Around 1000 year B.P. *Alnus* dominates over *Quercus* and there was increase in Rhododendrons. This shows that the climate became more moist.

(vi) *Rajasthan :*

Singh *et al.* (1974) while defining the Holocene vegetation and environment considered all pollen diagrams collectively and grouped them into five phases.

Phase I (10,000 year B.P.) - represents severe arid conditions and strong winds. Extensive sand dunes were deposited.

Phase II (*ca* 9500 years B.P.)- is characterised by open grassland steppes dominated by sedges but poor in halophytes. *Artemisia*, a taxa of comparatively higher rainfall, was characteristic of the phase.

Phase III (ca 9,500-5000 years B.P.) - This phase is characterised by Gramineae-Artemisia-Cheno-Ams assemblage. The vegetation was ± similar to the previous phase. The continued growth of *Typha angustata, Artemisia* and *Oldenlandia* in good frequency is indicative of higher precipitation.

Phase IV (*ca* 5000-3000 year B.P.)- This phase begins with abrupt increase in sedges and rise in trees and shrubs. *Prosopis cineraria, Acacia* sp., *Capparis* sp., *Tamarix* sp. and *Mimosa rubicaulis* are recorded in semi-arid belt. *Ziziphus* sp. and *Calligonum polygonoides* in arid belt whereas *Syzygium cuminii* and sedges reached their maximum in semi-arid and arid belts. Singh (1974) deduced that during this period there was probably an increase in rainfall over Rajasthan by about 50 cm than at present.

Phase V-(*ca* 1200 years B.P.) is characterised by Gramineae-Cheno-Ams-Cyperaceae-Calligonum assemblages and resembles existing climatic condition i.e. very arid climate.

(vii) *Gujarat* :

The pollen diagram constructed by Vishnu-Mittre and Sharma (1975) from Ox-bow Lake, Surat District is divisible into three phases.

Phase 'I' is characterised by high and consistent values of Gramineae and Cheno-amaranths followed by Leguminosae, Myrtaceae and *Holopetelea*.

Phase 'II' is characterised by high but inconsistent values of previous taxa.

Phase 'III' is characterised by reversal of high values in Gramineae and Cheno-amaranths accompanied by Cyperaceae etc. It seem that estuarine condition prevailed throughout or is indicated by high values of cheno-amaranths etc.

The pollen analytical investigation of brackish water Nal Lake (Vishnu-Mittre & Sharma, 1979) revealed existence of grassland-chenopod savannah in the vicinity right from the Early Holocene (*ca* 8000 years B.P.). It continued till 3000 year B.P. After 6000 year B.P. The vegetation around Nal Lake got a set-back as is indicated by a serious decline in total vegetation. The enhanced salinity might have been the causative factor for the decline.

(viii) *Maharashtra :*

While investigating stratigraphy and palynology of the Mangrove swamps of Bombay Vishnu-Mittre and Guzder (1975) reported stray occurrence of taxa such as *Avicennia* type, *Sonneratia acida, S. apetala, Acanthus ilicifolius, Excoecaria agallocha, Carallia* sp., Chenopodiaceae, *Phyllanthus*, Myrtaceae and Leguminosae.

(ix) *Uttar Pradesh :*

Gupta (1978) constructed pollen diagram from the deposits of Meander Lake in the Ganga Valley of district Pratapgarh. He divided the profile into four zones.

Zone I : depicts open grassland where chenopods grew in great profusion. The climate was very arid.

Zone II : depicts commencement of arboreal vegetation comprising elements such as *Anogeissus, Tecomella* and *Prosopis*. After a sharp decline Gramineae regained high values in rest of the zone. Decline in Gramineae corresponds with high values of *Chenopodium* and commencement of Cerealia pollen.

Zone III : is characterised by an overall increase in pollen frequencies with some new addition such as *Impatiens, Potamogeton, Liliaceae, Nymphaea* and *Ferns*. These are indicative of relatively higher precipitation as compared to zone II.

Zone IV : reflects maximum development of Cyperaceae and Liliaceae and overall decline in trees and shrubs. The decline of Gramineae and sharp rise of Cyperaceae, Liliaceae, *Alternanthera* and *Potamogeton* indicates inundation of lake margin.

(x) *Southern India :*

Gupta and Sharma (1982) reviewed the Quaternary pollen analytical work carried out earlier in Southern India. The investigation carried out by them on the Kakathope swamp, Ootacamund, Nilgiri depicts complete Late Quaternary vegetational history. The pollen diagram has been divided into three stages.

Stage 'I' (Ca 40,000-35,000 year B.P.) : The vegetation was open Savannah and largely comprised grassland with few strand of shrubs and trees. *Impatiens* pollen showed high values. This stage corresponds in time to last glaciation in Northern India (Vishnu-Mittre & Gupta, 1972).

Stage 'II' (24,275 ± 700 years B.P.) : During this stage the grassland was first invaded by *Ligustrum* then followed the other components such as Rosaceae, Malvaceae, *Rhododendron* and *Dipsacus* indicating a phase of tree/shrub Savannah.

Stage 'III' (15000 year B.P.) : The forest vegetation comprising *Gordonia, Euonymus* and *Elaeocarpus* alongwith a few shrubs such as *Dipsacus, Lonicera, Strobilanthes,* Malvaceae and Leguminosae was established during this stage which soon declined. Savannah formation started again during Early Holocene period.

(xi) *Eastern India* :

(a) *Bengal Basin* :

Gupta and Sharma (l.c.) reviewed the pollen analytical work done in Bengal Basin. Gupta (1981) States "The pollen diagram constructed from Kolara, Barrackpore and Namkhana have been divided into 3-5 pollen asemblage zones. The vegetation pattern is metachronous throughout the Bengal Basin. In western and eastern parts of Bengal, the vegetational history begins with brackish-water mixed *Heritiera* forest during phase I where *Phoenix paludosa* and Leguminosae are quite frequent and *Sonneratia* is sporadic. The ground vegetation is dominated by ferns and Gramineae. Phase II shows an overall increase in values of *Heritiera* and decline in *Phoenix paludosa*. Stray occurrence of *Rhizophora, Ceriops* and *Sonneratia* is recorded. Gramineae curve shows a notable increase whereas *Suaeda* and *Typha* have improved but Cyperaceae and other hydrophytes have declined. Phase III is determined exceedingly high values of *Sonneratia, Acanthus ilicifolius, Phoenix paludosa* and *Loranthus* are co-dominants arboreal taxa. The values for the above taxa either dwindled down or disappeared during phase IV. *Heritiera, Ceriops* and Leguminosae show gradual upward increase during phase IV.

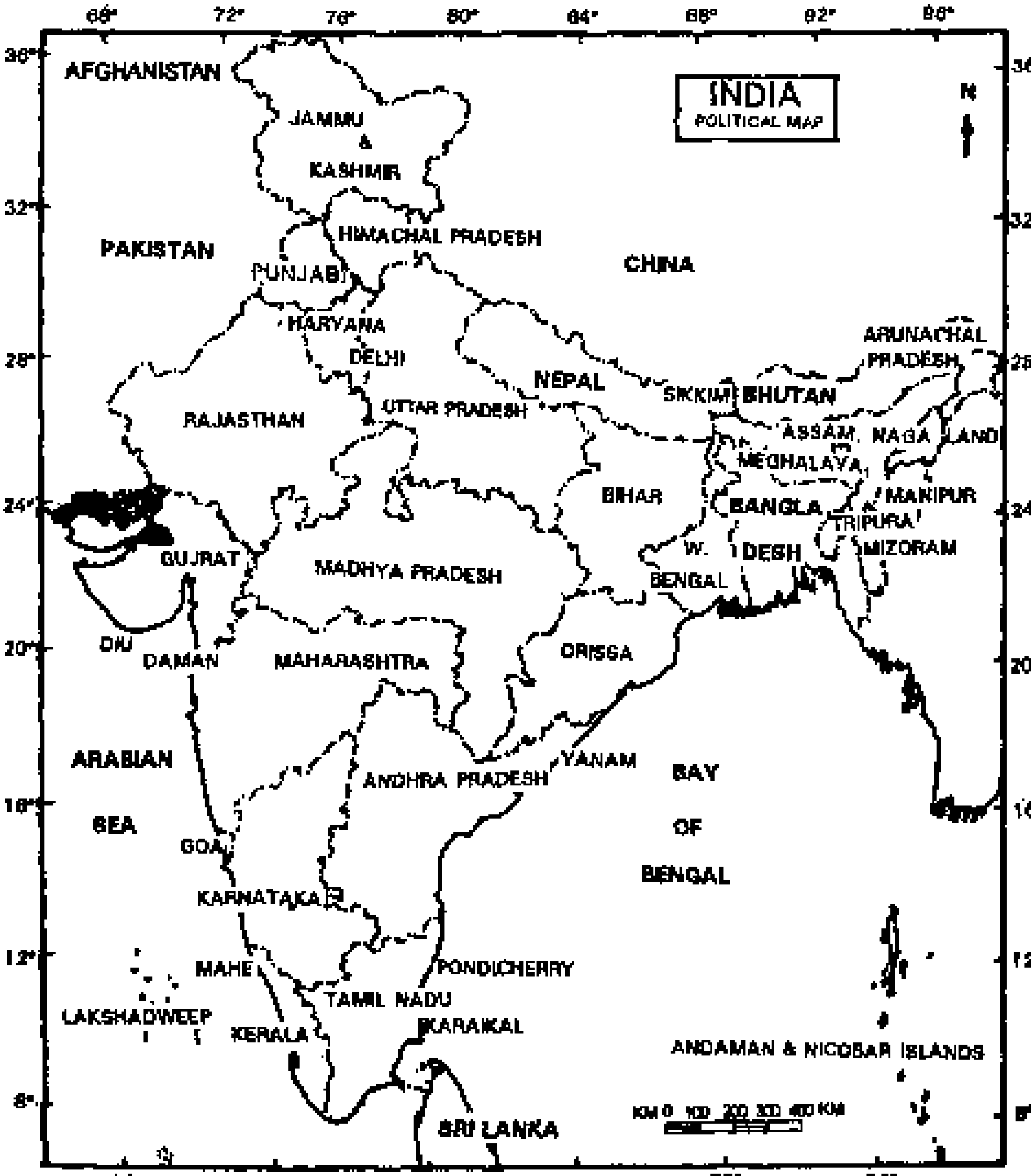
In the southern part of the Bengal basin the vegetation history begins with *Ceriops-Rhizophora* complex indicating tidal mangrove conditions during phase-I. Phase-II is marked by the sudden disappearance of *Ceriops* and *Rhizophora* and appearance of Leguminosae in good frequency. This shows a short period of cessation of the tides. Phase III is marked by reversal of *Rhizophora* alongwith *Nipa fruticosa* and *Concytricystes rubinus* indicating submergence of land by sea-water during *ca* 5000-5800 year B.P. Phase IV signifies the admixture of both tidal mangroves and prohyaline vegetation whereas phase V records an improvement of salt-tolerant fresh-water elements indicating reduction in the magnitude of tides".

(b) *Assam* :

The pollen analytical studies carried out by Gupta (1971) from a trench near Tockalai Experimental station at Cinnamara in north Assam revealed that forest vegetation comprised *Dillenia, Ardisia, Cinnamomum, Eurya, Quercus, Syzygium, Ternstroemia* and Leguminosae. The bamboos and fern festooned the forest. The composition is indicative of subtropical climate with high precipitation.

III. BRIEF RESUME OF VEGETATION AND FLORA OF INDIA

The present day India occupies a remarkable geographic position and is situated between 8°4'N and 37°6'N of the equator (Map 8). It has an area of 3,280,383 sq. km. It is surrounded by Arabian sea in the west, Indian ocean in the south and Bay of Bengal in the east. The coastline runs to *ca* 7000 km. In the north it is surrounded by the mighty Himalaya with loftiest mountain peaks. The upper reaches beyond vegetation lines are perpetually snow-clad. Its situation between 8°4'N and 37°6'N gives this country a great latitudinal spread which means wide range of temperature conditions. Altitudinally, the extremes are even greater ranging from sea level to the loftiest mountains of the world. Between the plains and the mountains India has practically all climatic zones from torried to arctic. The highest rainfall area (Cherrapunji) is located in India. The Rajasthan desert is located in the west where extremely high temperature have been reported. The cold desert (Ladakh) is located in the north. All these factors have contributed to the provision of an ideal and congenial niche for the diversification and enrichment of the flora. It is often said that few other countries of comparable size possess such a rich and varied vegetation as India.



Map 8. Political map of India.

It is estimated that about 45000 plants species occur in India out of which more than 17000 species belong to angiosperms alone. The angiosperms species are spread over 315 families (out of 400 families now defined) and 2250 genera.

Nayar (l.c.) provided species number in the major plants groups which is given in the following table.

Table-9. Species number in the major plant groups in India and the World

Kingdom	Division		Approx. number of species in India	Approx. number of species in the World
Monera	Bacteria	Bacteria including Cynobacteria	850	2700
Fungi			23000	100000
Protista	Algae (including water and saline moulds)		2500	22050
Plantae	Bryophyta	Liverworts, Mosses & Hornworts	2564	160000
	Psilopsida	Psilopsids	12	Several
	Lycophyta	Clubmosses	103	1000
	Sphenophyta	Horsetails	7	30
	Pteridophyta	Ferns	900	12000
	Coniferophyta	Conifers	55	550
	Cycadophyta	Cycads	5	100
	Gingkophyta	Gingko	0	1
	Gnetophyta	Gnetum	4	70
	Anthophyta	Flowering plants	15000	250000

Table-10. 10 Largest families of flowering plants of India by number of species

	Name of the family	No. of species
1.	Poaceae (Graminae)	1291
2.	Orchidaceae	1229
3.	Fabaceae (Leguminosae)	1192
4.	Asteraceae (Compositae)	800
5.	Rubiaceae	616
6.	Cyperaceae	545
7.	Euphorbiaceae	527

	Name of the family	No. of species
9.	Lamiaceae (Labiatae)	435
8.	Acanthaceae	500
10.	Scrophulariaceae	8

Table-11. 10 Largest genera of flowering plants of India by number of species

	Name of the genus	No. of species
1.	*Impatiens* (Balsaminaceae)	200
2.	*Carex* (Cyperaceae)	140
3.	*Primula* (Primulaceae)	104
4.	*Pedicularis* (Scrophulariaceae)	100
5.	*Bulbophyllum* (Orchidaceae)	97
6.	*Crotalaria* (Fabaceae)	96
7.	*Dendrobium* (Orchidaceae)	91
8.	*Astragalus* (Fabaceae)	72
9.	*Ficus* (Moraceae)	70
10.	*Euphorbia* (Euphorbiaceae)	
	Begonia (Begoniaceae)	60
	Hedyotis (Rubiaceae)	(each)

Table-12. Phytogeographical zones (sensu-lato) of India with approximate number of species

	Phytogeographic zone	No. of species
1.	Himalayas	8000
2.	Eastern Ghats	2000
3.	Western Ghats	4000
4.	Deserts (Thar and Ladakh)	1000
5.	Gangetic Plains	2000
6.	Peninsular India	3000
7.	North Eastern India	5000
8.	Islands	2000

Monogeneric families of flowering plants in India

There are 80 monogeneric families of flowering plants in India. Out of these 62 belong to Dicotyledones and 18 to Monocotyledones.

I. *Dicotyledones families :*

Barclayaceae, Basellaceae, Biebersteiniaceae, Cardiopterygaceae, Chrysobalanaceae, Circaeasteraceae, Eupteleaceae, Flindersiaceae, Frankeniaceae, Gyrocarpaceae, Ixonanthaceae, Lecythidaceae, Martyniaceae, Monimiaceae, Myricaceae, Nepenthaceae, Nelumbonaceae, Nyssaceae, Paeoniaceae, Pistaciaceae, Plagiopteraceae, Platanaceae, Polemoniaceae, Stachyuraceae, Tetracentraceae, Tropaeolaceae, Averrhoaceae, Carpinaceae, Casuarinaceae, Ceratophyllaceae, Coriariaceae, Corylaceae, Goodeniaceae, Hippocastanaceae, Hypecoaceae, Moringaceae, Podophyllaceae, Stylidiaceae, Symphoremataceae, Turneraceae, Avicenniaceae, Cactaceae, Erythropalaceae, Trapaceae, Ancistrocladaceae, Diapensiaceae, Illiciaceae, Menyanthaceae, Xanthophyllaceae, Dichapetalaceae, Callitrichaceae, Erythroxylaceae, Alangiaceae, Pittosporaceae, Plantaginaceae, Parnassiaceae, Aceraceae, Aquifoliaceae, Ebenaceae, Begoniaceae, Balsaminaceae and Clethraceae.

II. *Monocotyledones families :*

Flagellariaceae, Hydatellaceae, Philydraceae, Ruppiaceae, Trichopodaceae, Zannichelliaceae, Juncaginaceae, Trilliaceae, Triuridaceae, Cannaceae, Taccaceae, Typhaceae, Sparganiaceae, Xyridaceae, Aponogetonaceae, Najadaceae, Potamogetonaceae and Eriocaulaceae.

Monogeneric flowering plant genera in India

Approximately 266 genera of flowering plants in India are monotypic. These are :

1. *Acrachne* Wight & Arn. ex Chiov (Poaceae)
2. *Actinostemma* Griff. (Cucurbitaceae)
   A. tenerum Griff.
3. *Adenoon* Dalz. (Asteraceae)
   A. indicum Dalz.

4. *Adoxa* L. (Adoxaceae)
   A. moschatellina L.
5. *Alcimandra* Dandy (Magnoliaceae)
   A. cathcartii Hook.f. & Thoms.
6. *Aldrovanda* L. (Droseraceae)
   A. vesiculosa L.
7. *Allmania* R. Br. ex Wight (Amaranthaceae)
   A. nodiflora (L.) R. Br. ex Hook.f
8. *Anamirta* Colebr. (Menispermaceae)
   A. cocculus (L.) Wight & Arn.
9. *Anthogonium* Wallich. ex Lindl. (Orchidaceae)
   A. gracile Lindl.
10. *Apluda* L. (Poaceae)
   A. mutica L.
11. *Arcyosperma* Schultz. (Brassicaceae)
   A. primulaefolium (Thoms.) Schultz.
12. *Ariopsis* J. Grah. (Araceae)
   A. peltata J. Grah.
13. *Ascopholis* Fisch. (Cyperaceae)
   A. gamblei Fisch.
14. *Asperugo* L. (Boraginaceae)
   A. procumbens L.
15. *Aspidocarya* Hook.f. & Thoms. (Menispermaceae)
   A. uvifera Hook.f. & Thoms.
16. *Baeolepis* Decne ex Moq. (Periplocaceae)
   B. nervosa (Wight & Arn.) Decne. ex Moq.
17. *Baphicacanthus* Bremek. (Acanthaceae)
   B. cressia (Nees) Bremek.
18. *Benincasa* Savi (Cucurbitaceae)
   B. hispida (Thunb.) Congm.
19. *Bhidea* Stapf ex Bor (Poaceae)
   B. burnsiana Bor
20. *Bischofia* Blume (Bischofiaceae), (Euphorbiaceae)
   B. Javanica Blume
21. *Biswarea* Cogn. (Cucurbitaceae)
   B. tonglensis (C.B. Clarke) Cogn.
22. *Blepharistemma* Wallich ex Benth. (Rhizophoraceae)
   B. membranifolia (Miq.) Ding Hou.

23. *Blumeopsis* Gagnep. (Asteraceae)
B. flava (DC.) Gagnep.
24. *Boenninghausenia* Reichb. ex Meissn. (Rutaceae)
B. albiflora (Hook.) Reichb. ex Meissn.
25. *Bonnayodes* Blatt. & Hallb. (Scrophulariaceae)
B. limnophiloides Blatt. & Hallb.
26. *Brachystemma* D. Don. (Caryophyllaceae)
B. calycinum D. Don.
27. *Brasenia* Schreb. (Cabombaceae)
B. rosea W.W. Smith
28. *Bryocarpum* Hook.f. & Thoms. (Primulaceae)
B. himalaicum Hook.f. & Thoms.
29. *Bulleyia* Schlechter (Orchidaceae)
B. yunnanensis Schlechter
30. *Butomus* L. (Butomaceae)
B. umbellatus L.
31. *Bythophyton* Hook.f. (Scrophulariaceae)
B. indicum Hook.f.
32. *Coesulia* Roxb. (Asteraceae)
C. axillaris Roxb.
33. *Calacanthus* T. And. ex Benth. & Hook.f. (Acanthaceae)
C. grandiflorus (Dalz.) Radlk.
34. *Calycopteris* Lamk. (Combretaceae)
C. floribunda (Roxb.) Lamk.
35. *Campbellia* Wight (Orobanchaceae)
C. cytinoides Wight
36. *Cannabis* L. (Cannabinaceae)
C. sativa L.
37. *Carmona* Cav. (Ehretiaceae)
C. microphylla (Lamk.) G. Don.
38. *Carvia* Bremek. (Acanthaceae)
C. callosa (Nees) Bremek.
39. *Castellia* Tineo (Poaceae)
C. tuberculosa (Moris) Bor
40. *Catamixis* Thoms. (Asteraceae)
C. baccharoides Thoms.
41. *Cavea* W.W. Smith & Small. (Asteraceae)
C. tanguensis (Drumm.) W.W. Smith & Small.

42. *Cerasiocarpum* Hook.f. (Cucurbitaceae)
    C. bennettii (Miq.) Cogn.
43. *Chamaesphacos* Schrenk. (Labiatae)
    C. brachuicus Aitch. ex Hemsl.
44. *Chionocharis* Johnston (Boraginaceae)
    C. hookeri (C.B. Clarke) Johnston
45. *Chlamydites* Drumm. (Asteraceae)
    C. prainii Drumm.
46. *Chloroxylon* DC. (Flindersiaceae)
    C. swietenia DC.
47. *Choerospondias* Burtt & Hill. (Anacardiaceae)
    C. axillaris (Roxb.) Burtt & Hill.
48. *Chukrasia* A. Juss. (Meliaceae)
    C. tabularis A. Juss.
49. *Chydenanthus* Miers. (Barringtoniaceae)
    C. excelsus (Blume) Miers.
50. *Circaester* Maxim. (Circaesteraceae)
    C. agrestis Maxim.
51. *Cleisocentron* Bruhl (Orchidaceae)
    C. trichromum (Reichb.f.) Bruhl
52. *Cocos* L. (Palmae)
    C. nucifera L.
53. *Colebrookea* Smith (Labiatae)
    C. oppositifolia Smith
54. *Corallobotrys* Hook.f. (Ericaceae)
    C. acuminata Hook.f.
55. *Corbichonia* Scop. (Aizoaceae)
    C. decumbens (Forssk) Excell.
56. *Cortia* DC. (Umbelliferae)
    C. lindleii DC.
57. *Cottonia* Wight (Orchidaceae)
    C. peduncularis (Lindl.) Reichb.f.
58. *Craniotome* Reichb. (Labiatae)
    C. furcata (Link) O. Ktze.
59. *Cucubalus* L. (Caryophyllaceae)
    C. baccifer L.
60. *Curanga* Juss. (Scrophulariaceae)
    C. feltterrae Merr.

61. *Cydonia* Mill. (Rosaceae)
C. oblonga Mill.
62. *Dactyliandra* (Hook.f.) Hook.f. (Cucurbitaceae)
D. welwitschii Hook.f.
63. *Danthonidium* C.E. Hubb. (Poaceae)
D. gammiei (Bhide) C.E. Hubb.
64. *Decalepis* Wight & Arn. (Periplocaceae)
D. hamiltonii Wight & Arn.
65. *Desmostachya* Stapf. (Poaceae)
D. bipinnata (L.) Stapf.
66. *Dichaetaria* Nees ex Steud. (Poaceae)
D. wightii Nees ex Steud.
67. *Dicoelospermum* C.B. Clarke (Cucurbitaceae)
D. ritchiei C.B. Clarke
68. *Diectomis* Kunth (Poaceae)
D. fastigiata (Sw.) Kunth
69. *Didiciea* King & Prain (Orchidaceae)
D. cunninghami King & Prain
70. *Dinebra* Jacq. (Poaceae)
D. retroflexa (Vahl) Panz.
71. *Dipentodon* Dunn. (Dipentodontaceae)
D. sinicus Dunn.
72. *Dipterygium* Decne. (Cruciferae)
D. glaucum Decne.
73. *Ditrichospermum* Bremek. (Acanthaceae)
D. secundum (T. And.) Bremek.
74. *Drimycarpus* Hook.f. (Anacardiaceae)
D. racemosus Hook.f.
75. *Edgaria* C.B. Clarke (Cucurbitaceae)
E. darjeelingensis C.B. Clarke.
76. *Eleiotis* DC. (Leguminosae-Papilionaceae)
E. sororia (L.) DC.
77. *Eleutheranthera* Poit ex Bosc. (Asteraceae)
E. ruderalis (Sw.) Sch.-Bip.
78. *Ellisiophyllum* Maxim. (Scrophulariaceae)
E. pinnatum (Benth.) Makino
79. *Enhalus* Rich. (Hydrocharitaceae)
E. acoroides (L.f.) Rich. ex Steud.

80. *Enicostema* Blume (Gentianaceae)
    E. hyssopifolium (Willd.) Verdoorn
81. *Erinocarpus* Nimmo ex J. Grah. (Tiliaceae)
    E. nimmonii J. Grah.
82. *Erioglossum* Blume (Sapindaceae)
    E. rubiginosum Blume
83. *Eriophyton* Benth. (Lamiaceae)
    E. wallichianum Benth.
84. *Euclasta* Franch (Poaceae)
    E. condylotricha (Hochst.) Stapf
85. *Euryale* Salisb. (Eurylaceae)
    E. ferox Salisb.
86. *Falconeria* Hook.f. (Scrophulariaceae)
    F. himalaica Hook.f.
87. *Fergusonia* Hook.f. (Rubiaceae)
    F. tetracocca (Thw.) Baill
88. *Finlaysonia* Wall. (Periplocaceae)
    F. maritima (Blume) Backer ex K. Heyne
89. *Frerea* Dalz. (Asclepiadaceae)
    F. indica Dalz.
90. *Gentelbua* Bremek (Acanthaceae)
    G. urens (Heyne ex Roth) Bremek.
91. *Goniocaulon* Cass. (Asteraceae)
    G. glabrum Cass.
92. *Griffithella* (Tul.) Warm. (Podostemaceae)
    G. hookeriana (Tul.) Warm.
93. *Gynocardia* R. Br. (Flacourtiaceae)
    G. odorata R. Br.
94. *Halopyrum* Stapf (Poaceae)
    H. mucronatum Stapf
95. *Halostachys* C.A. Mey. (Chenopodiaceae)
    H. caspica (Pall.) C.A. Mey.
96. *Haplothismia* Airy-Shaw (Burmanniaceae)
    H. exannulata Airy-Shaw
97. *Hardwickia* Roxb. (Leguminosae-Caesalpinioideae)
    H. binata Roxb.
98. *Hedinia* Ostenf. (Cruciferae)
    H. tibetica (Thoms.) Ostenf.

99. *Helicanthes* Danser (Loranthaceae)
H. elastica (Desr.) Danser
100. *Hemidesmus* R. Br. (Periplocaceae)
H. indicus (L.) Schult.
101. *Hemiphragma* Wallich (Scrophulariaceae)
H. heterophyllum Wallich
102. *Hemsleya* Cogn. (Cucurbitaceae)
H. graciliflora (Harms) Cogn.
103. *Herpetospermum* Wallich ex Hook.f. (Cucurbitaceae)
H. pedunculosum (Ser.) Baill.
104. *Hesperethusa* M.J. Roem (Rutaceae)
H. crenulata (Roxb.) M.J. Roem.
105. *Hewittia* Wight & Arn. (Convolvulaceae)
H. sublobata (L.f.) O. Ktze.
106. *Hodgsonia* Hook.f. (Cucurbitaceae)
H. macrocarpa (Blume) Cogn.
107. *Homalocladium* (F.V. Muell.) Bailey (Polygonaceae)
H. platycladum (F.V. Muell.) Bailey
108. *Houttuynia* Thunb. (Saururaceae)
H. cordata Thunb.
109. *Hubbardia* Bor (Poaceae)
H. heptaneuron Bor
110. *Hunnemannia* Sweet (Papaveraceae)
H. fumariaefolia Sweet
111. *Hyalisma* Champ. (Triuridaceae)
H. janthina Champ.
112. *Hydrilla* Rich. (Hydrocharitaceae)
H. verticillata (L.f.) Royle
113. *Hydrobryopsis* Engl. (Podostemaceae)
H. sessilis (Willis) Engl.
114. *Hydrocera* Blume (Balsaminaceae)
H. triflora (L.) Wight & Arn.
115. *Hydrolythrum* Hook.f. (Lythraceae)
H. wallichii Hook.f.
116. *Hygroryza* Nees (Poaceae)
H. aristata (Retz.) Nees ex Wight & Arn.
117. *Hymenandra* A. DC. ex Spach (Myrsinaceae)
H. wallichii A.DC. ex Spach

118. *Hypopitys* Hill. (Monotropaceae)
    H. lanuginosa Nutt.
119. *Indobanalia* Henry & Roy (Amaranthaceae)
    I. thyrsiflora (Miq.) Henry & Roy.
120. *Indofevillea* Chatterjee (Cucurbitaceae)
    I. khasiana Chatterjee
121. *Indopiptadenia* Brenan (Mimosaceae)
    I. oudhensis (Brandis) Brenan
122. *Indopoa* Bor (Poaceae)
    I. paupercula (Stapf.) Bor
123. *Indotristicha* van Royen (Podostemaceae)
124. *Ipsea* Lindl. (Orchidaceae)
    I.speciosa Lindl.
125. *Ischnochloa* Hook.f. (Poaceae)
    I. falconeri Hook.f.
126. *Jamesbrittenia* O. Ktz. (Scrophulariaceae)
    J. dissecta (Del.) O. Ktze.
127. *Jansenella* Bor (Poaceae)
    J. griffithiana (C. Muell.) Bor
128. *Jerdonia* Wight (Gesneriaceae)
    J. indica Wight
129. *Kandelia* (DC.) Wight & Arn. (Rhizophoraceae)
    K. candel (L.) Druce
130. *Kendrickia* Hook.f. (Melastomataceae)
    K. walkeri Hook.f.
131. *Kingiodendron* Harms. (Leguminosae-Caesalpinioideae)
    K. pinnatum (Roxb.) Harms.
132. *Koelzella* Hiroe (Umbelliferae-Apiaceae)
    K. pabularia (Lindl.) Hiroe
133. *Kurziodendron* Balakr. (Euphorbiaceae)
    K. viridissimum (Kurz) Balakr.
134. *Lacaitaea* Brand. (Boraginaceae)
    L. calycosa (Coll. & Hemsl.) Brand.
135. *Lamarckia* Moench. (Poaceae)
    L. aurea (L.) Moench.
136. *Lamprachaenium* Benth. (Asteraceae)
    L. microcephalum Benth.

137. *Lawsonia* L. (Lythraceae)
L. inermis L.
138. *Lepidostemon* Hook.f. & Thoms. (Cruciferae)
L. pedunculosus Hook.f. & Thoms.
139. *Leptocodon* Lam. (Campanulaceae)
L. gracilis (Hook.f. & Thoms.) Lem.
140. *Leptorhabdos* Schrenk. (Scrophulariaceae)
L. parviflora (Benth.) Benth.
141. *Lopholepis* Decne. (Poaceae)
L. ornithocephala (Hook.) Steud.
142. *Martynia* L. (Martyniaceae)
M. annua L.
143. *Megacodon* (Hemsl.) H. Smith (Gentianaceae)
M. stylophorus (C.B. Clarke) H. Smith
144. *Menyanthes* L. (Menyanthaceae)
M. trifoliata L.
145. *Meteoromyrtus* Gamble (Myrtaceae)
M. wynaadensis (Bedd.) Gamble
146. *Meyenia* Nees (Thunbergiaceae)
M. hawtayneana (Wall.) Nees
147. *Micholitzia* N.E. Br. (Asclepiadaceae)
M. obcordata N.E. Br.
148. *Microcarpaea* R. Br. (Scrophulariaceae)
M. minima (Koen.) Merr.
149. *Microgynoecium* Hook.f. (Chenopodiaceae)
M. tibeticum Hook.f.
150. *Microschoenus* C.B. Clarke (Cyperaceae)
M. duthiei C.B. Clarke
151. *Milula* Prain (Alliaceae)
M. spicata Prain
152. *Mischodon* Thw. (Euphorbiaceae)
M. zeylanicus Thw.
153. *Myriostachya* (Benth.) Hook.f. (Poaceae)
M. wightiana (Nees ex Steud.) Hook.f.
154. *Nanothamnus* Thoms. (Asteraceae)
N. sericeus Thoms.
155. *Nechamandra* Planch. (Hydrocharitaceae)
N. alternifolia (Roxb.) Thw.

156. *Nelsonia* R. Br. (Scrophulariaceae)
N. canescens (Lam.) Spreng.
157. *Neodistemon* Babu & Henry (Urticaceae)
N. indicum (Wedd.) Babu & Henry
158. *Neoluffa* Chakravarty (Cucurbitaceae)
N. sikkimensis Chakravarty
159. *Neurada* L. (Neuradaceae)
N. procumbens L.
160. *Nothosaerva* Wight (Amaranthaceae)
N. brachiata (L.) Wight
161. *Notochaete* Benth. (Lamiaceae)
N. hamosa Benth.
162. *Nyctanthes* L. (Verbenaceae)
N. arbor-tristis L.
163. *Nypa* Steck. (Nypaceae)
Nypa fruticans Wurmb.
164. *Orinus* Hitchc. (Poaceae)
O. thoroldii (Stapf) Bor
165. *Otonephelium* Radlk. (Sapindaceae)
O. stipulaceum (Bedd.) Radlk.
166. *Ougeinia* Benth. (Papilionaceae)
O. oojeinensis (Roxb.) Hochr.
167. *Oxyria* Hill. (Polygonaceae)
O. digyna (L.) Hill.
168. *Pajanelia* DC. (Bignoniaceae)
P. longifolia (Willd.) K. Schum.
169. *Pamburus* Swingle (Rutaceae)
P. missionis (Wight) Swingle
170. *Parajeschkea* Burkill (Gentianaceae)
P. smithii Burkill
171. *Parastyrax* W.W. Smith (Styraceae)
P. lacei W.W. Smith
172. *Parochetus* Buch.-Ham. ex D. Don (Leguminosae-Papilionoideae)
P. communis Buch.-Ham. ex D. Don.
173. *Paroxygraphis* W.W. Smith (Ranunculaceae)
P. sikkimensis W.W. Smith
174. *Parrotiopsis* (Nied.) Schneid. (Hamamelidaceae)
P. jacquemontiana (Decne.) Rehder

175. *Pauella* Ramam. & Sebast. (Araceae)
P. sivagangana Ramam. & Sebast.
176. *Pauia* Deb & Dutta (Solanaceae)
P. belladona Deb & Dutta.
177. *Pedalium* L. (Pedaliaceae)
P. murex L.
178. *Pednogyne* Brand. (Boraginaceae)
P. tibetica (C.B. Clarke) Brand.
179. *Pentabothra* Hook.f. (Asclepiadaceae)
P. nana Hook.f.
180. *Pentapetes* L. (Sterculiaceae)
P. phoenica L.
181. *Peracarpa* Hook.f. & Thoms. (Campanulaceae)
P. carnosa (Wall.) Hook.f. & Thoms.
182. *Phaenosperma* Munro ex Benth. & Hook.f. (Poaceae)
P. globosum Munro ex Oliver
183. *Philydrum* Banks ex Gaertn. (Philydraceae)
P. lanuginosum Banks ex Gaertn.
184. *Phryma* L. (Phrymataceae)
P. leptostachya L.
185. *Pistia* L. (Araceae)
P. stratiotes L.
186. *Plagiopteron* Griff. (Plagiopteraceae)
P. suaveolens Griff.
187. *Platystemma* Wallich (Gesneriaceae)
P. violoides Wallich
188. *Plesmonium* Schott. (Araceae)
P. margaritiferum Schott.
189. *Pleurospermopsis* Norman (Umbelliferae)
P. sikkimensis (C.B. Clarke) Norman
190. *Pogonachne* Bor (Poaceae)
P. racemosa Bor
191. *Polysolenia* Hook.f. (Rubiaceae)
P. wallichii Hook.f.
192. *Polyura* Hook.f. (Rubiaceae)
P. geminata Hook.f.
193. *Polyzygus* Dalz. (Umbelliferae)
P. tuberosus Dalz.

194. *Pommereulla* L.f. (Poaceae)
P. cornucopiae L.f.
195. *Porteresia* Tateoka (Poaceae)
P. coarctata (Roxb.) Tateoka
196. *Pottingeria* Prain (Saxifragaceae)
P. acuminata Prain
197. *Praecitrullus* Pang. (Cucurbitaceae)
P. fistulosus (Stocks) Pang.
198. *Pseudaechmanthera* Bremek. (Acanthaceae)
P. glutinosa (Nees) Bremek.
199. *Pseudechinolaena* Stapf (Poaceae)
P.polystachya (HBK) Stapf
200. *Pseudodanthonia* Bor & C.E. Hubb. (Poaceae)
P. himalaica (Hook.f.) Bor & C.E. Hubb.
201. *Pseudodichanthium* Bor (Poaceae)
P. serrafalcoides (Cooke & Stapf.) Bor
202. *Pseudoglochidion* Gamble (Euphorbiaceae)
P. anamalayanum Gamble
203. *Pseudosorghum* A. Camus (Poaceae)
P. fasciculare (Roxb.) A. Camus
204. *Pseudostachyum* Munro (Poaceae)
P. polymorphum Munro
205. *Pubistylus* Thoth. (Rubiaceae)
P. andamanensis Thoth.
206. *Pycnospora* R. Br. ex Wight & Arn. (Leguminosae Papilionoideae)
P. lutescens (Poir.) Schindl.
207. *Queenslandiella* Domin (Cyperaceae)
Q. hyalina (Vahl) Ballard
208. *Remirea* Aubl. (Cyperaceae)
R. maritima Aubl.
209. *Rhagadiolus* Scop. (Asteraceae)
R. hedypnois Fisch. & Mey.
210. *Risleya* King & Pantl. (Orchidaceae)
R. atropurpurea King & Pantl.
211. *Roylea* Wallich (Lamiaceae)
R. cinerea (D. Don) Baill.
212. *Rubiteucris* Kudo (Lamiaceae)
R. palmata (Benth. ex Hook.f.) Kudo

213. *Rytilix* Rafin. (Poaceae)
R. granularis (L.) Skeels
214. *Santapaua* Balakr. & Subram. (Acanthaceae)
S. madurensis Balakr. & Subram.
215. *Sarcochlamys* Gaud (Urticaceae)
S. pulcherrima (Roxb.) Gaud.
216. *Schleichera* Willd. (Sapindaceae)
S. oleosa (Lour.) Oken.
217. *Scirpodendron* Kurz (Cyperaceae)
S. ghaeri (Gaertn.) Merr.
218. *Scyphiphora* Gaertn.f. (Rubiaceae)
S. hydrophyllacea Gaertn.f.
219. *Sechium* P. Br. (Cucurbitaceae)
S. edule (Jacq.) Sw.
220. *Smithiella* Dunn. (Urticaceae)
S. myriantha Dunn.
221. *Solena* Lour. (Cucurbitaceae)
S. heterophylla Lour.
222. *Soymida* A. Juss. (Meliaceae)
S. febrifuga A. Juss.
223. *Sphaerocaryum* Nees ex Hook.f. (Poaceae)
S. malaccense (Trin.) Pilger.
224. *Sphaeromorphaea* DC. (Asteraceae)
S. russeliana DC.
225. *Sphenoclea* Gaertn. (Sphenocleaceae)
S. zeylanica Gaertn.
226. *Sphyranthera* Hook.f. (Euphorbiaceae)
S. lutescens (Kurz) Pax. & Hoffm.
227. *Stellera* L. (Thymelaeaceae)
S. chamaejasme L.
228. *Stilbanthus* Hook.f. (Amaranthaceae)
S. scandens Hook.f.
229. *Stiptanthus* (Benth.) Briq. (Lamiaceae)
S. polystachyus (Benth.) Briq.
230. *Stracheya* Benth. (Leguminosae-Papilionoideae)
S. tibetica Benth.
231. *Streptolirion* Edgew. (Commelinaceae)
S. volubile Edgew.

232. *Struchium* P. Br. (Asteraceae)
S. sparganophorum (L.) O. Ktze.
233. *Taeniandra* Bremek. (Acanthaceae)
T. micrantha (Wight) Bremek.
234. *Tainiopsis* Schlechter (Orchidaceae)
T. barbata (Lindl.) Schlechter.
235. *Tamarindus* L. (Leguminosae-Caesalpinoideae)
T. indica L.
236. *Tarphochlamys* Bremek. (Acanthaceae)
T. affinis (Griff.) Bremek.
237. *Tecomella* Seem. (Bignoniaceae)
T. undulata (Smith) Seem.
238. *Tenagocharis* Hochst. (Limnocharitaceae)
T. latifolia (D. Don) Buchen.
239. *Terniola* Tul. (Podostemaceae)
T. zeylanica (Gardn.) Tul.
240. *Testudipes* Markgr. (Apocynaceae)
T. recurva (Roxb.) Markgr.
241. *Tetracentron* Oliver (Tetracentraceae)
T. sinense Oliver
242. *Tetrameles* R. Br. (Tetramelaceae)
T. nudiflora R. Br.
243. *Tetrapanax* Koch (Araliaceae)
T. papyriferum (Kh.) Koch.
244. *Thelepogon* Roth ex Roem. & Schult. (Poaceae)
T. elegans Roth ex Roem. & Schult.
245. *Theropogon* Maxim. (Liliaceae)
T. pallidus Maxim.
246. *Thylacospermum* Fenzl. (Caryophyllaceae)
T. rupifragrum Schrenk.
247. *Thysanolaena* Nees (Poaceae)
T. maxima (Roxb.) O. Ktze.
248. *Toddalia* Juss. (Rutaceae)
T. asiatica (L.) Lamk.
249. *Trachys* Pers. (Poaceae)
T. muricata (L.)
250. *Treutlera* Hook.f. (Asclepiadaceae)
T. insignis Hook.f.

251. *Triaenacanthus* Nees (Acanthaceae)
T. griffithianus Nees
252. *Trichopus* Gaertn. (Trichopodaceae)
T. zeylanicus Gaertn.
253. *Triplopogon* Bor (Poaceae)
T. ramosissimus (Hack.) Bor
254. *Trochiscus* Schulz. (Cruciferae)
T. cochlearioides (Roth) Schulz.
255. *Tupidanthus* Hook.f. & Thoms. (Araliaceae)
T. calyptratus Hook.f. & Thoms.
256. *Urochondra* C.E. Hubb. (Poaceae)
U. setulosa (Trin.) C.E. Hubb.
257. *Utleria* Bedd. (Periplocaceae)
U. salicifolia Bedd.
258. *Vossia* Wall. & Griff. (Poaceae)
V. cuspidata (Roxb.) Griff.
259. *Moullava* Dalz. (Leguminosae-Caesalpinoideae)
M. spicata (Dalz.) Nicols.
260. *Willisia* Warm. (Podostemaceae)
W. selaginoides (Bedd.) Warm.
261. *Zannichellia* L. (Zannichelliaceae)
Z. palustris L. ssp. *pedicellata* Wahlen. & Rosen.
262. *Zanonia* L. (Cucurbitaceae)
Z. indica L.
263. *Silentvalleya* V.J. Nair *et al.* (Poaceae)
S. nairii V.J. Nair *et al.*
264. *Nayariophyton* T.K. Paul (Malvaceae)
N. zizyphifolium (Griffith) T.K. Paul

Nayar (1996) has published comprehensive account of endemism in India flora. As per his estimates there are 5725 endemic species of flowering plants in India which are distributed over 147 genera and 47 families. The families Acanthaceae and Poaceae have largest number of endemic genera (17 genera each).

Nayar (l.c.) recognised following 3 Megacentres and 24 Microcentres of endemic plants in India.

Megacentres

1. Eastern Himalaya
2. Western Ghats
3. Western Himalaya

Microcentres

1. Andaman Group of Islands
2. Nicobar Group of Islands
3. Agasthyamalai Hills
4. Anamalai and High Ranges (Cardamon Hills)
5. Palni Hills
6. Nilgiris, Silent valley, Wynad, Kodagu
7. Shimoga Kanara
8. Mahabaleshwar Khandala Ranges
9. Konkan - Raigarh
10. Marathwara Satpura Ranges
11. Tirupati Cuddappa Nallamalai Hills
12. Vizagapatnam - Ganjam - Jeypore Hills
13. Southern Deccan (Leeward side)
14. Chotanagpur plateau
15. Kathiawar Kutch
16. Rajasthan Aravalli Hills
17. Khasia Jaintia Hills
18. Patkoi Manipur Lushai Hills
19. Assam
20. Arunachal Pradesh Himalaya
21. Sikkim Himalaya
22. Garhwal Kumaon Himalaya
23. Lahul Himachal Pradesh Himalaya
24. Kashmir Ladakh Himalaya

Of the 5725 endemic species of India :

3471	species occur in Himalaya
2015	species occur in Peninsular India
239	species occur in Andaman and Nicobar Islands

Megacentre of endemic plants of Western Ghats has	1500 endemic species (60 endemic genera)

Megacentre of endemic plants of Eastern Himalaya has	1808 endemic species
Megacentre of endemic plants of Western Himalaya has	1195 endemic species
Among the microendemic centres Andaman and Nicobar Islands has	239 endemic species

Table-12. Endemism in plants of India

Taxon	No. of species	Percentage of endemic
Bryophyta	2700	29.00%
Pteridophyta	1022	24.50%
Gymnosperms	64	12.40%
Angiosperms	17000	33.50%

Takhtajan (1967) considered Eastern Himalaya alongwith Northern Myanmar and Yunan axis as cradle of flowering plants.

Some of the Monocot families, viz. Eriocaulaceae, Marantaceae, Musaceae, Orchidaceae, Pandanaceae and Zingiberaceae show high endemism. The family Poaceae has about 360 endemic species (Jain, 1986). Of the 17000 flowering species 2560 species belong to tree species.

The insectivorous families are represented by Droseraceae (3 species), Lentibulariaceae (36 species) and Nepenthaceae (1 species). The parasitic families are represented by Loranthaceae (46 species), Santalaceae (10 species), Balanophoraceae (6 species), Burmanniaceae (7 species), Rafflesiaceae (1 species), Mitrastemonaceae (1 species), Orobanchaceae (54 species) and Cuscutaceae (12 species).

The Aquatic angiosperms account for more or less 600 species.

Mangroves occupy an area of 6740 sq. km. These are represented by 59 species distributed over 41 genera and 29 families.

Some of the interesting saprophytes, such as *Monotropa uniflora*, *Galeola falconeri*, *Epipogeum roseum*, *Aeginetia indica*, etc. are also found in Indian Flora.

A number of primitive angiosperms such as *Magnolia pealiana*, *M. griffithii*, *M. pterocarpa*, *M. gustavii* (Magnoliaceae), *Tetracentron sinensis* (Tetracentraceae), *Holboellia latifolia* var. *angustifolia* (Lazardizabalaceae), Hamamelidaceae members, viz. *Exbucklandia populnea*, *Distylium* sp., *Altingia* sp., *Carylopsis himalayana* alongwith *Myrica esculenta*, *Manglietia caveana*, *Talauma hodgsonii* and *Houttuynia cordata* are represented in the Flora of N.E. India. Occurrence of these primitive species makes this area a cradle of flowering plants.

Orchidaceae is represented by over 1200 species. Bamboos, which consistute one of the most important renewable biomass resources, show great diversity in India. Of the known 30 genera and 550 species in the world about 136 species occur in India. The Indian subcontinent is one of the twelve centres of genetic resources (Zeven & de Wet, 1982) and has given the world over two dozen crop plants. The cultivar diversity is so enormous that Indian region formed the "Hindustan Centre of Origin of Cultivated plants" (Vavilov, 1951).

Nature has blessed India with large number of plant groups having beautiful flowers. Some of these are species of Orchids, *Rhododendron*, *Hedychium*, *Primula*, *Pedicularis*, *Meconopsis*, *Corydalis*, etc.

Some of the rare and ornamental Orchids are :

Paphiopedilum fairieanum	*Cymbidium eburneum*
P. venustum	*Vanda coerulea*
P. insigne	*Renanthera imschootiana*
P. villosum	*Pleione maculata*
P. hirsutissimum	*Dendrobium nobile*
P. druryi	*D. hookerianum*
Anoectochilus sikkimensis	*D. densiflorum*, etc.

Some of the ornamental and threatened Rhododendrons are :

Rhododendron nuttalli	*R. hookeri*
R. falconeri	*R. macabeanum*
R. elliotii	*R. wattii*
R. arboreum	*R. hodgsonii*

Some of the ornamental species of Hedychiums are :

Hedychium luteum	*H. radiantum*
H. greenii	*H. robustum*
H. aureum	*H. dekianum*
H. longipedunculatum	*H. gardnerianum*

Some of the Primula species are :

Primula rosea
P. munroi
P. atrodentata
P. stuartii
P. sessilis
P. nivalis var. *macrophylla*

Some of the attractive species of Pedicularis, Maconopsis and Corydalis are :

Pedicularis rhinanthoides
P. siphonantha
P. pyramidata
P. pectinata

Meconopsis aculeata
M. paniculata

Corydalis cashmeriana
C. govaniana

The Indian flora is further enriched by migration of plant species from the neighbouring countries with which India has land connections and also far flunged area. The land connections in the north-west and north-east have provided corridors for the migration of the plant species. The high ranges of mountains in the north and seas surrounding the three sides of the Peninsular India have acted as effective barriers for the migration of plants. More than 500 new records have been reported during the current century. The areas from which plants have migrated and some of their migrants are given below.

1. *African elements :*

Some of the African taxa of common occurrence in India are *Acacia* spp., *Alstonia scholaris*, *Blepharis* spp., *Calophyllum inophyllum*, *Catharanthus* spp., *Dicanthium* spp., *Flacourtia*, *Geissapis cristata*, *Grewia*, *Halorrhena*, *Hyphaene*, *Kalanchoe pinnata*, *Lancea coromandelica*, *Pedalium murex*, *Pseudarthria viscida*, *Ricinus communis*, *Xemenia americana*. *Cocculus hirsutus*, *Nymphaea nouchali*, *N. pubescens*, *Capparis sepiaria*, *Cleome monophylla*, *Hybanthus enneaspermus*, *Pavonia ordorata*, *Melochia corchorifolia*, *C. aestuans*, *Biophytum sensitivum*, *Melia composita*, *Cassine glauca*, *Celastrus paniculata* etc. Some of the recently reported elements are *Cleome rutidosperma*, *Gressocephalum crepidioides*, *Euphorbia chamaesyce*, *Gisekia pharncioides*, *Hibiscus micranthus*, *Indigofera spicata*, *Ludwigia erecta*, *L. hyssopifolia*, *Micrococca mercuiialis*, *Mitracarpus verticillata*, *Brachiaria mutica*, *Melinus minutiflora*, *Rhynchelytrum villosum* etc. Raizada and Jain (1951, 1961) discovered two African genera *Dignanthia* and *Euclasta*. Bhandari and Singh (1964) recorded *Dactyliandra welwitchii*, a monotypic *genus*, hitherto reported only from Angola and S.W. Africa for the first time from Indian Desert.

2. *Arabian elements :*

Arabian elements are represented by genera such as *Acacia*, *Dodonaea*, *Heliotropium*, *Peganum*, *Salvadora*, *Zygophyllum*, *Periploca aphylla*, *Commiphora mukul*, *Capparis decidua*, *Sida grewioides*, *Indigofera anabaptista*, *Tribulus alatus*, *Melhania denhamii*, *Cucumis prophetarum* etc.

3. *Middle Asian elements :*

These are normally restricted to interior ranges of Ladakh, Lahul and Spiti Valley. Some of these are *Acantholimon lycopodioides*, *Biebersteinia odora*, *Halogeton glomeratus*, *Lathyrus humilis*, *Myricaria squamosa*, *Oxytropis microphylla*, *Rosularia alpestris*, *Salix karelinii*, *Sorbaria tomentosa* etc.

4. *Mediterranean elements :*

These are mostly represented by families viz., Brassicaceae, Caryophyllaceae etc. Some of the example are : *Fagonia arabica, Mansonia senegalenesis, Argyrolobium flaccidum, Trifolium fragiferum, Trigonella, Mellilotus, Medicago, Traverniera, Ebenus, Alhagi, Papaver rhoeas, P. dubium, Hypecoum, Farsetia, Alyssum, Malcolmia, Diplotaxis, Eruca, Moricandia, Capsella, Iberidella, Istais, Eryngium caeruleum, E. billardieri* etc.

5. *European elements :*

The European elements are mainly represented by the herbaceous species belonging to genera *Ranunculus, Gentiana, Swertia, Anemone* etc. A large number of species viz., *Aconogonum alpinum, Artemisia abysinthium, A. martima, Briza media, Barbarasa vulgaris, Cardamine impatiens, Carthamus lanatus, Chenopodium foliosum, Centaurea iberica, Cuscuta europea, Dactylis glomerata, Draba nemarosa, Epilobium roseum, Europhila verna, Geranium pratense, Hieracium virosum, Lotus corniculatus, Lycium ruthenicum, Lycopsis arvensis, Medicago falcata, Melilotus officinalis, Mentha longifolia, Orobanche cernua, Poa trivalvis, Primula sibirica, Ribes alpestre, Saxifraga oppositifolia, Trifolium repens, T. pratense* etc. are found in temperate regions of Himalayas. Some of the recently reported European elements viz., *Chrysanthemum leucanthemum, Convolvulus arvensis, Cuscuta campestris, Lepidium ruderale, Rumex acetosella, Senecio vulgaris, Anthoxanthum odoratum, Phalaris minor, Lathyrus aphaca, Vicia sativa, Senebiera pinnatifida, Alyssum maritimum, Lepidium sativum* have been reported from elsewhere in India.

6. *Elements common with Afghanistan :*

Anaphalis contorta, Arabidopsis thalianum, Arenaria griffithii, Artemisia sacrorum, Astragalus coluteocarpus, Barbarea vulgaris, Bergenia stracheyi, Brassica nigra, Bupleurum falcatum, Campanula aristata, Centaurea wallichii, Clematis orientalis, Dianthus crinitus, Dipsacus mitis, Draba alpina, Erigeron multiradiatus, Ferula jaeschkeana, Gallium aparine, Geranium collinum, G. mseboldii, Gnaphalium luteo-album, Indigofera heterantha, Lappula barbata, Lepidium ruderale, Lonicera heterophylla, Lycopsis arvensis, Mathiola odoratissima, Melilotus officinalis, Papaver nudicaule, Potentilla atrosanguinea, P. sericea, Prangos pabularia, Rosa webbiana, Ribes alpestre, Sedum roseum, Senecio pedunculatus, Sibbaldia cuneata, Silene vulgaris, Sisymbrium columnae, *Stellaria palustris, Swertia petidata, Thalictrum alpinum, Trichometum venetum, Trigonella corniculata. Vernonia perpusila* are some of the elements occurring in Himalayas and common with Afghanistan.

7. *Elements common with the Eastern United States* :

The following species found in Ladakh are common with the Eastern United States.

Astragalus alpinus, Barbarea vulgaris, Braya humilis, Cardamine pratensis, Carex rigida, C. stenophylla. Catabrosa aquatica. Chenopodium hybridum, Cystopteris fragalis, Deschampsia caespitosa, Eleocharis palustris, Epilobium angustifolium, Equisetum arvense, Festuca rubra, Galium aparine, G. boreale, Glaux maritima, Hippuris vulgaris, Koeleria cristata, Lemna minor, Limosella aquatica, Milium effusum, Oxyria digyna, Parnassia palustris, Phragmitis communis, Plantago major, Poa alpina, P. pratensis, P. nemoralis. Polygonum aviculare, P. viviparum, P. hydropiper, Potentilla anserina, P. fruticosa, Potamogeton pectinatus, Primula farinosa, Ranunculus agitalis, Sagina procumbens, Saxifraga oppositifolia, Sedum rhodiola, Scirpus pauciflorus, S. rufus. Triglochin maritima. Utricularia minor, Veronica anagallis, Zannichellia palustris etc.

Some of the recently reported North American elements found elsewhere in India are - *Alternanthera pungens, Calceolaria mexicana, Cassia corymbosa, Cassia laevigata, Centrosema virgianicum, Eleutheranthera ruderalis, Eupatorium adenophorum, E. erythropappum, E. ligustricum, Gnaphalium purpureum, Hyptis pectinata, Mellchia pyramidata, Nothosaerva brachiata, Oxalis latifolia, Oxalis maritima. Parthenium spicata, Petivera alliacea, Psdudo-elephantopus spicata, Solanum glaucum, Tithonia diversifolia, Bromus uniloides, Setaria paniculifera, Argemone mexicana, Malvastrum coromandelianum, Malachra capitata. Passiflora suberosa, P. foetida, Melochia pyramidata, Erigeron karvinskianus, Opuntia dillenii, Neptunia plena* etc. Some of these are now naturalized in the country.

Some of the South American elements are: *Alternanthera ficoidea, Boerhavia erecta, Croton bonplandianum, Gomphrena celosioides, Ipomoea carnea, I. congesta, I. fistulosa, Melochia pyramidata, Solanum viarum, Spermacoce latifolia, Turnera subulata, Echinochloa cruspavonia, Eichhornia crassipes, Paspalum dilatum* etc.

8. *Siberian elements :*

In temperate regions of India many species belonging to *Potentilla*, *Pedicularis* and *Lonicera* are common. The other elements common with Siberia are *Arabidopsis humile*, *Astragalus densiflorus*, *A. nivalis*, *A. subulatus*, *Artemisia desertorum*, *Chenopodium foliosum*, *Erodium stephanianum*, *Erysimum hieracifolium*, *Gentiana aquatica*, *G. squarosa*, *Geranium collinum*, *G. sibiricum*, *Isopyrum grandiflorum*, *Lactuca scariola*, *Lomatogonium carinthiacum*, *Medicago lupulina*, *Oxytropis lapponica*, *Polygala sibirica*, *Ranunculus cymbalariae*, *R. pulchellus*, *Rosa eglantaris*, *Rubus saxatilis*, *Sedum quadrifidum*, *Torularia humilis*, *Tussilago farfara* etc.

9. *Tibetan elements :*

The genus *Hippophae* is common with Indian flora. The other species common with Himalayan elements are *Arabis tibetica*, *Arnebia tibetiana*, *Astragalus zanskarensis*, *Atriplex crassifolia*, *Braya alpina*, *Chrysanthemum tibeticum*, *Corydalis crassifolia*, *Delphinium brunonianum*, *Elsholtzia densa*, *Hippuris vulgaris*, *Inula falconeri*, *Leontopodium nanum*, *Lomatogonium thomsoni*, *Lychnis macrorhiza*, *Mattiastrum tibeticum*, *Nepeta tibetica*, *Onosma hispidum*, *Oxytropis lapponica*, *Plantago minima*, *Polygonum sibiricum*, *Potentilla multifida*, *Primula elliptica*, *Rubia tibetica*, *Saussurea subulata*, *Sedum tibeticum*, *Stachys tibetica*, *Tanacetum tibeticum*, *Waldheimia stoliczkai*.

10. *Chinese elements :*

Androsace delavayi, *Boschniakia himalaica*, *Cotoneaster frigidum*, *Rrubus calycinus* which originated in S.W. China are found in Kumaon hills. Other Chinese elements worth mentioning are *Acer oblongum*, *Buddleja asiatica*, *Calotropis gigantea*, *Cardiocrinum giganteum*, *Dactylorhiza hatagirea*, *Diospyros*, *Hedera helix*, *Jasminum dispermum*, *Lonicera webbiana*, *Leycesteria formosa*, *Primula denticulata*, *Svida oblonga*, *Sympolocos paniculata*, *Taxus baccata* ssp. *wallichiana*, *Valeriana hardwickii*, *V. jatamansii* etc. are common to Himalayan flora.

Betula alnoides, *Callicarpa rebella*, *Cardamine griffithii*, *Cinnamomum obtusifolium*, *Dalbergia mimosoides*, *Helwingia himalaica*, *Litsea cubeba*, *L. kingii*, *L. sericea*, *Lonicera adonophora*, *Magnolia campbellii*, *Meconopsis* *nepaulensis, Michelia doltsopa, Millettia cinerea, M. pachycarpa, Neillia rubiflora, Osmanthus suavis, Panax pseudoginseng, Potentilla griffithii, Rhododendron micromeres, R. neriflorum, Rubus fragarioides, Salix sikkimensis, Schuteria hirsuta, Smilax ferox, Tetracentron* etc.

11. *Japanese elements :*

Some of the important elements are *Cornus controversa, Mucuna macrocarpa, Stachyurus, Helwingia, Schima, Quercus, Taxillus kaempferi, Mitrastemon yamomotoi, Desmodium heterocarpa, Hydrangia macrophylla, Viola thomsonii, Primula malacoides* etc.

12. *S.E. Asia and Malaysian elements :*

The Malesian elements common to Indian flora are members of families such as Dipterocarpaceae, Clusiaceae (Guttiferae) and Myristicaceae. Jain and Paul (1968) reported occurrence of *Polytrias* in Indian Flora.

The other elements of S.E. Asia and Malaysian region are : *Actinidia callosa, Ampelocissus barbata, Antidesma acuminata, Bischofia javanica, Brassaiopsis glomerulata, Cavallia brachiata, Crateva religiosa, Cynometra iripa, Debregeasia longifolia, Dendrobium aggregatum, Duabanga grandiflora, Engelhardtia spicta, Eria paniculata, Exbucklandia populnea, Firmiana colorata, Garuga pinnata, Guettarda speciosa, Hedychium coccineum, Heritiera formes, Hodgsonia macrocarpa, Lepisanthes senegalensis, Lithocarpus elegans, Lumnitzera racemosa, Mangifera indica, Meliosma simplicifolia, Michelia champaca, Mucuna nigricans, Musa balbisiana, Ochrosia oppositifolia, Oroxylum indicum, Procris crenata, Raphiodophora peepla, Spondias pinnata, Sonneratia caseolaris, S. griffithii, Talauma hodgsonii, Tetrameles nudiflora, Toona sureni, Trevesia palmata, Veronia volkamerifolia* etc.

13. *Australian elements :*

There are few species in India of genera like *Baeckea, Leptospermum, Melaleuca, Casuarina, Stylidium* and *Helicia* which have their original home in Australia. Some other elements are *Cotula australis, Dentella serpyllifolia, Eryngium foetidum, Ipomoea quinata, Lobelia radicans, Pseudarthia viscida, Rothia trifoliata, Digitaria adscendens, Digitaria preslii, Polytrias amaura* etc.

14. *Sri Lankan elements :*

A number of Sri Lankan elements have been reported from south India. Recently, Henery and Subramanyam (1981) and Henery *et al* (1984) have reported several typical Sri Lankan plants from Agasthymalai hills. Some of these are

Aberema subcoriacea, Biophytum nudum, Chrysoglossum maculatum, Eugenia rotunda, Fahrenheitia zeylanica, Filicium decipiens, Pavetta zeylanica, Rubus micropetalus, besides *Andrographis zeylanica, Antidesma mabaeoides* and *Neonotis nummularia* which were considered so far as endemic to Sri Lanka.

Rao and Sastry (1974) reported occurrence of *Messerschimidia argentea,* a Sri Lankan element, along the shores of Krusadi islands. Some of the other species common with Sri Lanka are - *Diospyros ebenum, Ardisia solanacea, Ipomoea eriocarpa, Phoebe lanceolata, Chloroxylon swietenia, Tabernaemontana coronarea, Vitex negundo, Flacourtia ramnotchii, Terminalia chebula, Humboldtia* sp. etc.

Ramachandran and Nair (1988) in flora of Cannanore reported large number of species having remarkable affinities with Sri Lanka such as -*Acacia tora, Albizia amara, Begonia malabarica, Caryota pedata, Clematis gouriana, Fagraea zeylanica, Filicium decipiens, Gordonia obtusa, Gouania microcarpa, Harpullia arborea, Indigofera constricta, Kydia calycina, Litsea deccadensis, Miliosma simplicifolia, Mesua nagassarium, Myristica dactyloides, Naravelia zeylanica, Neurocalyx calycina, Hedyotis nitida, Pterocarpus marsupium, Rourea minus, Sarcandra chloranthoides, Schumannianthus virgata, Tarenna assiatica, Tetrastigma leucostaphylum, Thottea siliquosa, Ziziphus xylocarpus.*

IV. PHYTOGEOGRAPHICAL REGIONS

Sharma and Balakrishnan (see Chapter 5. Phytogeographic Divisions in Part I of the Introductory volume of the Flora of India) broadly classified flora of India into eleven broad phytogeographic entities (Map 9). Based on the knowledge gained by the extensive floristic surveys of the country during the last 35 years by Botanical Survey of India and universities coupled with the available literature these are :

1. North-Western Himalayas
2. Indo-Gangetic Plains

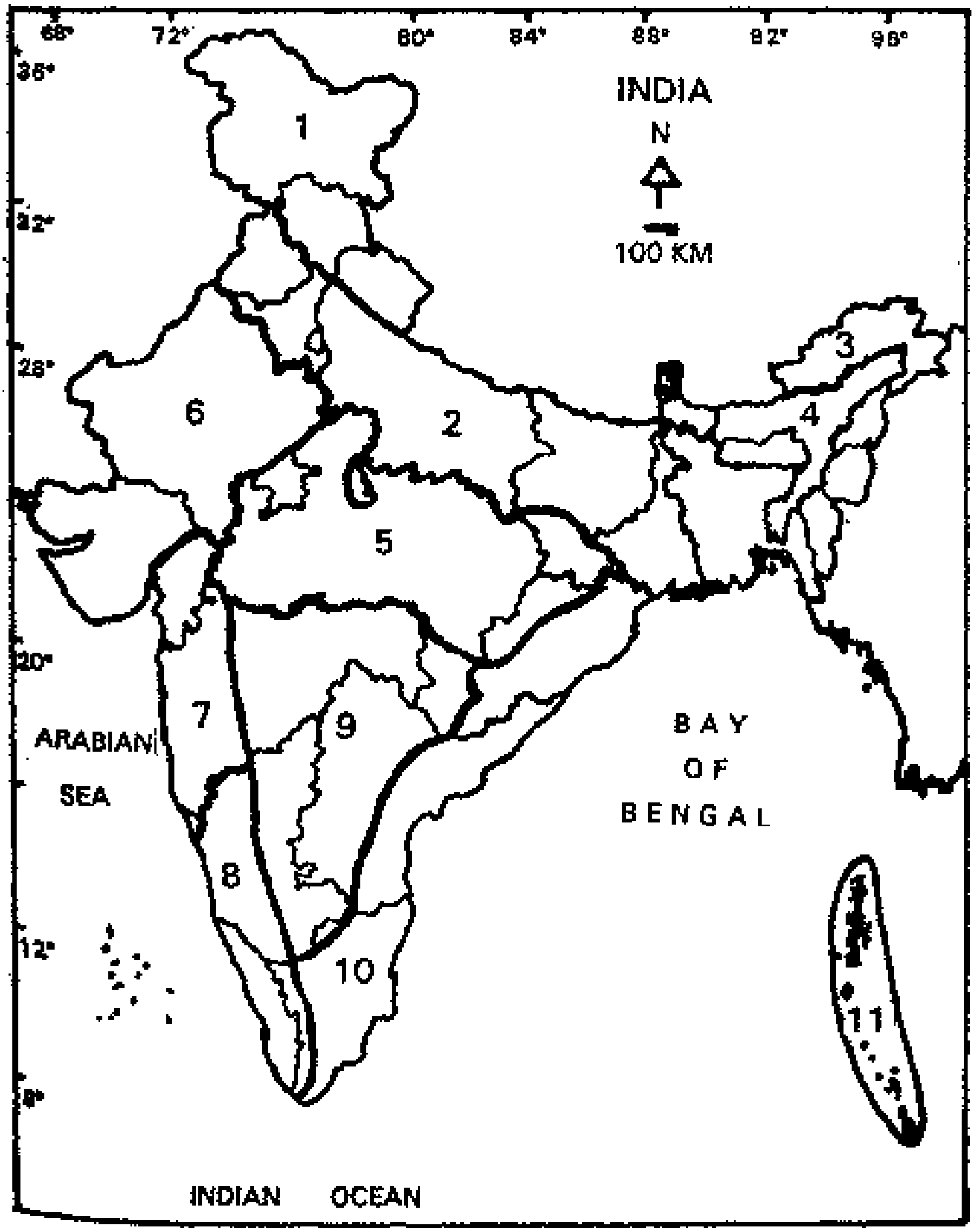
3. Eastern Himalayas
4. Assam
5. Central India
6. Arid zone
7. Northern Western Ghats and West coast (Goa, N. Maharashtra & Gujarat)
8. Southern Western Ghats, West coast and Lakshadweep Islands
9. Deccan
10. Eastern Ghats and Coromandel Coast
11. Andaman and Nicobar Islands

1. *North-Western Himalayas*

The natural vegetation in Himalaya show altitudinal zonations. In the foothills of the Northwestern Himalayas below 1000 m, the forests are subtropical Dry evergreen type. The important plant components are species of *Acacia*, *Olea*, *Pistia*, *Punica* etc. The lower altitudes comprise subtropical pine forests which is chiefly represented by *Pinus roxburghii* and species of *Quercus* or *Syzygium* or Rhododendrons are occasionally associated. Between 1500-3000 m, Moist Temperate Zone forests of *Abies*, *Quercus*, *Cedrus*, *Picea* and *Acer* are found. The coniferous forests in Temperate Zone comprise species of *Pinus*, *Cedrus*, *Picea* and *Tsuga*. Occasionally, *Taxus* and *Betula* also occur. The inner ranges of mountains have Dry Temperate forests comprising *Pinus gerardiana* and species of *Cedrus*, *Quercus*, *Acer*, *Fraxinus*, *Celtis* and *Olea*. In sub-alpine zone the forests mainly comprise *Pinus wallichiana* and species of *Abies*, *Picea*, *Taxus*, *Betula*, *Rhododendron* and rosaceous plants. Above 3000 m, the vegetation is of Moist Alpine Scrub comprising species of *Betula*, *Rhododendron*, *Lonicera* and *Berberis*. Around 4000 m, the uppermost limit of vegetation has Dry Alpine scrub. The main representatives are species of *Juniperus*, *Lonicera*, *Artemisia* etc.

2. *Indo-Gangetic Plains :*

This region extends from eastern Rajasthan through Uttar Pradesh to Bihar and Bengal which is mostly under cultivation. The sub-montane moister parts have Tropical Moist Deciduous forests having plant components such as *Shorea robusta* mixed with species of *Lagerstroemia*, *Adina*, *Kydia*, *Litsea*, *Syzygium*, *Mallotus* etc. The larger forest areas is under Tropical Dry Deciduous forests comprising species of *Terminalia*, *Anogeissus*, *Semecarpus*, *Buchanania*, *Acacia* and *Aegle* etc. Tall grasses belonging to such genera as *Themeda*, *Saccharum* and *Narenga* and species of *Cymbopogon*, *Apluda*, *Dicanthium*, *Bothriochloa*, *Desmostachya*, *Chloris*, *Vetiveria* occur in this area. The south eastern end of Gangetic Plain merges with the Littoral and Mangrove region of Sunderbans where species of *Heritiera*, *Bruguiera*, *Sonneratia*, *Rhizophora* etc. predominate the forest vegetation.



Map 9. Phytogeographical divisions of India, (after Balakrishnan, 1996).
1. North-West Himalayas, 2. Indo-Gangetic Plains, 3. Eastern Himalayas, 4. Assam, 5. Central India, 6. Arid Zone, 7. Northern Western Ghats and West Coast, 8. Southern Western Ghats, West Coast and Lakshadweep, 9. Deccan, 10. Eastern Ghats and Coromandel Coast, 11. Andaman and Nicobar Islands.

3. *Eastern Himalayas :*

The Eastern Himalayas are wetter and warmer as compared to the Western Himalayas and, as a consequence, floristically richer also. The foothill forests have species of *Dipterocarpus*, *Artocarpus* and *Shorea assamica*. The lower slopes have tropical semi-evergreen forests of *Terminalia microcarpa, Michelia champaca, Phoebe, Dysoxylum, Canarium, Litsea,* Mango and *Catanopsis*. Patches of subtropical broad-leaved hill forests comprising species of *Quercus, Castanopsis, Phoebe, Schima* and *Terminalia* are also seen. Between the altitude of 1800-3000 m, the forests are of Montane Wet or Moist type having species chiefly of *Machilus, Cinnamomum, Litsea, Magnolia* and *Schima*. *Cedrus deodara,* a significant component of Western Himalaya, is conspicuous by its absence in Eastern Himalayas. Dry Temperate Forests chiefly of conifer trees are found in inner ranges of Sikkim; they comprise species of *Picea, Larix, Abies* and *Tsuga*. Above 3000 m, the Moist Alpine Scrub is found. Out of the 990 species of Indian orchids *ca* 600 species are found in Sikkim and Eastern India.

4. *Assam :*

This area consists of Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. Over the greater parts of this region the rainfall exceeds 200 cm, while Cherrapunji in the Khasi Hills, with a normal rainfall of 1080 cm, is reported to be the rainiest spot in the world. The vegetation is luxuriant and the valleys, where they are not under tea or agricultural crops, are clothed with expanses of tall savannah grass or with dense forest often of an evergreen type.

The hill forests of Assam region approximate in type to those of Eastern Himalayan region, except that there is no alpine zone. These hills may be separated broadly into Evergreen forests, Broad-leaved forests and Pine forest.

(i) *Tropical Forests :*

In covers upto an elevation of 900 m. It comprises Evergreen, Semi-evergreen forests, Deciduous forests (dry & moist) and scattered riparian forests and swamps. Tropical Evergreen Forests are found in Assam valley, foothills of Eastern Himalaya and in the lower parts of Nagaland hills and Manipur. The tallest trees comprises *Dipterocarpus turbinatus, Canarium resiniferum,* *Artocarpus chaplasha, Tetrameles nudiflora, Ailanthus grandis, Euphorbia longana, Kayea assamica, Terminalia chebula, Mesua ferrea* etc. Lower trees are *Amoora wallichii, Ficus rumphii, Lagerstroemia parviflora, Terminalia myriocarpa, Michelia* and all the member of family Magnoliaceae.

Palm species belonging to genera *Caryota, Licuala, Arenga, Pinanga and Didymosperma* occur in the area. Tree ferns belonging to genera *Cyathea* and *Angiopteris* also occur.

(ii) *Deciduous Forests :*

These are dominated by *Shorea robusta, Carya arborea, Kydia calycina, Sterculia villosa, Bombax ceiba,* species of genera *Grewia, Terminalia, Bauhinia, Albizia* and *Adina cordifolia, Gmelina* etc.

Tall grasses such as *Arundo donax, Phragmites communis* and species of genera *Saccharum, Anthistiria* etc. are found in abundance.

Swamp and Marsh vegetation :

It comprises families Nymphaeaceae, Lemnaceae, Araceae, Cyperaceae, Eriocaulaceae, Najadaceae etc. *Typha elephantina, Arundo donax, Phragmites, communis* are of common occurrence.

The shrubby elements comprise *Crataeva lophosperma, Eugenia cuneata, Homonia riparia* etc. The stunted trees belong to *Salix tetrasperma* etc.

(iv) *Temperate vegetation :*

It is found at an elevation of 1300-2500 m in Shillong Plateau, Naga Hills, Mizo (Lushai) and Mikir Hills. Some of the components are *Albizia, Acer, Juglans, Quercus, Michelia, Magnolia, Rhododendron, Rubus* spp., etc. On the higher altitudes *Alnus nepalensis, Cornus controversa, Ilex* spp., etc. are found. With the increase of altitude species of *Rhododendron, Pyrus, Prunus, Spiraea, Eriobotrya* and other Rosaceae are found which gradually ends up in *Tsuga-Picea-Abies* association.

Sacred forests comprise species of *Quercus, Rosa, Photinia, Pyrus, Prunus, Sorbus, Castanopsis* etc. A number of other elements belonging to genera *Corylopsis, Exbucklandia, Albizia, Manglietia* with *Schizandra, Kadsura, Acer* and occasional *Alnus, Engelhardtia, Mahonia, Agapetes, Vaccinium* etc. Trees are clothed with numerous epiphytes.

The Grassland on the hills are covered with species of *Arundinella, Chrysopogon, Cymbopogon, Echinochloa, Erianthus, Ischaemium, Panicum, Paspalum* etc.

(v) *Subalpine vegetation :*

It occurs in Nagaland, Manipur, etc. The dominant trees are *Abies, Tsuga* and *Picea* and dense bushy Rhododendrons, *Berberis, Salix, Agapetes, Juniperus recurva, Sorbus, Rubus*. The herbaceous components also belong to families Ranunculaceae, Rosaceae, Polygonaceae, Gentianaceae, etc.

Some of the interesting plants found in Assam are *Sapria himalayana, Balanophora dioica, Mitrastemon yamomotai, Monotropa uniflora, Epipogon roseum, Galeola falconeri, Aldrovanda* sp., *Nepenthes khasiana* etc.

5. *Central India :*

The forests can be divided into two major types, viz. 1. Tropical forests and, 2. Montane subtropical forests.

1. Tropical forests :

(i). *Northern tropical semi-evergreen forests :*

Some eastern parts of Madhya Pradesh adjoining Orissa and having rainfall of *ca* 1400-1700 mm have this kind of forests. Some of the main components are:

Terminalia alata, Stereospermum suaveolens, Tetrameles sp., *Shorea robusta, Artocarpus lakoocha, Michelia champaca, Celtis tetranda, Bridelia squamosa, Calamus* spp; *Dillenia* spp., *Ficus* spp., *Glochidion* spp., *Phoebe lanceolata, Litsea nitida, Leea* etc. *Bambusa arundinacea* bamboo breaks are common.

(ii). *Tropical moist deciduous forests :*

The major part of this forest occurs on hilly ground in region with about 1500 mm and higher annual rainfall. The common components are :

Shorea robusta, Pterocarpus marsupium, Terminalia elata, T. bellirica, T. chebula, Lannea coromandelica, Dalbergia paniculata, Adina cordifolia, Bombax ceiba, Stereospermum chelonoides, Garuga pinnata, Soymida febrifuga, Lagertroemia parviflora, Anogeissus latifolia. Some of the small trees and shrubby components are

Bridelia squamosa, Cleistanthus collinus, Mallotus philippensis, Diospyros melanoxylon, Buchanania lanzan, Cassia fistula, Schleichera oleosa, Ougenia oojeinsis, Miliusa tomentosa, Carya arborea, Dillenia pentagyna, Chloroxylum swietenia, Helicteris isora, Antidesma ghaesembilla, Gmelina arborea, Grewia latifolia, Breynia vitisidaea, Embelia tsjeriameottam, Ochna obtusata, Casearia graveolens, Holarrhena antidysenterica, Semecarpus anacardium, Ficus spp., *Leea* spp., etc. In the valleys and gorges of parts of Raipur, Bastar, Balaghat, Hoshangabad and Shahdol the forests are dominated by evergreen species such as *Trewia nudiflora, Toona ciliata, Diospyros montana, D. malabarica, Putranjiva roxburghii, Ficus* spp. etc.

(iii). *Tropical dry deciduous forests :*

The common components of these forests are *Terminalia* spp., *Tectona grandis, Pterocarpus marsupium, Cochlospermum religiosa, Diospyros melanoxylum, Butea monosperma, Lagerstroemia parviflora, Anogeissus latifolia, A. pendula, Emblica officinalis, Sterculia* sp., *Boswellia serrata, Hardwickia binata, Bauhinia* spp., *Aegle marmelos, Acacia* spp., etc.

(iv). *Tropical Thorn forests :*

The common components of these forests are *Acacia* spp., *Ziziphus* spp., *Albizia* spp., *Aegle marmelos, Gardenia* spp., *Randia* spp., *Cordia obliqua, Balanitis roxbburghli, Prosopis specigera, Mimosa* spp., *Gymnosporia spinosa, Flacourtia inditica*, etc.

II. *Montane subtropical forests :*

The following central Indian type of subtropical forests found on some hill-tops of Madhya Pradesh, Orissa and Mt. Abu of Rajasthan.

These forests resemble dry deciduous forests though with a higher proportion of the evergreen. These occur in patches in Pachmarhi and Bailadila regions. The main components are *Michelia champaca, Syzygium cumini, Manilkara hexandra, Mangifera indica, Symplocos lauriana, Salix tetrasperma, Litsea monopetala, Dillenia* spp., *Mallotus philippensis, Toona ciliata, Gnetum scandens, Calamus* spp. Tree fern - *Cyathea* spp. are of common occurrence in these forests.

6. *Arid Zone :*

The western dry region of India has four fairly distinct habitat conditions (i) sandy plains and dunes (ii) gravelly plains (iii) rocky habitat and (iv) saline depressions. The sand dunes have very sparse vegetation and the sandy plain a few scattered trees of *Acacia* and *Prosopis* and bushy plants chiefly comprising *Calligonum, Lycium, Aerva, Leptadenia, Crotalaria* and *Capparis*. The gravelly plains or rocks have species of *Calotropis, Gymnosporia, Ziziphus, Cassia, Commiphora, Indigofera*, etc. Species of *Phoenix* are common. The rocky habitats have bushes of *Euphorbia* and *Grewia*. In moist or shaded places species of *Anogeissus, Dichrostachys, Prosopis, Acacia* and *Zizyphus* are found. Species of *Salvadora* and *Tamarix* occur near saline depressions.

7. *Northern Western Ghats and West coast :*

This area covers the northern parts of Western Ghats and adjoining west coast, covering Goa, Western Maharashtra and Southern Gujarat. The main type of vegetation in Western Ghats of Maharashtra comprises Montane Evergreen forests and Moist Deciduous forests on the windward side of Western Ghats. Qureshi (1965) remarks that the Evergreen forests occurring in Western Ghats of Maharashtra are not typical tropical evergreen forests. Though this region receives rainfall of 625-750 cm, the evergreen trees are dwarfish with no tree tiers or canopies. Hence they are classified as Montane subtropical Evergreen forests. The main components of which are *Amoora lawii, Aphanamixis rohutuka, Walsura trijuga, Toona ciliata, Holopetalia integrifolia, Alstonia scholaris, Pongamia pinnata, Caryota urens, Tetrameles nudiflora, Terminalia chebula, Bridelia squamosa*, etc.

The second layer of these forests consists mainly of *Miliosma tomentosa, Murraya paniculata, Syzygium cumini, Meyna laxiflora, Mammea suriga, Gnetum ula,* etc. A large number of herbaceous species become conspicuous during monsoon. A number of terrestrial, epiphytic and Lithophytic orchids occur in these forests. *Platanthera sussane, Vanda tessellata, Aerides crispum* and *Dendrobium lawiana* are some of the beautiful orchids.

"The vegetation shows north to south variation which can be closely correlated with climate. Occurrence of evergreen forests vegetation is dependent on humid conditions and in the more arid climate of the northern Sahyadris such forest only occurs as low, stunted, semi-evergreen patches isolated along the upper slopes of the Ghats and surrounded by the deciduous forests on the lower slopes. As one goes southwards along the Sahyadris the area of semi-evergreen forests increases, forming a wider band on the upper slopes culminating in the tropical low, semi-evergreen canopy of the Mahableshwar Ghats. This steady change correlates with the increase in the rainfall and decrease in the length of the dry period.

The species composition of the semi-evergreen/evergreen forests also becomes richer as one goes south. Typical giant trees of evergreen forests such as species of *Calophyllum, Hopea, Canarium, Mammea* and several others begin to appear along Phonda - Amboligbat and Goa Ghats : at first occurring in small numbers mixed with deciduous species which form majority of the stand.

The Phonda - Amboligbat and Goa Ghats are northern limit of completely evergreen vegetation on the Western Ghats. Further south, in the Agumbe Ghats area and in Coorg Ghats, typical evergreen forests of entirely different floristic pattern predominate" (Rao, 1978).

Semi evergreen type of forests occur along lower slopes in the Sahyadris and extend even to the evergreen forest belt of Karnataka Ghats. Some of the species are *Schleichera oleosa, Miliusa tomentosa, Pongamia pinnata, Trema orientalis, Syzygium cumini, Ixora bracteata, Xeromphis spinsoa,* etc. Shrubs and climbers such as *Leea indica, Jasminum malabaricum, Tylophora dalzellii,* etc.

The tree species like *Memecylon umbellatum, Carallia brachiata, Xantolis tomentosa, Oleea dioica, Mimusops elangi, Mammea suriga, Sageraea laurifolia, Amoora lawii , Actinodaphne, angustifolia* and *Ancistrocladus heyneanus* are restricted to higher slopes above 800 m as representative components of semi-evergreen belts of Sahyadris but also extends to the evergreen forests of Karnataka Ghats.

Some of the Goa Ghats semi-evergreen elements are *Hydnocarpus laurifolia, Garcinia indica, Hopea wightiana, Canarium strictum, Euphoria longana, Nothopegia dalzellii, Syzygium hemisphericum, Aporosa lindleyana, Artocarpus heterophyllus*, etc.

Some of the deciduous type forests components are *Hymenodictyon excelsum, Holopetalea integrifolia, Casearia graveolens, Dalbergia latifolia, Gmelina arborea, Bauhinia racemosa, B. malabarica, Albizia odoratissima, Meyna laxiflora, Mitragyna parvifolia, Stereospermum personatum, Milliusa tomentosa, Zizyphus mauritina, Lannea coromandelica, Albizia lebbeck, Terminalia paniculata, Mudhuca longifolia*, etc.

8. *Southern Western Ghats, West Coast and Lakshadweep :*

The area includes Western Ghats and West Coast Konkan region of Karnataka and Kerala and Western Ghats of Tamil Nadu.

Floristically, it is richest part of Western Ghats, the main types of vegetation is Tropical Evergreen Rain forests and Moist Deciduous forests.

The dominant species of Wet Evergreen forests are *Palaquium ellipticum, Cullenia exarillata, Mangifera indica, Canarium strictum*, etc.

Some Semi-evergreen forests species are *Xylia xylocarpa, Vateria indica, Terminalia paniculata, Mangifera indica*, etc.

The Moist Deciduous Type Forests comprise species of *Terminalia paniculata, T. tomentosa, Lagerstroemia lanceolata, Tectona grandis*, etc. *Bambusa arundinacea* is a typical component of the understorey.

Southern Western Ghat Rain Forests basically differ from Rain Forests of Assam and Andaman Islands, though some species of *Calophyllum* and *Mesua ferrea* are common to all the three regions. Arora (1960) recognised following layers in Coorg. First layer comprising tree species such as *Tetrameles nudiflora, Elaeocarpus tuberculatus, Dipterocarpus indicus, Dysoxylum malabaricum, Diospyros microphylla*, etc.

Second layer consists of tree species of *Alstonia scholaris, Hardwickia pinnata, Strychnos nux-vomica, Xylia xylocarpa, Xanthophyllum flavescens, Artocarpus lakoocha*, etc. Third layer comprises tree species, viz. *Callicarpa tomentosa, Flacourtia montana, Leea indica* and species of *Memecylon, Psychotria*, etc.

The undergrowth forms dense thickets and are composed of shrubs and climbers such as *Ancistrocladus heyneanus, Calycopteris floribunda, Enteda pursaetha, Hemidesmis indicus, Nervelia zeylanica, Calamus* spp., *Gnetum ula, Pothos scandens, Smilax zeylanica, Piper nigrum, Psychotria* spp., etc.

The Nilgiris which falls under Western Ghats of Tamil Nadu, has most characteristic vegetation type called "Shola". It comprises evergreen forests with thick undergrowth. Some of the important species are *Hydnocarpus alpina, Michelia nilgirica, Berberis tinctoria, Mahonia leschenaultii, Garcinia cambogia, Gordonia obtusa, Ternstroemia gymnanthera, Ilex denticulata, I. wightiana, Euonymus crenulatus, Microtropis ramiflora, Cinnamomum wightii, Meliosma wightii, M. microcarpa, Osyris wightiana, Pentapanax leschenaultii, Schefflera racemosa, Macaranga indica*, etc.

The undergrowth comprises *Clematis wightiana, Polygala arillata, Viola serpens, Parthenocissus neilgheriensis, Osbeckia leschenautiana* etc. In the open downs there are many herbaceous and shrubby species such as *Anemone rivularis, Ranunculus reniformis, Cardamine hirsuta, Viola* spp., *Polygala* spp., *Hypericum mysorense, Impatiens* spp., *Crotalaria* spp., *Indigofera pulchella, Smithia gracilis, Rubus moluccanus, Parnassia mysorensis, Rhodomyrtus tomentosa, Bupleurum mucronatum, Heracleum rigens, H. hookerianum, Galium asperifolium, Campanula fulgens, C. wightii, Swertia* spp. etc. (Subramanyam & Nayar, 1974).

(9) *Deccan* :

The large part of the plateau is clothed with tropical thorn forests comprising species of *Acacia, Dichrostachys, Butea, Anogeissus, Azadirachta, Grewia, Strychnos*, etc.

Tropical Dry deciduous forests occur in northern, central and southern parts of plateau; they have teak forests intermixed with species of *Anogeissus, Diospyros, Dalbergia, Pterocarpus, Cassia, Butea, Adina, Aegle, Lagerstroemia* and bamboos.

In Andhra Pradesh this forest type has *Pterocarpus santalinus*, *Anogeissus*, *Hardwickia*, *Terminalia*, *Buchanania*, *Gardenia* etc. The Eastern parts of plateau in Andhra Pradedsh and Orissa have moist deciduous forests comprising species of *Terminalia*, *Bombax Dalbergia*, *Madhuca*, *Ceiba*, *Grewia*, *Phyllanthus*, *Cleistanthus*, *Schleichera* and bamboos. *Shorea robusta* is abundant in north-eastern part of the plateau.

10. *Eastern Ghats and Coromandel Coast* :

The forest vegetation on the Eastern Ghats is poor as compared to the Western Ghats. Vast area is under Tropical Dry Deciduous or Thorn Forests, whereas some northern part bordering Orissa has Moist Deciduous Forests. The "Sholas" predominate in evergreen species belonging to genera *Alsodaphne*, *Antidesma*, *Elaeocarpus*, *Memceylon* and abundance of *Miliusa*, *Myristica*, *Olea*, *Symplocos* etc. The Evergreen forests of Tamil Nadu, Carnatic region predominate in species of *Diospyros*, *Litsea*, *Pterocarpus*, *Syzygium*, *Trema* and *Vitex*. Species of *Dalbergia*, *Elaeodendron*, *Memecylon*, *Polyalthia* and *Wendlandia* are found in abundance.

The flora of Coromandel coast, to some extent, differs from rest of the Deccan. It occupies the strip of lowland between the Eastern Ghats and Sea, and stretches from Orissa to Tirunelveli. Thickets of thorney evergreen and deciduous trees and shrubs abound, belonging to genera *Flacourtia*, *Randia*, *Scutia*, *Diospyros*, *Mimusops*, *Garcinia*, *Sapindus*, *Pterospermum* etc. (Hooker, 1904, 1907 : 37). *Strychnos nux-vomica* is also characteristic. The evergreen forests components are *Eugenia bracteata*, *Memecylon umbellatum*, *Carallia integerrima*, *Linociera malabarica* etc. *Mimusops hexandra* is confined to the coastal areas from north of Madras to Point Calimere. In the extreme southern coast *Acacia planifrons*, *Cocculus leaba*, *Capparis aphylla*, *Cassia ovata* and *C. angustifolia* are characteristic (Mani, 1974a). The coastal area supports mangrove swamps with *Avicennia officinalis*, *Lumnitzera racemosa*, *Bruguiera* spp., *Rhizophora* spp. and Chenopodiaceae in the mouth of the rivers. The sandy beaches support *Hydrophylax maritima*, *Ipomoea pes-caprae*, *Sesamum prostractum* and *Spinifex squarrosus*.

11. *Andaman and Nicobar Islands* :

Renvoize (1979) remarked that Andaman Islands are continental fragments, whereas the Nicobar Islands are volcanic in character. Both these Islands show remarkably different vegetation. However, the Tropcial Wet Evergreen, Semi-evergreen and Moist Deciduous forests are main forests types in both the islands.

The Andaman Islands have rich *Dipterocarpus* and *Pterocarpus* forests. The North Islands of Andaman have Tropical Wet Evergreen forests with tall arborescent species such as *Dipterocarpus griffithii, Endospermum malaccense* and *Terminalia bialata*. The Moist Deciduous forests have species of *Pterocarpus, Terminalia, Canarium, Chukrasia* and *Albizia*.

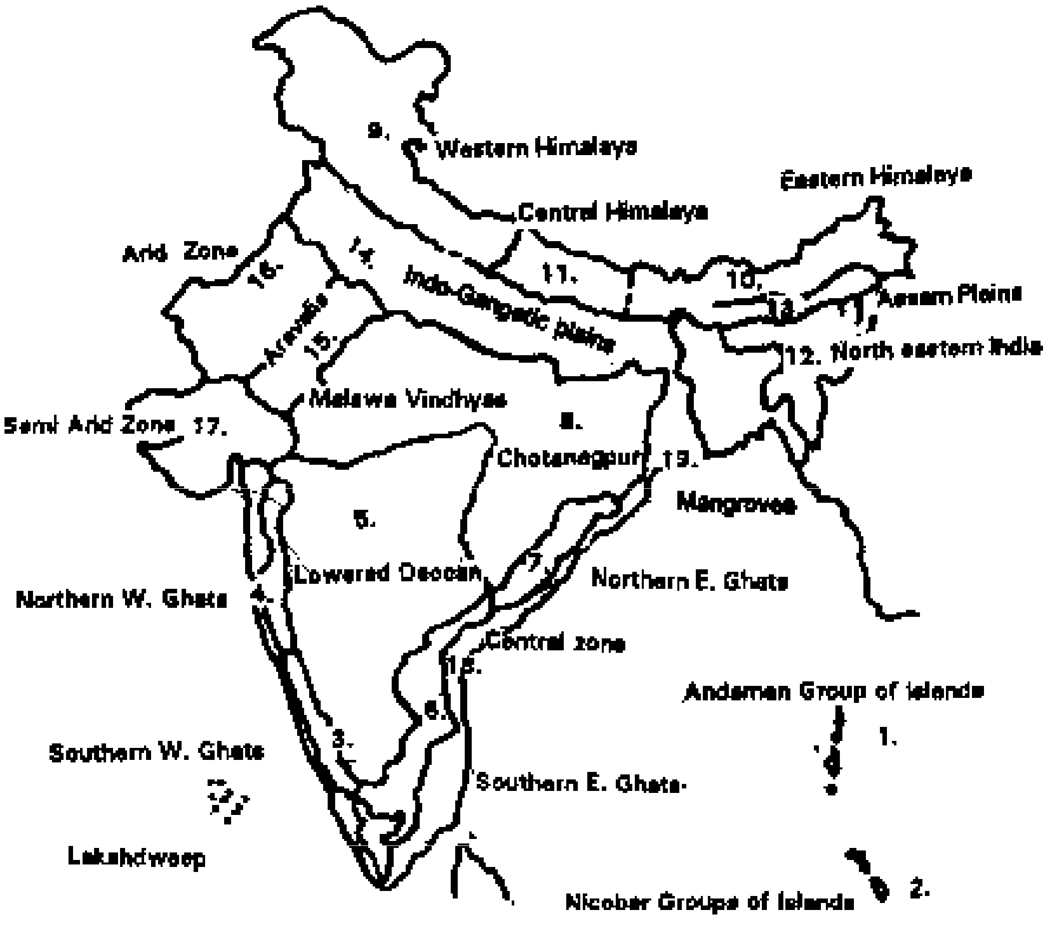
The predominant arborescent species in Great Nicobar Islands belong to genera such as *Terminalia, Canarium, Artocarpus, Calophyllum, Miliusa, Horsfieldia, Amoora, Alstonia, Hopea* and *Syzygium*. Significantly genera *Dipterocarpus* and *Pterocarpus* are absent in Nicobar Islands.

The coastal and marshy areas support mangrove and littoral species of such genera as *Ceriops, Rhizophora, Sonneratia, Bruguiera, Heritiera, Avicennia, Nypa, Thespesia, Pandanus, Aquillaria*, etc.

On the basis of endemism and species assemblages Nayar (1996) proposed the following 20 phytogeographical division (Map 10).

1. Andaman Group of Islands
2. Nicobar Group of Islands
3. Southern Western Ghats
4. Northern Western Ghats
5. Leeward Deccan Plateau
6. Southern Eastern Ghats
7. Northern Eastern Ghats
8. Chotanagpur, Malva, Vindhya Plateau
9. Western Himalaya
10. Central Himalaya
11. Eastern Himalaya
12. North Eastern India
13. Assam plains

14. Indo-Gangetic plains
15. Aravalli hills
16. Arid Zone (W. Rajasthan)
17. Semi-arid Zone (Kathiawar and Kutch)
18. Coastal zone
19. Mangroves
20. Lakshadeep Islandes



Map 10. Phytogeographical divisions of India, Nepal and Bhutan (after Nayar, 1996).

V. PHYTOGEOGRAPHICAL AFFINITIES AND MIGRATION

(I) MIGRATION FROM OUTSIDE INDIA :

The occurrence and vertical distribution of plant fossils in the geological past has thrown ample light on the relationship of palaeo-flora of India with the neighbouring countries. The data provided by Dr. J.S. Guleria (Personal communication) and review papers by Awasthi (1992), Guleria (1992), Bande (1992), Lakhanpal (1973), Mahabale (1966), Vishnu-Mittre (1969) and host of other palaeobotanists explicitly exhibits relationship of flora and vegetation of Palaeogene and Neogene of Indian subcontinent with the neighbouring countries. Readers are referred to the recently published detailed account of Micro and Megafossils; on Cenozoic (Tertiary) megafossils by Srivastava (1992), and on Cenozoic (Quaternary) palynology and palaeobotany by Chauhan (1992). The passing remarks on the palaeo-ecology and palaeoclimate provide further evidence on the relationships.

The breaking away of Indian Plate from the massive Gondwanaland, movement towards north and shrinking of Tethys, formation of foredeep or basin extending from west to east, complete obliteration of the Tethys, upliftment of Himalayas, formation of land bridges and land connections, migration, spread and almost disappearance of warm humid tropical vegetation, continuous increase in arid condition and migration of large number of neighbouring taxa from all sides into Indian subcontinent has changed the floristic and vegetational scenario. The discovery of plant megafossils bear testimony to this change. The Indo-Malayan taxa, which were abundant during Neogene period are hardly available today. Among the dipterocarps only genus *Shorea* represents in the north.

The diverse climate and habitats provided an ideal and congenial niche to different elements migrating from the neighbouring areas to colonise them. Today, the flora is an admixture of taxa drawn from regions such as, South America, Africa, Europe, Mediterranen, Middle East, Afghanistan, Central Asia, Russia, China, Tibet, Burma, Japan, Indo-Malaya, Australia etc.

Hooker (1904) commented "The flora of British India is more varied than that of any other country of equal area in the eastern hemisphere, if not in the globe. This is due to its geographical extension, embracing so many degrees of latitude, temperate and tropical; to its surface rising from almost absolute aridity to a maximum of humidity; and to the migration of plants from widely different bordering countries, notably of Chinese and Malayan on the east and the south, of oriental European and African on the west, and of Tibetan and Siberian on the north".

Hooker and Thomson (1855) attempted phytogeographical analysis of the Flora of Indian Empire. C.B. Clarke (1898), based on the distribution of family Cyperaceae recognised Eastern Himalayas and Assam as distinct areas. Hooker (1907) in his botanical divisions of India recognised Eastern Himalaya as distinct entity and placed major parts of Assam, Shillong Plateau, Nagaland and Manipur hills with Myanmar. Hooker (1904) further stressed that the floristic diversity and richness of the Indian subcontinent is due to the migration of plant species from different adjoining areas Chinese and Malayan in the East and South; European, Siberian and Tibetan in North and African, Oriental and European elements in the West.

(i) NORTH WESTERN CORRIDOR

North Western Himalaya

The vegetation in Himalaya shows altitudinal zonations. In the foot hills of North-Western Himalaya below 1000 m, the forest are sub-tropical Dry Evergreen type. Between 1500-3000 m, Moist Temperate zone forest of *Abies, Quercus, Cedrus, Picea* and *Acer* are found. The coniferous forests in Temperate zone comprise species of *Pinus, Cedrus, Picea, Tsuga* etc. Occasionally *Taxus* and *Betula* also occur. The inner ranges have Dry Temperate forests comprising *Pinus gerardiana* and species of *Cedrus, Quercus, Acer, Fraxinus, Celtis* and *Olea*. In sub-alpine zone the forests mainly comprise *Pinus wallichiana* and species of *Abies, Picea, Taxus, Betula, Rhododendron* and Rosaceous plants. Above 3000 m, the vegetation is Moist Alpine scrub comprising species of *Betula, Rhododendron, Lonicera* and *Berberis*. Around 4000 m, the uppermost limit of vegetation has Dry Alpine scrub. The main elements are species of *Juniperus, Lonicera, Artemisia*, etc.

A bulk of species of the temperate zone origin are derived from Europe and their distribution is characteristically restricted to the Himalaya, the Khasi Hills in Assam, parts of Eastern Ghats like Mahendragiri, Yercaud and Palni-Anamalai Hills and the southern part of the Western Ghats. The distribution is thus markedly discontinuous. *Clematis, Anemone, Thalictrum, Ranunculus* and *Caltha* which occur in Himalayas are also found in higher reaches of Western and Eastern Ghats. *Corydalis* and *Fumaria* occur in Himalaya and Nilgiri Hills. *Viola patrinii* occurs in Himalaya, Western Tibet, Khasi Hills, Eastern and Western Ghats and Sri Lanka, in addition to Afghanistan, Russia, North Asia and Japan. *Thermopsis, Trifolium pratense* (Europe, Siberia, Afghanistan and the Himalaya), *T. repens* (Himalaya, Nilgiri, Sri Lanka, North Asia, Europe and North America). *Podophyllum* which occurs in North America is also found in Himalaya. *Seseli sibiricum* (Siberia, Russia (European) to Noth-West Himalaya).

The North-Western Himalaya provided a gateway for the migration of plants from the surrounding regions. The phytogeographical affinities of Northwestern Himalaya with that of Europe, the near East and Middle East have been intensively investigated (Legris, 1963; Gupta, 1962, 1964, 1982; Meher-Homji, 1973; Rao 1974, 1975, 1981; Dhar 1978; Sahni, 1982; Hajra & Rao, 1990).

The Mediterranean elements comprise partly the southern European and partly also the North African species of plants. Some of the latter come from Abyssinia, Sudan and Sahara and have been termed the Sudano-Deccan elements in our flora by some botanists (Meher-Homji, 1965). They extend eastward through Iraq, Arabia, Baluchistan and sometimes partly also through Afghanistan to North-West Himalaya.

The European and Central Asian taxa are found in the area west of river Sutlej while the Chinese taxa extend from Yunan in the east right through the East Himalayan ranges. Many of the elements from dry mountains of Western and Middle Asia have spread to the western ranges of the Himalayas. The migration is greatly due to the arid and dry conditions prevailing in the interior ranges of Ladakh, Lahul and Spiti valley. Some of the elements of Middle Asia which are found in the North-Western Himalaya are *Rosularia alpestre, Salix karelinii, Sorbaria tomentosa, Lathyrus humilis, Acantholimon lycopodioides, Myricaria squamosa, Oxytropis microphylla, Halogeton glomeratus, Bieberstenia odora* etc. *Cedrus deodara* which is common on the Western Himalayan slopes extends upto Afghanistan.

The Steppes Elements :

The dry conditions prevailing towards the western ranges, particularly in the interior have favoured influx of taxa from western and middle Asian mountains.

The *Artemisia* dominated the steppes of the extreme north-west and include taxa, which have wide distribution in the Middle Asian Highlands.

The Steppes species have their homes in lowlands of Turkestan, in the Pamirs, Afghanistan and also occur in Northwestern Himalaya. Some of these elements come partly from West Asia and partly from East Mediterranian and extend eastwards to Sind and Punjab. They rarely penetrate western part of the Upper Gangetic Plains. One or two species spread southward to Deccan and Nilgiri Hills. Steppes elements form minor constituent of Indian Flora. Some of the important elements of the steppes are : *Megacarpea, Tauscheria, Euclidium, Hippophe rhamnoides* ssp. *turkistanica, Myricaria, Guldenstaedtia, Astragulus, Triplostegia, Morina, Scabiosa, Dipsacus, Anthemis, Artemisia, Cnicus, Hyoscymus, Eurotia ceratoides, Axyris amaranthoides, Haloxylon recurvum, Kochia, Juniperus semiglobosa, Juniperus turkistanica, Acantholimon lycopodioides, Eremurus, Ferula, Prangos*, etc. *Cedrus deodara* (Himalayan Cedar) is distributed from Afghanistan to West Nepal.

The species of West and Middle Asian mountains, suited to comparatively dry conditions, extend along upper region of the Himalaya from Afghanistan to West Nepal. Some of the Western, Middle and Northern Asian components are distributed upto the extreme of Western Himalaya. They show varying extent of penetration, some reaching only Kashmir and the other extending to the length of Western Himalaya and such species are *Thylacospermum rupifragum, Lamium rhomboideum* and *Physochlaina praealta*.

The second type of distribution includes species confined to North Western Himalaya and extending upto Afghanistan, viz. *Paeonia emodi, Christolea himalayensis, Epilobium* spp., *Primula floribunda* and *P. rosea*.

A number of species from Europe and other temperate regions are found here. Some of these are *Melilotus officinalis, Medicago falcata, Aconogonum alpinum, Trifolium repens, Lotus corniculatus, Onopordum acanthium, Chenopodium foliosum, Centaura iberica, Geranium pratense, Mentha longifolia, Carthamus lanatus, Artemisia absinthium, Briza media, Dactylis glomerata, Poa trivialis, Draba nemorosa, Erophila verna, Barbaraea vulgaris, Cardamine, Impatiens* etc. *Viola biflora*, a common component of North-Western Himalaya also occurs in Europe, Siberia, Central Asia, North Korea, Japan, North America.

Capparis spinosa in known from Afghanistan to Nepal, West Asia, and Europe. *Poa alpina* is widely distributed in Pakistan, India, Europe, Mediterranean region, Middle East, Central Asia and North America.

The third type of distribution is the species of West China, which are distributed all along Himalaya and reach Kashmir in the West. Such species are *Aletris pauciflora, Anemone rupicola* and *A. vitifolia. Primula sikkimensis* and *Magnolia campbelli* species originate in western China and reach Kumaon in the West. *Circaeaster agrestis*, a curious little plant, extends from North-western China across Tibet to Garhwal Himalaya.

Himalaya has served primarily as a "route of emigration and colonization from east and northwest, secondarily of endemic development" (Stearn, 1968).

Some of the species viz., *Cotoneaster frigidus, Rubus calycinus, R. acuminatus, Androsace delavayi, Osmanthus suavis, Boschniakia himalaica* etc. originating in South-West China reach only upto Kumaon in Uttar Pradesh. *Cypripedium elegans, Cypripedium himalaicum, Roscoea purpurea, Primula tibetica, Primula primula* extend from South-West Tibet to Uttar Pradesh. *Circaeaster agrestis*, a plant of North-West China, extends across Tibet to Himalaya upto Garhwal.

Some of the extraneous elements of flora of South-West China, Central Asia, West Asia, Europe have so co-mingled with the North Western Himalayan flora that they form its permanent components today. However, some of these, viz. *Melilotus alba, Melica nutans, Potentilla fruticosa, Aconogonum alpinum, Flemingia strobilifera, Nasturtium officinale*, etc. remained unchanged.

Table-13. Some species of Chinese origin widely distributed in the Himalaya

Name	Family	Distribution
Valeriana jatamansii	Valeriaceae	Afghanistan to S.W. China, Myanmar
Valeriana hardwickii	Valeriaceae	Pakistan to S.W. China, Myanmar, S. Asia.
Cardiocrinum giganteum	Liliaceae	Kashmir to S.W. China, Myanmar
Dactylorhiza hatagirea	Orchidaceae	Pakistan to S.E. Tibet, Europe, N. Africa, Central, West and S.E. Asia.

Name	Family	Distribution
Primula denticulata	Primulaceae	Afghanistan to S.E. Tibet, Myanmar.
Taxus wallichiana	Taxaceae	Afghanistan to S.W. China, Myanmar, S.E. Asia.
Primula denticulata	Primulaceae	Afghanistan to S.E. Tibet, Myanmar.
Taxus baccata ssp. *wallichiana*	Taxaceae	Afghanistan to S.W. China, Myanmar, S.E. Asia.
Symplocos paniculata	Symplocaceae	Pakistan to S.W. China, Myanmar, Japan, S.E. Asia.
Jasminum dispermum	Oleaceae	Kashmir to S.W. China, S.E. Asia.
Buddleja asiatica	Loganiaceae	Pakistan to Bhutan, Central and South China, Myanmar, S.E. Asia.
Acer oblongum	Aceraceae	Pakistan to S.W. China, Myanmar, S.E. Asia.
Hedera nepalensis	Araliaceae	Afghanistan to S.W. China, Myanmar
Svida oblonga	Cornaceae	Kashmir to S.W. China, Myanmar, S.E. Asia.
Leycesteria formosa	Caprifoliaceae	Pakistan to S.W. China, Myanmar
Lonicera webbiana	Caprifoliaceae	Afghanistan to S.W. China.

(after P.K. Hajra & R.R. Rao, 1990).

Anemone vitifolia extends from Himalaya to South China, Formosa and Luzon in the Philippines. According to van Steenis (1934) this species has followed the Formosan - Luzon migratory track. *Sarcococca saligna* extends from Afghanistan and Himalaya to China, Formosa, Sumatra, Java and Lesser Soenda Islands; it is also found in Sri Lanka.

"The Chinese mountains, being much older in age, have had considerable influence on the Himalayan flora, and many plants from these mountains have spread westwards to the younger Himalaya. During the Tertiary Period, a common flora must have covered the whole of East Asia, including Himalaya, China and Japan" (Hara, 1966).

The Himalaya run from Nanga Parbat on the Indus to Namcha Barwa on the bend of the Tsang-Po in S.E. Tibet (*ca* 2250 km), the floristic pattern of Western Himalayas is very distinct. The Eastern Himalaya is richer and more diverse in plant wealth because of greater amount of precipitation as compared with the Western Himalaya.

Notwithstanding, that flora of North-Western Himalaya is admixture of floras from Mediterranean region, Central Asia, Europe, S.W. China etc. the area is very rich in endemics. The Himalayas as a whole and Peninsular India are two main regions of India which are very rich in endemics. Some of the endemic species of North-Western Himalaya are *Androsace primuloides, Hedysarum cashemirianum, H. microcalyx, Saussurea atkinsonii, Saussurea clarkei, Poa falconeri, Poa koelzii, Puccinellia stapfiana, Puccinellia thomsonii, Catabrosella himalaica, Arabis tenuirostris. Hyalopoa nutans, Delphinium roylei, Carex munroi, Microschoenus duthie, Dicranostigma lactucoides, Erophila tenerrima, Christolea scaposa* etc.

Some of the primitive species, viz. *Circaester agrestis, Parrotiopsis jacquemontiana, Myrica esculenta, Holboellia latifolia* var. *angustifolia, Michelia kisopa* are also found in the region.

The spread and recession of Ice Sheet (Glacial and Interglacial periods) must have exterminated some of the taxa during glaciation and provided suitable niche for influx of species from neighbouring area during Interglacial Period (warmer period). The alternate movements of Ice Sheet must have been responsible for the isolation and disjunct distribution of many plant and animal species.

Rau (1975) while discussing the phytogeographic affinities of Himalayan flora states "In the Himalaya, the glaciation, however, did not affect the foothills, with the result that the vegetation of the lower belt was not affected. Migration of flora, survival of relicts, evolution of new species by an intermixing of different floras and acclimatisation of species from the lower altitudes must have all had a determining role in the present day composition and distribution of the Himalayan flora of high altitude"

(ii) NORTH-EASTERN CORRIDOR

Eastern Himalaya :

The Eastern Himalaya includes the present Sikkim, Darjeeling district of West Bengal and Arunachal Pradesh. The Eastern Himalaya has been considered as a distinct phytogeographical region (Clarke, 1898; Hooker 1907, Chatterjee, 1940). The Western Himalaya is known for magnificient snow covered peaks, the Eastern Himalaya stands out for their rich floristic wealth.

Rao (1974) phytogeographically considered Arunachal Pradesh (formerly NEFA) as part of Assam Flora and recognised close affinities between flora of Assam and Myanmar. He further treated them as part of the Eastern Border lands comprising mostly the Tertiary mountains with highly tropical climate and remarkably diverse flora and vegetation. Biogeographically Assam and north Myanmar are highly transitional regions where large scale commingling of Asiatic and Indian Peninsular Flora has taken place.

Takhtajan (1986) places Arunachal Pradesh in Eastern Himalayan Province within Eastern Asiatic region of Boreal Sub-Kingdom alongwith parts of eastern Nepal in the West upto Kali river valley, Darjeeling, Sikkim, Bhutan, large parts of Assam Himalaya, certain extreme south and southern parts of Tibet.

The Eastern Himalaya is considered to be the treasure house of a myriad of plant species. There are numerous reasons for floristic richness and biological diversity in comparatively so small an area. The topography is one of the main factors behind this. The Eastern Himalayas, though lower in altitude on the average than its Western and Central counterparts, are in a position to directly confront the moisture laden monsoon winds, blowing inland across the Bay of Bengal. This leads to a high degree of precipition which has no equal on the planet.

The Eastern Himalayas are wetter and warmer as compared to the Western Himalayas. As a result, these are comparatively richer floristically. The foot-hills have species of *Dipterocarpus*, *Artocarpus* and *Shorea assamica*. The lower slopes have tropical semi-evergreen forests. Between 1800-3000 m, the forests are Montane Wet or Moist type. *Cedrus deodara* is conspicuous by its absence in Eastern Himalayas. Dry Temperate forests chiefly of conifer trees are found in inner ranges of Sikkim. Above 3000 m Moist Alpine Scrubs are found.

The special horseshoe-shaped arrangement of the fold of mountains in the Eastern Himalayan region, ensures plenty of rain in most of the places. Along with region of high rainfall, there are also regions of moderate to low rainfall zones, which account for the great diversity in plant wealth found here. Added to this, the altitude of the area is also greatly varied from a few hundred metres in the plateaus and valleys to the lofty ice capped mountains with Mt. Kanchanjungha towering over all the other peaks at a height of 8598 m. All these factors greatly contributed to the varied and rich floristic diversity. Because of the great altitudinal variation, the area finds represehtation of tropical, temperate and alpine forests. The Eastern Himalaya has rich representation of orchids, rhododendrons, bamboos and species hedychiums. Out of the *ca* 1200 species of orchids so far known from India *ca* 650 species are reported from Eastern Himalaya. King and Pantling (1898) estimated *ca* 480 species of orchids in Sikkim Himalaya and *ca* 425 species in Arunachal Pradesh. Out of a total of *ca* 82 species Rhododendrons *ca* 70 species have been recorded from Eastern Himalaya. Sikkim has *ca* 37 species and 2 varieties of Rhododendrons. Arunachal Pradesh has 52 species, 5 subspecies and 5 varieties of Rhododendrons. Out of the *ca* 60 species of *Hedychium* in the world 34 species are represented in the Eastrn Himalaya. Out of the 100 known species of bamboos in India *ca* 58 species are found in Eastern India. The Eastern Himalaya is rich in endemic species.

As stated earlier the flora of Arunachal Pradesh has a large number of migrant species from the adjacent areas. Some of these are

(1) *South-East Asian-Malaysian elements :*

Actinidia callosa, Ampelocissus barbata, Antidesma acuminatum, Bauhinia purpurea, Bischofia javanica, Brassaiopsis glomerulata, Carallia brachiata, Crataeva religiosa, Debregeasia longifolia, Dendrobium aggregatum, Duabanga grandiflora, Engelhardtia spicata, Eria paniculata, Exbucklandia populnea, Firmiana colorata, Garuga pinnata, Hedychium coccineum, Hodgsonia macrocarpa, Lepisanthes senegalensis, Lithocarpus elegans, Mangifera indica, Meliosma simplicifolia, Michelia champaca, Mucuna nigricans, Musa balbisiana, Oroxylum indicum, Procris crenata, Raphiodophora peepla, Spondias pinnata, Talauma hodgsonii, Tetrameles nudiflora, Toona sureni, Trevesia palmata, Vernonia volkamerifolia, etc.

(2) *Himalayan-Chinese-Japanese elements :*

Floristically, Western and Eastern Himalayas have distinct entities. The Eastern Himalayas have many species common with China and Japan. Some of these are -

(a) *Chinese elements :*

Betula alnoides, Callicarpa rebella, Cardamine griffithii, Cinnamomum obtusifolium, Dalbergia mimosoides, Helwingia himalaica, Litsea cubeba, L. kingii, L. sericea, Lonicera adenophora, Magnolia campbellii, Meconopsis nepaulensis, Michelia doltsopa, Millettia cinerea, M. pachycarpa, Neillia rubiflora, Osmanthus suavis, Panax pseudoginseng, Potentilla griffithii, Rhododendron micromeres, R. neriiflorum, Rubus fragarioides, Salix sikkimensis, Shuteria hirsuta, Smilax ferox, Tetracentron, etc.

(b) *Japanese elements :*

Some of the species common with and extended upto Japan are : *Cornus controversa, Mucuna macrocarpa, Taxillus kaempferi, Stachyurus, Helwingia* etc.

(3) *Euro-Siberian elements :*

Goodyera repens, Hedera sp., *Juncus inflexus, Lithospermum officinale, Polygala siberica, Prunella vulgaris, Ranunculus sceleratus, Stellaria uliginosa, Thlaspi arvense, Veronica, Anagallis aquatica, Viola biflora* etc.

A number of primitive angiosperms are present in Arunachal Pradesh which gives distinct phytogeographical position to Arunachal Pradesh within Indian subcontinent. Some of these elements are : *Alnus nepalensis, Altingia excelsa, Betula alnoides, Exbucklandia populnea, Holboellia latifolia* var. *angustifolia, Houttuynia cordata, Magnolia griffithii, M. pterocarpa, Manglietia caveana, Talauma hodgsonii, Tetracentron sinense.*

(b) *Assam :*

From phytogeographical point of view the Assam area consists of Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. The vegetation is luxuriant. The hill forests of Assam region approximate in type to those of Eastern Himalayan region, except that there is no alpine zone. These hills may be separated broadly into Evergreen forests, Broad Leaved forests and Pine forests.

Some of the interesting plant found in Assam are *Supria himalayana, Balanophora dioica, Mitrastemon yamomotai, Monotropa uniflora, Epipogon roseum, Galeola falconeri, Aldrovanda* sp., *Nepenthes khasiana*, etc.

The influx of humid tropical Asiatic elements has taken place through the Assam gateway. The tropical Asiatic elements largely of Indo-Chinese and Malayan affinities represent perhaps the most dominant component member of our present day flora, not only in the lower slopes of the Himalayas but also deep south in the Peninsula. These elements have spread far west along the southern slopes of Himalaya practically upto Kashmir and along Eastern Ghats to the Peninsula. In many cases the species are identical in the Peninsula, Myanmar, Assam, Thailand and Malaya and in other cases local species have evolved in the Peninsula (Mani, 1974).

In Eastern India the invasion is from West China (Yunan) and Myanmar, the common components are - *Congea tomentosa, Diospyros glandulosa, Edgeworthia chrysantha, Jasminum dumicola, Kalanchoe spathulata, Swertia lacei, Trachelospermum* etc. It is likely that some genera like *Photinia, Eriobotrya* and *Pygeum* have entered India from West China and Myanmar.

A large number of taxa from Siberia, China, Myanmar, Malacca and Tenasserim, Java, Japan, Sumatra, N. Guinea, Sri Lanka, Bhutan, Perak, West Africa, Australia, Penang, etc. entered Assam. Some of these taxa are - *Nympaea pygmaea* (Siberia, China) *Orophea polycarpa* (Myanmar), *Popowia kurzii* (Myanmar), *Homalium schleichii* (Myanmar), *Solomonia aphylla* (Malacca and Tenasserim), *Anneslea fragrans* (Myanmar), *Nertera sinensis* (China), *Alniphyllum fortunei* (China), *Cotylanthera tenuis* (Java), *Beccarinda cordifolia* (Myanmar), *Mitrastemon yamomotai* (Japan and Sumatra), *Aphyllorchis montana* (Sri Lanka), *Apostasia wallichii* (Sumatra, Java and N. Guinea) *Bulbophyllum listerii* (Bhutan), *B. Penicillium* (Tenasserim), *Coelogyne carnea* (Perak), *Dendrobium bensoniae* (Myanmar), *D. terminale* (Tenasserim), *Epipogium roseum* (W. Africa, Java and Australia), *Eria biflora* (Myanmar), *Eria fragrans* (Myanmar), *Paphiopedilum fairrieanum* (Bhutan), *Paphiopedilum spicerianum* (Bhutan), *Polystachya flavescens* (Java), *Sarcochilus hystrix* (Tenasserim), *Dioscorea laurifolia* (Penang), *Uvaria, Goniothalmus, Pittosporum glabratum* (extending from Hong Kong to Khasi Hills in Assam), *Decaspermum paniculatum* (occurs in Philippines, Australia, Java, Malaya, Myanmar and Assam), *Oxyspora* (from Sumatra, Eastern

Himalaya and Khasi Hills), *Medinilla* (from Malaya, Khasi Hills, E. Himalaya and Sri Lanka), *Gymnopetalum* (Malaya, Myanmar, Assam, E. Himalaya, Deccan and Sri Lanka), *Myristica* (Malaya, Andaman, Myanmar, E. Himalaya, Western Ghats), *Nepenthes* (Borneo, Sumatra, Malaya, Khasi Hills and Sri Lanka), *Uncaria* (Malaya, Myanmar, Assam, Eastern and Western Himalaya *Hedyotis* (Myanmar, Assam, Himalaya, Deccan, Western Ghats and Sri Lanka), *Knoxia* (Malaya, Myanmar, Assam, Himalaya, Western and Eastern Ghats and Sri Lanka). *Lasianthus* (Malaya, Myanmar, Andaman, Assam, E. Himalaya, Eastern and Western Ghats and Sri Lanka), *Willoughbeia* (Malaya, Myanmar, Assam and Sri Lanka), etc.

Hooker (1904) who used a unit of ten dominant families in his various botanical provinces as a measure of comparision on the distribution, includes major part of Assam with Gangetic Plain and treats Eastern Himalaya as a separate area by itself. He considers hill areas of Assam, including the Shillong Plateau, Patkai, Naga and Manipur hills as phytogeographically deeply related with Myanmar.

Clarke (1898) based on distribution of Cyperaceae, especially genus *Carex* considers Eastern Himalaya and Assam as distinct Subarea. Chatterjee (1962) following Clarke treats Assam as a distinct area because of its distinctive flora. Ridley (1942) states that "no story of plant distribution is complete without a considerable knowledge of Tertiary palaeobotany. It cannot also be understood fully without a comprehension of the position and form of land surfaces during that period and the time of the evolution of the flowering plants". Kingdon-Ward (1960) considers that the position of Manipur in the middle of the glaciated mountains and astride on of the glacial escape route was particularly favourable for receiving contributions of flora from all directions. It has very high percentage of Indo-Malayan species and an admixture of some Sikkim Himalayan, Burmese, Siamese and Chinese species. Joseph (1969) attempted to localize the cradle of flowering plants from an analysis of distribution of primitive plants. The table adopted from Takhtajan (1969) shows primitive species of plants, existing in the Northeastern parts of India, especially the Eastern Himalaya, Assam and Myanmar. It is remarkable that none of these species are found in any other part of India.

Table-14. Primitive flowering plants occurring in Northeastern India and Myanmar (from Takhtajan, 1969).

	Species	Distribution
1.	Magnoliaceae	
	Magnolia	Assam, Myanmar through Indo-China to Malayan Archipelago.
	Magnolia griffithii	Assam and Myanmar
	Magnolia pealiana	Assam
	Magnolia gustavii	Assam
	Manglietia	Assam, E. Himalaya and South China through Thailand and Indo-China to Java.
	Euptelea	E. Himalaya, China and Japan.
2.	Tetracentraceae	
	Tetracentron	E. Himalaya, Upper Myanmar and Southwest China.
3.	Menispermaceae	
	Pycnarrhena	Assam, E. Himalaya to northwest Australia.
	Haematocarpus	Assam, E. Himalaya, West Malaysia and New Guinea.
	Aspidocarya	Assam, Eastern Himalaya and Southeast Asia.
4.	Lardizabalaceae	
	Decaisnea	E. Himalaya and West China.
	Holboellia	Assam, E. Himalaya, China and Brikin.
	Stauntonia	Assam, South China, Taiwan, Laos, Vietnam, Korea and Japan.
	Parvatia	Assam, E. Bengal, South and West China.
5.	Hamamelidaceae	
	Exbucklandia	E. Himalaya, Assam to Sumatra.
	Distylium	Himalaya, Assam, China, Taiwan, Korea and Japan.
	Altingia	Assam, Japan and China to Java and Sumatra.
6.	Piperaceae	
	Houttuynia	Assam, Himalaya to China, Japan, Thailand, Indo-China and Taiwan.
7.	Myricaceae	
	Myrica esculenta	Assam, China, Korea and Japan.
8.	Betulaceae	
	Alnus	Himalaya, Assam and China.
	Betula	Himalaya and East Asia.

(iii) WESTERN CORRIDOR :

Rajasthan :

The western dry region can be distinguished into four habitats (i) Sandy plains and dunes Rajasthan desert or Thar desert fall in this area (ii) Gravelly plains (iii) Rocky habitat and (iv) Saline depressions. Sand dunes have very sparse vegetation and the sandy plains a few scattered trees of *Acacia* and *Prosopis* and bushy plants chiefly comprising *Calligonum, Lycium, Aerva, Leptadenia, Crotalaria* and *Capparis* The gravelly plains or rocks have species of *Calotropis, Gymnosporia, Ziziphus, Cassia, Commiphora, Indigofera*, etc. Species of *Phoenix* are common. The rocky habitats have bushes of *Euphorbia* and *Grewia*. In moist and shaded places species of *Anogeissus, Dicrostachys, Prosopis, Acacia* and *Ziziphus* are found. Species of *Salvadora* and *Tamarix* occur near saline depression.

With the advent of Indira canal a large number of weeds from Punjab have migrated into Western Rajasthan. These species are *Antirrhinum orontium, Arenaria serpyllifolia, Astragalus tribuloides, Centaurium centaurioides, Gastrocotyle hispida, Hypecoum procumbens, Kochia indica, Lophochloa pumila, Malcolmia africana, Malva sylvestris, Oenanthe javanica, Phalaris minor, Plantago amplexicaulis, Polygonum lanigerum, Psammogeton canescens*, etc. (Shetty & Singh, 1987).

The climate of desertic zone in the west of Aravalli is characterised by extremes of temperature, severe droughts 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 support comparively dense, deciduous vegetation.

Rajasthan in the west provided gateway for the influx of plants from Africa, Afghanistan, Baluchistan, Sind, Arabia, Egypt, Abyssinia, Persia, etc. Many of these found their way to Gujarat and the Western Ghats. Some of the elements of Mediterranean, Indo-Malayan and Indo-Chinese origin have also been reported. These elements tend to change the floristic spectrum. However, Rajasthan maintains its floristic individuality and shows high degree of endemicity.

Bhandari (1978) in his "Flora of the Indian desert" attempted to classify species of the area into different phytogeographic regions. He presented floristic analysis of the desert flora as follows :

Phytogeographic Regions		
Cosmopolitan	......	11.2%
Tropical	......	12.7%
African	......	39.1%
Mediterro-Tropical	......	12.4%
Afro-Rajasthani	......	20.0%
Afro-Oriental	......	39.7%
Afro-Malayan	......	4.7%
Afro-Australian	......	12.4%
Saharo Rajasthani	......	7.6%
Saharo-Oriental	......	2.8%
Iranian	......	6.1
Irano-Rajasthani	......	63.6%
Irano-Oriental	......	36.3%
Sindo-Rajasthani (Endemic)	......	10.8%
Oriental	......	17.0%
Oriental	......	73.7%
Indo-Malayan	......	14.2%
Indo-Chinese	......	12.0%
Australian	......	2.8

The data represented above show percentages of different ~~elements~~ of flora recorded from this region. It is observed that if the cosmopolitan and tropical species are not taken into account the Western elements (72.2%) is preponderant as compared to the Eastern elements (27.8%). It supports the view that this desert is a meeting place of Eastern and Western flora.

The African elements (39.1%) show overall dominance in this region as compared to the Oriental elements (17.0%).

The investigation carried out by Bhandari (1978) are in conformity with the analysis of the flora of this region brought out by Blatter and Hallberg (1918-21), in broader aspect of phytogeography.

Takhtajan, (1986) while discussing Sindian Province states "Despite the enormous area of this province, its flora is not rich, containing no endemic genera and only a few endemic species". However, studies carried out by Bhandari (l.c.) reveal endemic flora as high as 10.8% which is surprisingly high as compared with age of this desert which is only 5000-10000 years.

Blatter *et al.* (1925) while analysing the flora of India observed many of the Indian species which are common with Africa, Afghanistan, Baluchistan, Sindh, Arabia, Egypt, Abyssinia, Persia, etc. Mention may be made of the following species :

Nymphaea stellata (Africa and India)
Farsetia jaquemontii (Afghanistan, Baluchistan, N. India, Sind and Rajasthan)
Capparis decidua (Tropical Africa, Arabia, India)
Polycarpaea spicata (Egypt, Abyssinia, Sind and Gujarat)
Bergia odorata (Tropical Africa, Egypt, Persia, Sind and Gujarat)
Sida grewioides (Tropical Africa, Arabia to Baluchistan, Punjab and Sind)
Grewia villosa (Tropical Africa and India)
Melhania denhamii (Tropical Africa, Arabia, Baluchistan, Sind and Rajputana)
Tribulus alatus (N. Africa, Arabia to Sind and Rajputana)
Zygophyllum simplex (Tropical Africa, West Asia, Sind, Rajputana)
Commiphora mukul (Arabia, Baluchistan, Rajputana)
Crotalaria burhia (Afghanistan, Baluchistan, N.W. India, Sind and Gujarat)
Indigofera anabaptista (Arabia, Afghanistan, Sind, Punjab, Rajputana)
Cucumis prophetarum (Tropical Africa, Arabia, Baluchistan, Sind, Rajputana)
Periploca aphylla (Egypt, Arabia, Persia, Afghanistan, Baluchistan, Sind Punjab, Rajputana)
Heliotropium calcareum (Baluchistan, Sind, Rajputana)
Blepharis sindica (Sind, Punjab, Rajputana, Gujarat)
Ephedra folitata (Syria to Afghanistan, Punjab, Rajputana)
Commelina albescens (Tropical Africa, Arabia, Baluchistan, Sind, Rajputana)
Schweinfurthia sphaerocarpa (Afghanistan, Baluchistan, Sind and Rajputana)

Maheshwari (1962) while studying flora of Delhi observed presence of a large number of naturalised alien species in the area. He summerised the results and presented the data in the following tabular form. The African components almost comprise 21% of the total flora.

Table-15. Origin of plants of Delhi State

	Plants of	Number	Percentage
1.	North African - Indian Desert Belt	22	4.60
2.	Tropical Africa	37	7.74
3.	Tropical Africa and N. African-Indian Desert Belt	23	4.81
4.	Africa and West Asia	17	3.56
5.	Mediterranean Region	10	2.09
6.	Indian Region	81	16.95
7.	Indo-Malayan Region and E. Asia	33	6.90
8.	Indo-Malayan and Africa	33	6.90
9.	Temperate Region	8	1.67
10.	New World	14	2.93
11.	Tropical Cosmopolitan	200	41.84

He further commented "India is country with land connection on the north and west, and plants have migrated from N.E. Africa or West Asia, and South-West China by way of Arabia, Afghanistan, Kashmir and N. Myanmar and N.E. India respectively. The presence of these land connections together with isoclimatic conditions tends to distribute plants from one to other and *vice versa* by natural process of plant distribution." The surrounding countries which have contributed much to Indian flora are Sri Lanka, Myanmar, Malaysia, S.W. China, Eastern China, West Asia and Africa.

African and East Mediterranean elements are often found in Gujarat and Northwest India; such species belong to genera *Alstonia, Ancistrocladus, Caralluma, Ceropegia, Dicanthium, Elscholtzia, Flacourtia, Hollarrhena, Monsonia, Pterogata* and *Sansiveria*. Common East-Mediterranean plants found in Northern India are members of Boraginaceae, Capparidaceae, Caryophyllaceae, Cruciferae, Fumariaceae and Labiatae.

The Mediterranian elements :

These elements come partly from southern Europe and partly from North Africa. Some of the latter come from Abyssinia, Sudan and Sahara.

They extend eastward through Iraq, Arabia, Baluchistan and sometimes partly through Afghanistan to Northwest Himalaya, more commonly plains of Sind and Punjab and occasionally southward to Deccan. A number of Mediterranean species have penetrated to the Western margin of the Upper Gangetic Plains and Western Ghats and Sri Lanka. Some of these species are :

Fagonia arabica, F. bruguieria, Mansonia senegalensis, M. heliotropioides, Argyrolobium flaccidum, Trifolium fragiferum, Trigonella, Mellilotus, Medicago, Colutea, Traverniera, Ebenus, Alhagi, Prosopis, Papaver rhoeas, P. dubium, Hypecoum, Farsetia, Alyssum, Malcolmia, Diplotaxis, Eruca, Moricandia, Capsella, Iberidella, Istais, Chorispora, Cleome, Eryngium caeruleum, E. billardieri, etc.

Central India :

Two major forest types, viz. (i) Tropical Forests (ii) Montane subtropical forests are represented in Central India. Northern tropical semi-evergreen forests occur in some parts of Madhya Pradesh adjoining Orissa. Tropical moist deciduous forests occur on hilly ground. Tropical dry deciduous forests, tropical thorn forest, are quite conspicuous. Montane subtropical forests are found on some hill tops of Madhya Pradesh, Orissa and Mt. Abu of Rajasthan.

Two important mountain ranges Vindhya and Satpura are found right across Madhya Pradesh from South-West to North-East and distinctly meet the Chhota Nagpur plateau of Bihar. These ranges have played an important role in migration of plants from Eastern Himalaya, Assam, Myanmar, Malaya and other countries of the South-East. Plants have migrated from here to Western and Eastern Ghats and Sri Lanka. Some of the species from these region are still found in Central Indian region. However, the Eastern and Western Ghats have large number of migrants as compared to the Central India.

Western Ghats :

The Western Ghats exhibit two distinct zones, viz. (i) Northern Western Ghats and West Coast, covering Goa, Western Maharashtra and Southern Gujarat and (ii) Southern Western Ghats, West-coast and Lakshadweep : the area includes Western Ghats and West-coast Konkan region of Karnataka, Kerala and Western Ghats of Tamil Nadu.

Western Ghats of Maharashtra support Montane subtropical Evergreen forests. The main components are *Amoora lawii, Aphanamixis rohutuka, Walsura trijuga, Toona ciliate, Holopetalia integrifolia, Alstonia scholaris, Pongamia pinnata, Caryota urens, Tetrameles nudiflora, Terminalia chebula, Bridelia squamosa*, etc. The second layer comprises *Miliosma tomentosa, Murraya paniculata, Syzygium cumini, Meyna laxiflora, Mammea suriga, Gnetum ula*, etc. A number of terrestrial, epiphytic and lithophytic orchids occur in the area.

The vegetation shows north to south variation which can be closely related with climate. Typical giant trees of evergreen forests such as species of *Calophyllum, Hopea, Canarium, Mammea* etc. begin appearing along Phonda, Amboli ghats and Goa Ghats.

Southern Western Ghats are floristically richest part of Western Ghats. The main type of vegetation is Tropical Evergreen Rain forests and Moist Deciduous forests. Wet Evergreen forests comprise species of *Palaquium ellipticum, Cullenia excarillata, Mangifera indica, Canarium strictum* etc. Some Semi-evergreen forest species are *Xylia xylocarpa, Vateria indica, Terminalia paniculata, Mangifera indica*, etc. The Moist Deciduous type forests comprise *Terminalia paniculata, T. tomentosa, Lagerstroemia lanceolata, Tectona grandis*, etc.

Southern Western Ghat Rain Forests basically differ from Rain Forests of Assam and Andaman Islands, though some species of *Callophyllum* and *Mesua ferrea* are common to all three regions.

The Nilgiri which falls under Western Ghats of Tamil Nadu has unique type of vegetation called "Shola" It comprises Evergreen forests with thick undergrowth. Some of the important "Shola" species are *Hydnocarpus alpina*, *Michelia nilagirica, Berberis tinctoria, Mahonia leschenaultii, Garcinia cambogia, Gordonia obtusa, Ternstroemia gymnanthera, Ilex denticulata, I. wightiana, Euonymus crenulatus, Microtropis ramiflora, Cinnamomum wightii, Meliosma wightii, M. microcarpa, Osyris wightiana, Pentapanax leschenaultii, Schefflera racemosa, Macaranga indica,* etc. The undergrowth comprises *Clematis wightiana, Polygala arillata, Viola serpens, Parthenocissus neilgheriensis, Osbeckia leschenaultiana,* etc. In open downs there are many herbaceous and shrubby species such as *Anemone rivularis, Ranunculus reniformis, Cardamine hirsuta, Viola* spp., *Polygala* spp., *Hypericum mysorense, Impatiens* spp.; *Crotalaria* spp., *Indigofera pulchella, Smithia gracilis, Rubus moluccanus, Parnassia mysorensis, Rhodomyrtus tomentosa, Bupleurum mucronatum, Heracleum rigens, H. hookerianum, Galium asperifolium, Campanula fulgens, C. wightii, Swertia* spp., etc. (Subramanyam & Nayar, 1974).

The typical tropical African elements have become naturalised and differentiated into endemic forms on the Western Ghats and Sri Lanka. Some of the African components are *Ochrocarpus longifolius, Mundulea*, a South-African and Medagascan genus *Geissapsis, Leptodesmia congesta, Delonix regia, Tamarindus indicus, Acacia, Bryophyllum pinnatum, Plumbago capensis, Salvadora, Cryptostegia grandiflora, Sessamum, Pedalium murex, Ricinus communis, Pseudarthria, Hardwickia, Cephalandra, Ctenolepis, Gaertnera, Blepharis, Peristrophe bicalyculata, Lasiopogon, Vicoa, Carthamus, Dicoma tomentosa,* etc. (Mani, 1974).

The Malabar region is characterised by the presence of Guttiferae, Dipterocarpaceae, Myristicaceae, abundance of Malayan forms especially among Sterculiaceae, Tiliaceae, Anacardiaceae, Meliaceae, Myrtaceae, Melastomataceae, Vitaceae, Gesneriaceae, Piperaceae, Scitamineae, Orchidaceae etc. *Podocarpus latifolia* is confined to the hills of Tinnevelly and outside it is known from Myanmar and Malaya. Western Ghats flora shows great affinities with that of Malesian region (Hooker, 1904; Subramanyam and Nayar, 1974). Indo-Malayan genus *Sarcandra* (Chloranthaceae) is represented by *S. chloranthoides* (vesselless). *Kunstleria* predominantly Malayan genus is also represented in the Western Ghats.

Some of the other migrants are *Viola patrinii* (Siberia, Russia, Japan, Himalaya and Eastern and Western Ghats), *Polygala siberica* (Himalaya, Kahsi Hills, Siberia, China, Japan, Western Ghats from Nilgiri southwards to Sri

Lanka), *Stellaria saxatilis* (Siberia, Japan, Khasia Hills, Himalaya and Nilgiri), *Rhamnus virgatus*, etc. (China, Japan, Himalaya, Nilgiri and Palni), *Fagonia arabica* (Egypt to Western Ghats), *Rubia* (Himalaya, Western Ghats, Sri Lanka, Japan, etc.).

The following are some of the humid tropical Asiatic elements found in Western Ghats *Pittosporum tetraspermum, P. floribundum, P. dasycaulon, Garcinia indica, Xylia xylocarpa* (Malaya, Myanmar, Philippines), *Rhodomyrtus tomentosa* (Malaya, Nilgiri and Palni Hills, Sri Lanka), *Beilschmedia* (Western Ghats, Central and Eastern Himalaya, Assam, Myanmar and Sri Lanka), *Cinnamomum, Machilus, Phoebe* and *Litsea* (Myanmar, Malaya, E. Himalaya, Western Ghats and Sri lanka), *Hedyotis* (Myanmar, Assam, Himalaya, Deccan, Western Ghats, Sri Lanka), *Knoxia* (Malaya, Myanmar, Assam, Himalaya, Western and Eastern Ghats, Sri Lanka, Tropical Australia), *Lasianthus* (Malaya, Myanmar, Andaman, Assam, E. Himalaya, Western Ghats, Sri Lanka).

Sri Lankan elements

The monotypic genus *Kendrickia* which includes species *K. walkeri*, is restricted to Anamudi region of Anamalais in South India and Adam's Peak of Sri Lanka. In addition to this, numerous species of this region are common with Sri Lanka. Some of these are -*Filicium decipiens, Gyrinops walla, Gordonia obtusa, Kydia calycina, Myristica dactyloides, Polyalthia longifolia, Clematis gouriana, Narvelia zeylanica, Capparis grandis, Olax scandens, Gouania microcarpa, Zizyphus xylopyrus, Tetrastigma lanceolarium, Meliosma microcarpa, Crotalaria nana, Pterocarpus marsupium, Acacia suma, A. ferruginea, A. caesia, Albizia amara, Osbeckia wightiana, Begonia malabarica, Neurocalyx calycinus, Hedyotis nitida, Tarenna asiatica, Maesa perrottetiana, Canscorea wallichii, Premna tomentosa, Teucrium tomentosum, Apama siliquosa, Sarcandra irvingbaileyi, Litsea deccanensis, Helixanthera hookeriana, Schumannianthus virgatus, Molineria tricocarpa, Calamus pseudo-tenuis*, etc. Indo Sri Lankan genus *Humboldtia* (Leguminosae) is represented by 7 species in Western Ghats.

The common occurrence appears to support the view that in bygone times Sri Lanka and South India were united.

There are number of Western Ghat taxa which are common with Africa. Abraham and Vatsala (1981) reported occurrence of 10 genera of Orchidaceae, viz. *Acampe, Bulbophyllum, Diosporis, Eulophia, Habenaria, Liparis, Nervilia, Oberonia, Satyrium* and *Vanilla*. *Calanthe mascua, C. volkensis, Eulophia epidendrea, E. schimperiana* etc. are common with East Africa.

(iv) EASTERN GHATS AND COROMANDEL COAST

The Eastern Ghats pass through Andhra Pradesh and Tamil Nadu to Karnataka and touch the East Coast at several places and Bastar District of Madhya Pradesh. Eastern Ghats do not form continuous range because the great rivers Mahanadi, Godawari and Krishna cut across them. They form the continuous range only in Nallamalai Hills. The highest peak in these Ghats is 1750 m high in Biligirirangan Hills forming the Southern tip of these Ghats.

The Coromandel coast occupies the strip of lowland between the Eastern Ghats and sea. It stretches from Orissa to Tirunelveli in Tamil Nadu.

The forest vegetation of Eastern Ghats is poor as compared to the Western Ghats. Vast area in under Tropical Dry Deciduous or Thorn forests. Some northern parts bordering Orissa have Moist Deciduous forests.

A large number of species common with the Sri Lanka, Malaysia, Myanmar, Tropical America, Africa, Madagascar, Australia, South-East Asia, Middle-East, China, Malacca, New Guinea, Philippines, Japan, Afghanistan, Pakistan, Indonesia, etc. have been reported from towards Eastern portion of the Peninsular India and Eastern Ghats and Coromandel coast. Some of the examples are :

Naravelia zeylanica (India, Sri Lanka to Malaya)
Dillenia pentagyna (India, Myanmar, Malaya)
Annona squamosa (Trop. America, naturalized in India)
Cocculus hirsutus (Trop. Africa to India, Myanmar)
Tinospora cordifolia (India, Sri Lanka, Myanmar)
Tiliacora acuminata (India, Sri Lanka to Malaysia)
Nymphaea nouchali (Africa to India)
Nymphaea pubescens (Africa, India to Malaysia)
Capparis sepiaria (Africa, India, Sri Lanka to Myanmar, Malaysia)

Capparis zeylanica (India, Sri Lanka to Myanmar and Malaysia)
Cleome monophylla (Trop. Africa to India)
Hybanthus enneaspermus (Trop. Africa to India and Australia)
Cochlospermum religiosum (India, Sri Lanka to Malaysia)
Flacourtia indica (Madagascar to India)
Polygala elongata (India and Sri Lanka)
Polygala arvensis (India, Sri Lanka to Malysia)
Thespesia lampas (Trop. East Africa, to India, Sri Lanka and Malaysia)
Hibiscus vitifolius (Trop. Africa, India, Sri Lanka to Malaysia and Australia)
Hibiscus lunariifolius (Trop. Africa, India, Sri Lanka, Myanmar)
Hibiscus micranthus (Trop. Africa to India)
Hibiscus lobatus (Trop. Africa to S.E. Asia)
Pavonia odorata (East Trop. Africa, India, Sri Lanka to Myanmar)
Sida cordata (Trop America to Africa, India, Sri Lanka and Malaysia)
Sida acuta (Trop. Africa, India, Sri Lanka to Malaysia)
Melochia corchorifolia (Trop. Africa, India, Sri Lanka to Myanmar)
Helicteres isora (Middle East, India, Sri Lanka to Australia)
Sterculia urens (India, Sri Lanka, and Myanmar)
Firmiana colorata (India, Sri Lanka, Myanmar)
Corchorus aestuans (Tropical belt from Africa, India, Sri Lanka to Australia)
Corchorus fascicularis (Trop. Africa, India, Sri Lanka to Myanmar and Australia)
Triumfetta pilosa (From Africa to India, Sri Lanka, Malacca etc.)
Triumfetta rhomboidea var. *rhomboidea* (Africa, Sri Lanka, China to Australia)
Grewia tiliaefolia (Trop. East Africa, India, Sri Lanka to Myanmar)
Grewia flavescence (Trop. Africa to India)
Grewia tenax (Trop. Africa, Middle East, India in Dry localities)
Grewia hirsuta (India, Sri Lanka and Myanmar)
Hiptage benghalensis (India, Sri Lanka to China, Malacca)
Aspidopteris indica (India and Myanmar)
Tribulus terrestris (Trop. Africa, India, Sri Lanka to Australia and America)
Biophytum reinwardtii (India, Sri Lanka, China, Myanmar)
Biophytum sensitivum (Tropical belt of Africa, India, Sri Lanka and America)
Oxalis corniculata (India, Sri Lanka, Myanmar)
Naringi crenulata (India, Sri Lanka, Myanmar)
Micromelum pubescens (India, Sri Lanka, Myanmar and Malaysia)
Ailanthus excelsa (Trop. Africa, India, Sri Lanka, to Myanmar and Australia)
Balanites aegyptiaca (India, Sri Lanka and Myanmar)

Garuga pinnata (India, Myanmar)
Melia composita (Africa, India, Sri Lanka, Australia)
Ximenia americana (Trop. New World, Africa and India)
Olax psittacorum (India, Sri Lanka, Myanmar)
Opilia amentacea (India, Sri Lanka, Myanmar)
Maytenus emarginata (Trop. India, Sri Lanka to Myanmar and New Guinea)
Cassine glauca (Africa to India, Sri Lanka and Myanmar)
Celastrus paniculata (Trop. Africa, India, Sri Lanka, Philippines)
Loeseneriella obtusifolia (India and Myanmar)
Ventilago denticulata (Tropical from India to Malaysia)
Ventilago madraspatana (India, Sri Lanka, Myanmar)
Ziziphus rugosa (India, Sri Lanka, Myanmar)
Ziziphus oenoplia (India, Sri Lanka, Myanmar and Australia)
Ziziphus nummularia (Middle East to India)
Ziziphus mauritiana (Africa, India, China and Australia)
Cissus quadrangularis (Africa, Sri Lanka, Malaysia)
Cayratia trifolia (India, New Caledonia and Australia)
Leea macrophylla (India, Myanmar)
Leea indica (India, Sri Lanka, China, Myanmar and Australia)
Allophylus cobbe (India, Sri Lanka, Myanmar and extending upto America)
Derris scandens (India, Sri Lanka, China, Malaysia and North Australia)
Derris indica (India, Sri Lanka, Malaysia and N. Australia)
Dalbergia volubilis (India, Sri Lanka to Malaysia)
Mucuna pruriens (Africa, India, Sri Lanka, Myanmar and Malaysia)
Uraria picta (Africa, India, Sri Lanka, Malaysia and Philippine Islands)
Abrus precatorius (India, Sri Lanka to Malaysia)
Crotalaria calycina (Africa, India, Sri Lanka and Myanmar)
Indigofera cordifolia (Middle East, India, Sri Lanka, Malaysia and North Australia)
Indigofera linifolia (Middle East, India, Sri Lanka, Malaysia and North Australia)
Indigofera linnaei (Africa, India, Sri Lanka, Myanmar and N. Australia)
Indigofera cassioides (Pakistan, India, Sri Lanka, Myanmar to China and Indo-China)
Indigofera astragalina (Africa, India, Sri Lanka, Philippines, N. Australia, South America)
Indigofera glabra (Tropical Africa, India, Sri Lanka)
Atylosia scarabaeoides (Madagascar, India China, Malaya Peninsula)

Alysicarpus vaginalis (Africa, Middle East, India, Sri Lanka)
Stylosanthes fruticosa (Trop. Africa, India, Sri Lanka, Malaysia)
Zornia gibbosa (India, Australia)
Rhynchosia rufescens (India, Sri Lanka, Malaysia)
Rhynchosia viscosa (Africa, India, Sri Lanka)
Flemingia macrophylla (Africa, India, Sri Lanka, China, Malaysia, Australia)
Desmodium triquetrum (India, Sri Lanka, Myanmar)
Desmodium velutinum (Africa, India, Sri Lanka, Malaysia and Philippines)
Desmodium gangeticum (Africa, India, Sri Lanka, Malaysia and Philippines)
Desmodium pulchellum (India, Sri Lanka, Myanmar, North Australia)
Desmodium motorium (India, Sri Lanka, Myanmar, Malaysia and Philippines)
Desmodium triflorum (India, Sri Lanka, Malaysia and Australia)
Desmodium heterocarpa (India, Sri Lanka, Myanmar, China, Japan and Malaysia)
Bauhinia variegata (India, China, Myanmar)
Bauhinia tomentosa (India, Sri Lanka, Malaysia)
Bauhinia racemosa (India, Sri Lanka, Malaysia)
Pterolobium hexapetalum (India, Sri Lanka, Myanmar, Malaya Peninsula)
Tamarindus indica (Trop. Africa, India, Sri Lanka and Malaysia)
Cassia fistula (India, Sri Lanka, Myanmar, Malaysia)
Cassia auriculata (India, Sri Lanka, and Malaysia)
Cassia absus (Middle East, India, Sri Lanka, Australia)
Cassia pumila (India, Sri Lanka, Australia)
Dichrostachys cinerea (India, Sri Lanka, Myanmar, North Australia)
Mimosa polyuncistra (Mexico Peninsular India)
Entada pursaetha (India, Sri Lanka, Myanmar and Malaya Peninsula)
Albizia lebbeck (Africa, India, Sri Lanka, Myanmar and Australia)
Albizia odoratissima (India, Sri Lanka, Myanmar, Malaya Peninsula)
Acacia pinnata ((Africa, India, Sri Lanka, Myanmar and Malaysia)
Acacia intsia (India, Sri Lanka, Myanmar)
Acacia nilotica (Africa, India and Sri Lanka)
Acacia leucophloea (India, Sri Lanka, Myanmar, Malaya Peninsula)
Terminalia bellirica (India to Malaya Peninsula)
Terminalia chebula (India, Sri Lanka, Malaya Peninsula)
Calycopteris floribunda (India, Sri Lanka, Malaya Peninsula)
Careya arborea (India, Myanmar)
Barringtonia acutangula (India, Sri Lanka, Myanmar, Australia)
Woodfordia fruticosa (Africa, Pakistan, India, Sri Lanka, China)

Ammannia baccifera (Africa, Afghanistan, India, Sri Lanka, Malaysia, Australia)
Ludwigia prostrata (India, Sri Lanka, Malaysia)
Ludwigia perennis (Africa, India, Sri Lanka, Pacific Islands)
Trichosanthes cucumerina (India, Sri Lanka, Myanmar, Malaysia and North Australia)
Solena heterophylla (India, Sri Lanka, Myanmar, Indonesia)
Coccinia grandis (Africa, India, Myanmar, Malaysia)
Diplocos palmatus (Africa, India, Sri Lanka, Myanmar and North Australia)
Mukia maderaspatana (India, China, Malaysia and Australia)
Cucumis callosus (North Africa, Pakistan, India, Sri Lanka and North Australia)
Glinus oppositifolius (Africa, India, Sri Lanka, Australia)
Mollugo pentaphylla (India, Sri Lanka, China, Malaya Peninsula)
Alangium salvifolium (East Africa, India, Sri Lanka, Myanmar, Malaysia and Philippines)
Oldenlandia ovatifolia (Tropics from India, Malaysia)
Oldenlandia nitida (India, Myanmar)
Knowxia sumatrensis (India, Sri Lanka, Myanmar, Malaysia and Australia)
Borreria stricta (India, Sri Lanka, China, Malaysia)
Borreria articularia (India, China, Malaysia, Philippines)
Adina cordifolia (India, Sri Lanka, Myanmar and Indonesia)
Mitragyna parvifolia (India, Sri Lanka, Myanmar)
Morinda tinctoria (India, Sri Lanka and Malaysia)
Hymenodictyon orixense (India, Sri Lanka, Myanmar and Malaysia)
Terenna asiatica (India, Sri Lanka, Malaysia)
Pavetta indica (India, Sri Lanka, Malaysia and Australia)
Wendlandia tinctoria (India, Sri Lanka, Myanmar and Malaysia)
Gardena turgida (India, Myanmar)
Gardenia resinifera (India, Sri Lanka and Myanmar)
Randia spinosa (Africa, India, Sri Lanka and Malaysia)
Randia uliginosa (India, Sri Lanka and Myanmar)
Ensete glaucum found in Visakhapatnam hills, Meghalaya, Myanmar, Thailand etc. is relict species.

Coromandel Coast

The Coromandel coast occupies the strip of lowland between the Eastern Ghats and sea. It stretches from Orissa to Tirunelveli. Thickest of thorney evergreen and deciduous trees and shrubs abound belonging to genera *Flacourtia, Randia, Scutia, Diospyros, Mimusops, Garcinia, Sapindus, Pterospermum*, etc. (Hooker 1904, 1907 : 37). *Strychnos nux-vomica* is also characteristic. The evergreen species are *Eugenia bracteata, Memecylon umbellatum, Carallia integerrima, Lonicera malabarica* etc. *Mimusops hexandra* is confined to coastal areas from Madras to Point Calimere. In the extreme southern coast *Acacia planifrons, Cocculus laeba, Capparis aphylla, Cassia ovata* and *C. angustifolia* are characteristic (Mani, 1947a). The coastal area supports mangrove swamps with *Avecennia officinalis, Lumnitzera racemosa, Bruguiera* spp., *Rhizophora* spp., etc. The sandy beaches support *Hydrophylax maritima, Ipomoea pes-caprae, Sesammum prostratum* and *Spinifex squarrosus*.

Rao and Sastry (1974) while studying the coastal vegetation of India reported that the strand vegetation of India comprise admixture of Afro-Perso-Arabian/Western and Indo-Malayan/Eastern elements or Polynesian. They further stated that the terrestrial estuarine flora distributed in the estuarine and tidal mangrove zones is derived chiefly from Malesian and Polynesian Islands. The following are some of the elements which are found in the Coromandel coast and have distributional ranges upto Myanmar, Malay Peninsula, Australia and Polynesia *Allmania nodiflora, Bauhinia anquina, Callophyllum inophyllum, Calotropis gigantea, Cordia subcordata, Clerodendrum enerma, Cyperus penduncalatus, Ipomoea macrantha, I. Pes-caprae, Heritiera littoralis, Morinda citrifolia, Oldenlandia diffusa, Pemphis acidula, Scaevola plumieri, S. taccada, Schyphiphora hydrophyllacea, Spinifex littoreus.* Many of these taxa extend upto south western Indian Peninsula from Malesian Islands through Malacca, Tenasserim, Sunderbans and Coromandel coast.

The strand flora of Sri Lanka is well represented along the southern shores of Tamil Nadu including the islands in the Gulf of Mannar.

(V) DECCAN

The large part of the plateau is covered with tropical thorn forests comprising species of *Acacia, Dicrostachys, Butea, Anogeissus, Azadirachta, Grewia, Strychnos* etc. Tropical Dry Deciduous forests occur in northern, central and southern part of plateau. They have teak forests intermixed with species of *Anogeissus, Diopyros, Dalbergia, Pterocarpus, Cassia, Butea, Adina, Aegle,* *Lagerstroemia* and bamboos, the other deciduous components are -*Santalum album*, *Cedrela toona*, *Soymida febrifuga*, *Capparis*, *Grewia*, *Phyllanthus*, *Euphorbia nerifolia*, *Borassus flabellifer*, *Phoenix sylvestris*, *Flacourtia*, *Randia*, *Diospyros*. The Eastern parts of plateau in Andhra Pradesh and Orissa have moist deciduous forests comprising species of *Terminalia*, *Bombax*, *Dalberiga*, *Madhuca*, *Ceiba*, *Grewia*, *Phyllanthus*, *Cleistanthus*, *Schleichera*, etc. *Shorea robusta* is abundant in north-eastern part of plateau. A number of taxa from foreign countries having more or less identical climatic condition have migrated into the Peninsular India. Some such taxa are :

African Madagascan elements :

The tropical African, especially the East African and Madagascan elements constitute an improtant component of Peninsular flora. The following are the African components : *Erythroxylon monogynum*, *Mundulea*, *Geissapsis*, *Leptodesmia congesta*, *Delonix regia*, *Tamarindus indica*, *Acacia*, *Bryophyllum pinnatum*, *Plumbago capensis*, *Salvadora*, *Cryptostegia grandiflora*, *Sesamum*, *Pedalium murex*, *Ricinus communis*, *Pseudarthria*, *Hardwickia*, *Humboldtia*, *Cephalandra*, *Ctenolepis*, *Gaertnera*, *Blepharis*, *Peristrophe bicalyculata*, *Lasiopogon*, *Vicoa*, *Carthamus*, *Dicoma tomentosa*. Deccan has fewer Malesian elements, and in some dry arid area it contains an admixture of Omano-Sindian elements (Takhtajan, 1986).

Meher-Homji (1965) after analysing the floral elements of the dry region of India recognised two zones "one in the north contiguous to the desert of Thar, extending into Rajasthan, the Punjab, parts of Uttar Pradesh and north Gujarat. The other semi-arid zone, situated in the South, includes the Deccan Plateau and parts of Coimbatore, Ramanathpuram and Tirunelveli District in Madras". He further added that the concentration of the "Tropical and North African Indian Desert" elements in the northern semi-arid zone rather than in the Deccan. Also the sub-desertic climate does not enter Deccan. Only a very negligible percentage of flora of Sudan and South-West Arabia occurs in Deccan, thereby the relative floristic individuality of the Deccan from the rest of Suddan territory.

The woody temperate members, though very few, that are found in the present day flora of Deccan region suggest that they are ones which have been left over after the Pleistocene glaciation. The monsoon ephimeral flora also exhibits temperate elements which are interpolation in the tropical elements of the Palaeocene flora. Such elements of temperate type would have gradually disappeared as the aridity increased on the whole Deccan Plateau.

(VI) ANDAMAN AND NICOBAR ISLANDS :

The islands are considered crucibles of evolutionary sites where the evolutionary processes are still very active. The distances of islands from the continents play important roles in the phytogeographical distribution of plants.

The Arakan Yoma Indonesian arch of hill range on which the islands of Andaman and Nicobar are situated in the north-south direction has significantly contributed towards the distributional pattern of plants in Andaman and Nicobar Islands with Andaman group displaying plant constituents of many Burmese origin and Nicobar group with Indonesian elements.

The following table indicates presence and absence of some of the taxa in two groups of islands.

	Andaman	Nicobar
Pterocarpus dalbergioides	+	
Dipterocarpus spp.	+	
Pometia pinnata	+	
Areca triandra	+	
Scyphiphora hydrophyllacea	+	
Pemphis acidula	+	
Ancistrocladus tectorius	+	
Crypteronia paniculata	+	
Tetrameles nudiflora	+	
Pandanus andamanensium	+	
Podocarpus neriifolia	+	
P. wallichianus		+
Mangifera andamanica	+	
M. camptosperma		+
Hydnophytum fornicatum	+	
Burmannia championii		+
Phanera nicobarica		+
Phrynium paniculatum		+

Bentinckia nicobarica	+
Rhopaloblasta anguste	+
Glycosmis pilosa	+

Balakrishnan *et al* (1984) summarised "Great Nicobar Island shows no endemism at family level, the Dipterocarpaceae, Simaroubaceae and Polygalaceae are not represented in Great Nicobars but occur in Andamans and Malesia."

Great Nicobar and Indonesia share more common families than with Indo-Myanmar-Thailand families. At family levels Great Nicobar is more allied to Malesia than to Andamans. The presence of many species common between Andaman and Nicobars is considered as a sign of recent exchange. Out of 684 species, 72 are endemics, 210 species are strictly Malesian and the rest 402 species are having wide-spread distribution through Asia to Australia. They conclude (*op. cit.*) "... in the long distant past this island was connected by land with Sumatra and probably also with Burma through Andamans and this land connection enabled it to bear a large number of species of these adjacent regions. This longer period of connection with Sumatra also enable it to have more Malesian elements than northern elements. The later complete isolation of the island produced physical barriers which resulted in the evolution of several endemic species. This original flora got enriched by long distance migration from Sumatra, Malaya, Thailand and Andaman resulting in present day mixed flora of the Islands".

Rao (1987) gives the phytogeographical distribution of plants of Andaman and Nicobar Islands as follows.

Indo-pacific :

Aegiceras corniculatus, Asplenium nidus, Cyperus pedunculatus, Dodonaea viscosa, Euphorbia atoto, Hernandia peltata, Heritiera littoralis, Ipomoea macrantha, I. pes-caprae, Lumnitzera littorea, Messerschmidia argentea, Morinda citrifolia, Pemphis acidula, Scaevola sericea, Rhizophora stylosa, etc.

Indo-Malesian :

Cynometra iripa, Guettarda speciosa, Heritiera formes, Lumnitzera racemosa, Ochrosia oppositifolia, Sonneratia caseolaris, S. griffithii.

Indo-Burmese :

Phoenix paludosa, Sonneratia apetala, Aegialitis rotundifolia, Heritiera formes.

Indo-African :

Calophyllum inophyllum, Lancea coromandelica, Ximenia americana.

Neo-Tropical :

Cordia subcordata, Suriana maritima.

Balakrishnan (1984) enlisted 144 taxa as endemic to Andaman islands and 72 taxa to Great Nicobar Island.

Vasudeva Rao (1986) in his preliminary report on the Angiosperms of Andaman and Nicobar Islands records 1454 taxa. Of these approximately 14% angiosperms are endemic and about 54% occur in mainland India. Approximately 32% taxa extend to the adjacent areas of S.E. Asia and Malesia but do not occur in mainland India.

Phytogeographically, Andaman groups of Islands and the Nicobar group appear to be distinct. The angiospermic components of Andaman Islands show general affinities towards S.E. Asia and mainland India while those of the Nicobar Islands have affinities towards Malesia.

(VII) NATURALIZED EXOTIC PLANT SPECIES

During eighteen and nineteen centuries a large number of wild species were brought unwittingly by man from different countries, particularly from tropical America and Australia. Some of these also came from Africa. These have spread in different areas and naturalized during course of time. Some of these are :

(1) *American elements :*

Senebiera didyma, Guazuma tomentosa, Melochia nodiflora, Argemone mexicana, Swietenia mahagoni, Anacardium occidentale, Caesalpinia coriaria, *Parkinsonia aculeata, Cassia hirsuta, C. occidentalis, C. alata, Mimosa pudica, Desmanthes virgatus, Leucaena glauca, Acacia farnisiana, Enterolobium saman, Couropita guianensis, Turnera ulmifolia, T. trioniflora, Passiflora foetida, Cereus hexagonum, Opuntia coccinellfera, Flaveria contrayerba, Tridex procumbens, Erigeron mucronatum, Eupatorium odoratum, Lagascea mollis, Thevetia neriifolia, Rauwolfia canescens, Lochnera rosea, Quamoclit phoenicia, Q. pinnata, Ipomoea quinquefolia, Datura metel, Nicotiana plumbaginifolia, Solanum seaforthianum, Scophularia dulcis, Bigonia magapotamica, Martynia annua, Lantana aculeata, Clerodendron aculeatum, Hyptis suaveolens, Gomphrena globosa, G. decumbens, Pepromia pellucida, Euphorbia prostrata, Croton bonplandianum, Pilea microphylla, Eichchornia crassipes, Anona squamosa, A. reticulata*, etc.

(ii) *Australian elements* :

Acacia retinodes, A. longifolia, A. melanoxylon, A. decurrens, A. dealbata, Flaveria australasia, etc.

(iii) *African elements* :

Adansonia digitata, Bryophyllum pinnatum, Delonix regia, etc.

According to Maheshwari (l.c.), of the total number of Indian flowering plants, *ca* 40% are foreign and now naturalised in different parts of the country. He has classified these plants as :

(1) Pluri regional species (Palaeotropical, neotropical, pantropical and cosmopolitan groups)
(2) Weeds of the cultivation and other introduced weeds.
(3) Exotics and escapes from cultivation.
(4) Species of limited distribution in India and adjoining regions.

The first three groups may be considered to present 10% of total figure. The plants belonging to the fourth group have migrated into India from Malaysia, China and West Asia. It is assumed that 10% of Indian flora has come from West Asia and almost equal proportion respectively from the Chinese and Malayan sides. This, together, makes up the total to 40% for all the foreign plants. For details the readers are refered to the paper by Maheshwari (l.c.).

(II) MIGRATION OF PLANTS WITHIN INDIA :

In addition to the migration of plants from the neighbouring countries, as discussed earlier, a number of Himalayan plants both from Western and Eastern sides have migrated to Peninsular India and hill-tops of South India. Mukherjee (1935) reported many West Himalayan elements in Mahendragiri. Mooney (1944) reported occrrence of *Pyracantha crenulata, Pyrus pashia, Berberis asiatica,* etc. in the hills of Jashpur and Sarguja. *Rubus ellipticus* from Muyurbhanj. These are normally found in the temperate region from Kashmir to Bhutan, Khasia Hills etc. Gupta (1962) reported a number of Himalayan plants in Peninsular hills.

The "Shola" forests of the Nilgiris in South India are unique. The Pleistocene glaciation has repeatedly pushed the temperate taxa right down to South Indian Hills. They could not recede back to original habitat and got struck up to South Indian hill-tops particularly in the Nilgiris and Anamalai Hills etc. The temperate forests of Nilgiris have affinities with Flora of Naga Hills, Manipur, Khasia and Eastern Himalayas. The following species are common with Eastern Himalayas:

Hypericum hookerianum; H. nepalensis, Ternstroemia japonica, Eurya japonica, Rhamnus dahuricus, Photinia notoniana, Rubus ellipticus, R. lasiocarpus, Rhododendron arboreum, Gaultheria fragrantissima, Gardneria ovata together with species of *Kadsura, Berberis, Pittosporum, Elaeocarpus, Euonymus, Meliosma,* etc.

Species of *Thalictrum, Ranunculus, Cardamine, Geranium, Alchemilla, Fragaria, Scutellaria, Potentilla, Paranassia, Lysimachia, Swertia, Gentiana* and many Cyperaceae and Poaceae are common in ground flora.

An important aspect of the hill top flora of South India viz; the presence of temperate or semi-temperate members side by side with subtropical or tropical species such as *Cardamine hirsuta, Delphinium indicum, Thalictrum dalzellii, Impatiens parviflorus, Hypericum indicum, Senecio grahami, Clematis gouriana,* etc, are believed to have got stabilized here in the post-Pleistocene period. Their occurrence and proportionate increase with elevation of mountains in Nilgiris, Mahabaleshwar and other places in Western Ghats. They abruptly disappear towards the Northern end of Western Ghats. *Rosa multiflora, Spiraea* sp., *Salix tetrasperma, Ilex prinsepia, Pimpinella* sp., *Artemisia vulgaris* also disappear.

A good number of taxa of Himalaya, Meghalaya and Assam are found in Vishakhapatnam district and some species of Assam are still found in Kalahandi and Bailadila (Mooney, 1950). Of these mentioned may be made of : *Anaphalis adnata, Beilschmieda sikkimensis, Bulbophyllum densiflorum, Callicarpa macrophylla, Chirita hamosa, Eulophia explanata, Forrestia mollissima* var. *glabrata, Lysimachia alternifolia, L. decurrens, Mucuna nigricans, Parabaena sagittata, Polygala furcata, Prunus jenkinsii* (Balakrishnan, 1964; Subba Rao & Kumari 1968, 1971, 1972). *Ensete glaucum* found in Visakhapatnam hills, Meghalaya, Myanmar, Thailand, etc. is a relict species.

The presence of Himalayan, Meghalaya and Assam plant species in Eastern Ghats is of great phytogeographical significance. There are several views on the presence of these elements in the Eastern Ghats.

Haines (1921-25) explained them as relicts of the time when the hills of Orissa were much higher and served as stepping stones for migration of species from higher lands of the Deccan Peninsula to newer Himalayas.

Biswas and Sampathkumaran (1949) explained that they are relicts from the time when there was a land connection between Deccan Peninsula and Indo-Malayan region.

Mooney (1950) feels that some of these are relict species from an earlier and cooler climate and some are through bird migration.

Razi (1955) suggested that hills of Bihar and Orissa played an important role in migration. Seshagiri Rao and Narayanswamy (1960) consider the presence of Himalayan species on the hills of the Eastern Ghats "as instances of either discontinuous distribution or remnant vegetation of bygone days, got isolated on account of ancient geological disturbances".

The discovery of fossil Gymnosperms, *Gingko* from Deccan Intertrappean beds of Eocene and also from Rajamundry sand-stone series of Mid-Tertiary from Pangdi, *Taxaceoxylon* from Kateru and *Dadoxylon* alongwith *Mesembryoxylon* from Pangdi and Rajamundry has been interpreted as indication of cool climate in the region prior to upliftment of Himalayas (Meher Homji, 1980).

Some northern parts bordering Orissa have Moist Deciduous forests. The "Shola" forests are predominated by Evergreen species. A large number of species of Himalaya, Meghalaya and Assam are found in Vishakhapatnam district and some species are still found in Kalahandi and Bailadila (Mooney, 1950). Of these mentioned may be made of : *Saussurea heteromella, Polygala furcata, Sloanea sterculiacea, Sapium eugeniafolium, Bulbophyllum densiflorum* (A Bhutan orchid), *Eulophila explanata, Forrestia mollissima* var. *glabrata, Prunus jenkinsii, Chirita hamosa, Rhaphidophora decursiva, Beilschmiedia sikkimensis, Parabaena sagittata, Mucuna nigricans, Anaphalis adnata, Lysimachia alternifolia, L. decurrens, Callicarpa macrophylla*, etc.

The Malabar region is characterised by the presence of Guttiferae, Dipterocarpaceae, Myristicaceae, abundance of Malayan forms especially among Sterculiaceae, Tiliaceae, Anacardiaceae, Meliaceae, Myrtaceae, Melastomataceae, Gesneriaceae, Piperaceae, Orchidaceae, etc. *Podocarpus latifolia* is confined to hills of Tinnevelly and outside it is known from Myanmar and Malaya.

Some Eastern Himalayan species common with Malabar region are *Ternstroemia japonica, Hypericum hookerianum, H. nepaulense, Eurya japonica, Rhamnus dahuricus, Photinia notoniana, Rubus ellipticus, Rubus lasiocarpus, Carallia integerrima, Rhododendron arboreum, Gaultheria fragrantissima, Gardenia ovata* and species of *Meliosma, Rosa, Pygeum, Viburnum, Lonicera*, etc.

A number of Western Ghat elements are seen wild in the Eastern Ghats. Some of these are : *Nothopegia racemosa, Syzygium malabaricum, Glochidion ellipticum, Debregeasia malabarica, Xenacanthus pulneyensis, Mallotus rhamnifolius, Pouzolzia bennettiana, Knoxia mollis, Lobelia zeylanica, Dicliptera zeylanica, Platystoma flaccidum, Plectranthus mollis, Polypleurum filifolium, Pilea trinervia, Microstylis versicolor, Polystachya flavescens*, etc.

Probable reasons for the occurrence of Western Ghat taxa in the Eastern Ghats have been given by various botanists. Some of the reasons put forward are:

(i) Probably they might have extended in the past along the Western Ghats - Biligirirangan - Shevroy - Kalrayan - Javadi hills and further north to Eastern Ghats.

(ii) Northern drift of Indian Landmass probably accompanied by a slight southern shift of the equator (Auberville, 1969), the uplift of Himalayas and maximum rise of Western Ghats in the Pleiocene (Krishnan, 1968; Vaidyanathan, 1977) have contributed towards comparatively drier conditions on the Coromandel Coast and the Eastern Ghats (Mehr-Homji, 1980). Thus, these plants prefering moist climate may be relicts of earlier vegetation of cooler climate that prevailed in the Eastern Ghats prior to the uplift of Himalaya.

(iii) The original flora of the Deccan Intertrappeans from Miocene period of Andhra Pradesh has migrated either to the south or to the west near Nilgiris and Western Ghats where probably found better habitat or ecological niche than the Andhra Pradesh (Mahabale, 1979).

A few species exhibiting luxuriant growth in the evergreen forests of the Karnataka Ghats also occur under identical climatic conditions in the tropical rain forests of Assam and its surroundings. A few typical examples of giant tree species are : *Acrocarpus fraxinifolius, Aglaia roxburghiana, Aphanamixis polystachya, Artocarpus lakoocha, Bischofia javanica, Toona ciliate, Dipterocarpus turbinatus, Dysoxylum binectariferum, Michelia champaca* and *Tetrameles nudiflora* (Rao, 1978).

Similarly, there are several genera common to both the evergreen forests of Western Ghats and Eastern India although considerable variation in species occur; examples are *Calophyllum, Dipterocarpus, Hopea, Ailanthus, Canarium, Chickrasia, Carallia, Tetrameles, Palaquium, Cinnamomum, Phoebe, Antiaris* and *Artocarpus* (Rao, l.c.)

Anemone rivularis, an Himalayan plant, reached Western Ghats and Sri Lanka (Jain, 1967).

With the construction of Indira canal in Rajasthan, a number of weeds, viz. *Antirrhinum orantium, Arenaria serpyllifolia, Astragalus tribuloides, Centaurium centaurioides, Gastrocotyle hispida, Hypecoum procumbens, Kochia indica, Lophochloa pumila, Malcolmia africana, Malva sylvestris, Oenanthe javanica, Phalaris minor, Plantago amplexcaulis, Polygonum lanigerum, Psammogeton canescens* etc. have migrated from Punjab to Rajasthan recently (Shetty & Singh, 1987).

A large number of new distributional records from different parts of the country have been reported by the scientists of Botanical Survey of India and botanists of other institutions.

Different views have been expressed regarding migration of plants within the country. Some of the views are :

Clarke (1898) and Haines (1921-25) have suggested that the hills of Parasnath may have served in the past as stepping stone for the passage of plant species between the hills of Peninsular India and the Eastern Himalaya.

1. *Southern routes across the Indian ocean :*

This theory postulates the occurrence of a land connections between India, Australia and New Zealand. Puri (1960) states that land connections do not seem to have occurred over Bay of Bengal but across the Assam hills through the Vindhya-Satpura trend of mountains of the Western Ghats and then south to Sri Lanka. It is conjunctured that plant migration in the past has occurred according to these routes.

van Steenis (1962) indicated possibility of land bridges and their role in migration of the flora. His theory embodies the idea that in the dim geological past the palaeotropics and the neotropics were connected by a tropical land bridge across the Pacific, and should be imagined a more or less intermitently interrupted chain of islands, not unlikely the Malaysian and Australian continents.

2. *Deccan Trap theory :*

Occurrence of similar genera of birds in South India and Malayan Peninsula led to the postulation of the theory that Deccan traps were possibly responsible for this distribution. Hora (1949) showed that since migration occurred in waves during the Pleistocene period and not in Tertiary, this could not be the reason.

3. *Continuous range theory :*

According to this theory the localities at which species are found today must have, at one time, formed parts of a continuous range of distribution of species. This was postulated by Hora (l.c.) from the distribution of fishes and other animals and since then considerable evidences have been brought forward in favour of this hypothesis, resulting in famous Satpura Hypothesis.

The Satpura Hypothesis envisages that Satpura-Vindhyan ranges had an altitude of 5000-6000 ft. during Pleistocene, forming continuous ranges of mountains between Himalayas and Western Ghats. During this period the region had rainfall of 150 inches supporting thick tropical evergreen forests. This theory is based on the following fundamental concepts :

1. Contimuity of Vindhya-Satpura ranges with Assam Himalaya in the east and Western Ghats in the west.

2. Vindhya-Satpura ranges and northern sides of Western Ghats having an elevation of 5000-6000 ft.

3. Continuity of an ecological belt of mountains with rainfall of about 100 inches or above and consequently of tropical evergreen forests between Assam Himalaya and mountains of Ceylon via Vindhya-Satpura trend and Western Ghats.

4. Dispersal of fauna from east to west and consequent changes in topography therefore.

These concepts of Hora (*l.c.*) endeavour to explain the presence of Malayan Flora and fauna in Peninsular India and Ceylon conceiving the route of migration from Assam and Eastern Himalaya to the plateau of Chota Nagpur across Rajmahal gap. The migration to Chota Nagpur plateau was probably along Vindhhya-Satpura-Western Ghat route and Orissa- Eastern Ghat-Western Ghats. Puri (*l.c.*) adds that the modern distribution pattern of various species follow ecological conditions of the habitat of which temperature plays relatively unimportant part than annual precipitation. The migration has taken place during the Pleistocene.

Auden (1949) feels that "the evidence is not in favour, therefore, of the conception of major Satpura range extending across India during Teritary period that has subsequently been worn down to present elevation. It suggests rather the downfaulting along the Narmada and Tapti rifts at the close of the erruption of traps and unequal elevation of the regions since Miocene". He further states "It is necessary to suppose that, while the central part of the Peninsula was undergoing mild uplift during Pleistocene, the bordering areas of Cutch, Saurashtra and north Bengal were subjected to depression".

Hora (1951) reoriented his theory mainly based on the climatic fluctuations of the Pleistocene period. The hypothesis of Hora regarding the existence of Satpura across the gap has not, therefore, been finally agreed and the existence of northern elements in the flora of Peninsular India may have to be sought in the effect of glaciation during the Pleistocene.

4. *Glaciation Theory :*

During the glaciation in Himalayas the temperature was lowered throughout the country. Medicott and Blanford (1877) first suggested that "the occurrence of Himalayan plants and animals of the higher ranges of south India may be due to the retreat of the species in the first place towards the equator and subsequently as the temperature increased to the higher parts of the Hills".

However, Hora (*l.c.*) does not agree with the temperature factor. He considers that high humidity during the glacial period was more potential in the distribution of animals and aridity produced discontinuous distribution.

Puri (1962, *l.c.*) states that "It may appear that glaciation, by changing the ecological condition of the environment, has certainly influenced whatever factor, may have been responsible for bringing about discontinuous distribution of Indian plants. As a result of the refrigeration during the ice age, great quantity of limestone from the Himalayas are dissolved out and was washed to soils in plains, thus changing the fertility and mineral composition of soils, both in hills and plains. It seems probable that plant species which have been growing on these limestone soils in Himalayas were able to successfully migrate through the plains to south Indian Hills, where the conditions of the climate and soils were probably similar to that of Himalayan region during Pleistocene and post-glacial period".

Burkill (l.c.) considers that "There is no reason for thinking that there has been any lateral migration between the mountains of Deccan and Ceylon and mountains of Sumatra and Java : but into Malaysia there may well have been two routes for these northern plants, one via Burma to Sumatra and on Java, the other via Formosa and Philippine islands to Borneo and it is possible that in Borneo, Bothain peak in Celebes seems to owe the origin of some of its plants. New Guinea has very little common with Himalayas".

The spread of rainforest genera took place before glaciation period through the Bay of Bengal route and the deterioration of the climatic conditions after glacial period disrupted the continuity of vegetation in different areas. The Himalayan plants spread to other parts of India later than the rainforests elements came to southern India through the Ceylon-Deccan routes; Ceylon and Malaysia during the glacial period.

The glaciation destroyed the rainforest's Malayan elements from the Himalayan ranges to the west and further checked westward migration (Burkill, *l.c.*).

DISCUSSION

The Peninsular India which formed part of Gondwanaland got separated from it some 75 m Y.B.P. It started drifting towards northern direction and during this process the Indian Plate was subjected to different climatic stresses and volcanic eruption causing flow of Deccan lavas, leading to impoverishment of its flora. The extinction took toll of most of the groups of Gondwanic floristic stock druing northward movement. The history of the flora of Peninsular India is that of floristic impoverishment due to the flow of Deccan lavas during Cretaceous-Eocene period and spreading aridity during Neogene-Quaternary times.

The present day flora of Peninsular India is an extant relictual and was supplemented by later day migration and speciation.

The Indian Plate crashed against Laurasia in the northern tropcial latitudes during Late Cretaceous. The continued movement of Indian Plate towards north resulted in crumpling of sediments and progressive shallowing and narrowing of the Tethys. As a consequence of this, east-west basin with intervening highlands were formed between 37-53 million years ago. The last major phase of the northern movement of India occurred around 15 million years ago. The crash of Indian Plate against southern part of Laurasia resulted in the upliftment of Himalayas.

The closing of the Tethys sea and opening of the Indian ocean brought about new pattern of trade winds and monsoon regimes. The upliftment of Himalayas lead to chain of events resulting in the formation of land and river systems. These changes resulted in extinction of vulnerable groups, evolution of floras, migration of floras through corridors provided by the mountain system and adaptive radiation of species complex in conducive ecological niche.

There was progressive shallowing and narrowing of the Tethys during late Cretaceous, culminating in the splitting of the sea into two or more longitudinal basins in Eocene. By the end of the Oligocene the sea water completly evacuated the region, giving way to fresh water and subaerial facies. The vigorous elevation during Middle Miocene resulted into formation of a foredeep along southern side of rising Himalayas, into which Siwalik molassic sediments were deposited.

From late Pliocene to Pleistocene the molassic sediments were uplifted and continued elevation even after Pleistocene resulted in development of the present day structure. By the end of Palaeogene grounds were prepared for the development of the Himalayan land flora. Its major components were established during the Neogene and final details acquired in the Quaternary period.

So as to have an insight into the spread, diversification of angiosperms, phytogeographical affinities, palaeoecology and palaeoclimate of the Indian subcontinent it is imperative to examine the geological events and floristic changes that have taken place during the Tertiary period. The Tertiary flora can be divided into two groups.

(i) ***Palaeogene :***

The Palaeogene flora is found in Peninsular India. These are predominantly tropical floras, made up of the genera now confined to the old world, the notable feature of the Indian Palaeogene is the occurrence of a few southern hemisphere taxa which may recall the pre-Cenozoic relationship between India and Gondwana (Lakhanpal, 1970).

During the Palaeogene the Indian Plate got separated from the main landmass of Gondwana, but not yet joined the Asian Plate. It was the period when angiosperms of Indian subcontinent witnessed thier appreciable spread and diversification. The plant fossils are represented by the elements belonging to marine, estuarine, fresh water and terrestrial habitat with both evergreen and deciduous forms. It is siginificant to note that majority of the taxa reported from the Palaeogene localities find their place in present day flora of the region. The presence of African, Madagascarian, Australian and South American elements in the Palaeogene flora of the Indian subcontinent is indicative of Indias past connection with Gondwanaland countries.

The plant fossils recorded from the Palaeogene period have already been given in the text elsewhere under Intertrappean Flora, Eocene Flora of Kutch, Eocene plant fossils from Fuller's earth deposits near Barmer in Rajasthan and Eocene plants from Meghalaya. The Deccan Intertrappean is the oldest flora of the Indian Palaeogene. The fossil record for this period is from Rajamundry assemblage, the Nagpur Chhindwara assemblage and the Mandla assemblage. The presence of *Cocos* fossil in Rajamundry is indicative of sea shore. The Nagpur-Chhindwara assemblage is tropical in character and in which number of ecological facies are recognsable viz., (i) Marine (ii) Mangrove (iii) Coastal, (iv) Fresh water and (v) Terrestrial. The presence of Gymnosperms are normally indicative of high altitude. However, Florin (1963) pointed out that they can well grow at the sea level. Most of the comparable taxa of this assemblage are presently found in the evergreen to semi-evergreen forests of Western Ghats and N.E. India with some forms occurring in dry deciduous forests.

The Mandla assemblage is exclussively angiospermous dominated by arborescent taxa. This assemblage is also tropical and most of its extant taxa grow in Western Ghats and North East India.

Bande and Prakash (1982) while analysing the Nagpur-Chhindwara and Mandla assemblages envisaged in Central India a climate similar to present day climate of the Western Ghats. The area enjoyed a humid tropical climate.

The northwards drift of Indian Plate, the withdrawal of tethys sea and uplifting of the Western Ghats in the post trappean times resulted in the establishment of present day climate and tropical dry deciduous to moist deciduous vegetation (Bande & Prakash, 1987).

The occurrence of modern comparable forms of angiospermous species described from Panandhro (Lower Miocene, Kutch) viz., *Terminalia crenulata*, *Syzygium* sp., *Lagerstroemia speciosa, Cinnamomum zeylanicum, Ficus tomentosa, Pandanus diversus, P. furcatus* and *P. tectorius* is suggestive of a moist evergreen to deciduous vegetation around Panandhro. The presence of swampy components are indicative of marshes around the locality.

Middle Eocene flora of Kapurdi, Rajasthan is also typically tropical in nature. The presence of *Mesua* cf. *M. ferrea, Garcinia* and *Calophyllum* is indicative of moist tropical climate with evergreen forest flourished around Kapurdi. Fossil *Cocos* suggests that the shoreline was not far away from Kapurdi during Middle Miocene.

The small assemblage reported from near Damalgiri in the north east is indicative of evergreen to semi-evergreen vegetation and a tropical to subtropical climate. *Grewia tiliaefolia* reported from Damalgiri also occur in Africa. Similarly, *Eriodendron* occurs in America, *E. anfructuosum* occurs in Myanmar, Andamans, Malaya Peninsula and Archipelago, western part of Indian Peninsula and tropical America. *Bombax malabaricum* reported from this deposit occurs in tropical Himalaya, warmer forests of India to Myanmar, Sri Lanka, Java and Sumatra. *Bombax insigne,* common in mixed deciduous forests extends into evergreen or semievergreen forests. It is a tropical tree occurring in Myanmar, Andamans, Chittagong, Malaya Peninsula and Western Ghats of India (Lakhanpal, 1954). Four families viz., Palmae, Guttiferae, Nymphaeaceae and Moraceae and genera *Nipa* and *Artocarpus* are common in the Deccan Intertrappean Flora of Central India and Lower to Middle Eocene assemblage of Meghalaya.

The palaeogene flora of India suggests prevalence of wet evergreen to semi-evergreen forests and humid tropical climate in Central India during early Palaeogene ie. during Decaan Intertrappean sedimentation. It continued to prevail in the west and the north-east India till the Middle Eocene. In the post Palaeogene period, after the joining of the Indian Plate with the Asian Plate, that the Indian Subcontinent started acquirng its present day topography resulting in the onsetting of the current vegetational and climate pattern of this Subcontinent (Bande, 1992).

The palaeogene represents a period when the Indian Plate had already broken away from the rest of the continents of Gondwanaland but had not joined with Asian Plate. It seems natural to expect a few taxa having affinities and commoness with the countries forming the common landmass in the past. The Indian Palaeogenic flora, particularly the Deccan Intertrappean does have some taxa which lend support to this assumption. The affinities of *Rodeites* have been traced to *Regnellidium*, a fresh water fern; *Cyclanthodendron* and *Simarouboxylon* to tropical American genera *Cyclanthus* and *Simarouba* respectively. *Hyphaene* has been reported from Intertrappean beds of Peninsular India. This genus also occurs in Africa and Arabia. Another palm *Chrysalidocarpus*, a genus native to Madagascar, has been described. The occurrence of Australian taxa viz., *Eucalyptus*, *Tristania-Malaleuca* (Bande *et al.*, 1986) is also interesting.

The present day flora is usually considered Indo-Malayan in character. A comparision of Palaeogene flora of India vis-a-vis Palaeogene as well as Neogene floras of South-East Asia has shown migration of various taxa between these two masses. Some genera which migrated from India to South-East Asia during Neogene are : *Sterculia*, *Grewia*, *Polyalthia*, *Gomphandra*, *Lophopetalum*, *Syzygium* and *Sonneratia*. Similarly, the significant taxa which were added to the Indian flora from South-East Asia during Post-Palaeogene period are Dipterocarpaceae and many genera of Leguminosae.

The Indian flora of present day acquired its present composition only after the Indian Plate joined with the Asian Plate and establishment of land connection between India and South-East Asia (Bande & Prakash, 1986).

(ii) *Neogene :*

During the Neogene period the climate was warm tropical and more or less uniform throughout the Peninsular India. It was covered by the luxuriant tropical evergreen to deciduous forests. It was the period when Dipterocarpaceae was predominant from East to West and North to South alongwith other common elements. The gradual northward shift of Indian Peninsula from the equator and growing continentality caused by the rise of Himalayan mountain resulted in the decrease of rainfall during Neogene. Towards the end of Neogene there was further decrease in rainfall. It resulted in complete disapprearacne of the dipterocarps and these were replaced with dry or desertic elements towards the end of Pliocene in western (Gujarat and Rajasthan) and south-eastern (Guddalur) part of Indian Peninsula.

The establishment of land connection during Neogene period facilitated large scale migration and mingling of floras between Indian Peninsula, South-East Asia and Africa. The wide spread occurrence of Dipterocarpaceae and dominance of Leguminosae together with Ebenaceae, Rosaceae etc. distinctly demarcated Neogene from that of Palaeogene.

The Neogene sediments appear sporadically along the West (Kutch, Saurashtra, Cambay, Konkan and Karela) coast and East coast (Cauvery, Krishna, Godavari, Mahanadi and Bengal basin). Recently, fossils have been reported from Rajasthan, Madhya Pradesh and South Bihar.

1. *Western India Neogene Flora :*

The presence of calcarious fossil red algae belonging to modern comparable taxa *Lithophyllum, Mesophyllum, Aethesolithon, Archaeoporolithon* in Kuch is indicative of Marine habitat transgression and regression of sea in Kuch during Miocene.

The angiospermous petrified woods impressions of leaves and fruits and belonging to modern comparable taxa viz., *Afzelia-Intsia, Albizia, Bauhinia, Barringtonia, Cassia, Ceriops, Chlorophora, Cinnamomum, Cynometra, Dialium, Dipterocarpus, Euphorbia, Ficus, Gluta, Isoberlinia, Lagerstroemia, Millettia, Murraya, Podocarpus, Pterospermum, Schleichera, Sonneratia, Sterculia* and *Terminalia* have been reported from Neogene of Kutch. However, it is interesting to note that only *Bauhinia, Cassia, Ceriops, Ficus* and *Sterculia* are reported from the present day flora of Kutch.

Kutch had been a meeting ground of eastern (*Cinnamomum, Dipterocarpus, Euphorbia, Gluta, Murraya, Pterospermum, Schleichera*) and western elements especially African (*Isoberlinia, Chlorophora,* etc.). This could be possible due to establishment of land connection between Malaysia, India, Arabia and East Africa during Neogene. During Neogene Kutch supported luxuriant vegetation and warm condition with plenty of rainfall in contrast to predominantly scrubby vegetation and xeric conditions of present day Kutch.

Recently, fossil wood of *Hopea* (Dipterocarpaceae) has been discovered from near Bhavnagar (Saurashtra) which is indicative of luxuriant vegetation (Guleria, 1992).

Guleria (l.c.) reported numerous fossils from Jaisalmer and Bikaner basin (Rajasthan) which are comparable with modern taxa such as *Baphia, Bauhinia, Dialium, Dipterocarpus, Copaifera-Detarium-Sindora, Cordia, Cynometra, Entandrophragma, Erythrophleum, Khaya, Lagerstroemia, Mangifera, Millettia-Pongamia, Ormosia, Ougenia, Pterocarpus, Sterculia, Terminalia, Tetrapleura* and *Ziziphus*.

The occurrence of evergreen forest components viz., *Araucaria-Agathis, Podocarpus, Anisoptera* and *Dipterocarpus* is indicative of luxuriant vegetation and tropical humid climate. The numerical abundance of these genera is meagre. The deciduous genera predominate which indicates trend towards shift in rainfall. The occurrence of typical African genera viz., *Baphia, Entandrophragma, Erythrophleum, Khaya* and *Tetrapleura* further support it and have tremendous phytogeographical significane. These genera are primarily confined to tropical Africa and Madagascar. It indicates migration of plants from East Africa to western parts of India. The possible route of migration could be either Egypt to northern Arabia to Persia to Baluchistan and Sind to Western India or Ethiopia to Southern Arabia to Persia to Baluchistan, Sind to Western India.

Konkan fossil flora in comparable with such modern taxa as *Alangium, Diospyros, Dracontomelum, Eugeissona, Garcinia, Nothopegia, Nypa* and *Nyssa* and ranges from deciduous to evergreen trees. *Nypa* does occur in Ratnagiri at present. *Garcinia, Diospyros, Nothopegia* occur in Western Ghats. *Nyssa* is confined to Sikkim, North Bengal and Assam extending further to Malayan region. *Eugeissona* and *Dracontomelum* are typical Malaysian genera. *Dracontomelum* is found in Andaman and Nicobar Islands.

The Kerala coast fossil flora is comparable with modern taxa viz., *Anisophyllea, Anisoptera, Calophyllum, Canarium, Carya, Cassia, Cynometra, Fagaria-Acronychia, Gluta, Gonystylus, Hopea, Hydnocarpus, Leea, Litsea-Cinnamomum, Payena-Palaquium, Shorea, Swintonia* and *Terminalia*. Most of the genera are important components of tropical evergreen forests and found in present day flora of Western Ghats. The presence of *Dryobalanops*, *Gonystylus* and *Swintonia* which are tropical rain forest components are indicative of high rainfall and humid condition. Their complete absence from Western Ghats and Kerala coast indicate shift in the amount of precipitation since Neogene period.

(ii) *East-Coast Neogene Flora :*

The East-Coast Neogene flora deposits have been reported from Rajamundry area, Neyveli lignites and Cuddalur series near Pondicherry. The age of Rajamundry deposits is doubtful. The fossil flora of the rest two localities is quite significant and is comparable with the modern taxa such as - *Phoenix, Dracaena, Calophyllum, Mesua, Dipterocarpus, Shorea, Sterculia, Grewia, Gluta, Bouea burmanica, Cassia, Bauhinia malabarica, B. racemosa, B. retusa, Parinari indicum, P. travancoricum, Altingia excelsa, Terminalia, Lagerstroemia indicum, Careya, Randia uliginosa, Bassia, Mimusops, Diospyros, Maba, Melodinus monogynus, Cryptostegia grandiflora, Cordia myxa, Excoecaria agallocha* from Nyveli Lignite, and families Podocarpaceae, Palmae, Polygalaceae, Clusiaceae, Dipterocarpaceae, Sterculiceae, Simaroubaceae, Sapindaceae, Anacardiaceae, Leguminosae, Rosaceae, Combretaceae, Lecythiadaceae, Sonneratiaceae, Sapotaceae, Alangiaceae, Euphorbiaceae, Ulmaceae and Fagaceae (Cuddalore series).

The occurrence of evergreen moist taxa, viz., *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Calophyllum, Mesua, Cynometra, Afzelia-Intsia, Alangium, Duabanga, Sonneratia* and *Podocarpus* alongwith deciduous trees is indicative of occurrence of luxuriant vegetation supported by high amount of rainfall during Mio-Pliocene period. Most of these taxa are at present confined to Western Ghats. The flora is phytogeophically interesting since it contains Indo-Malayan taxa.

(iii) *North-east Neogene :*

The North-east fossil flora (Assam, Arakan basin) contain modern comparable taxa such as *Adenanthera, Afzelia-Intsia, Albizia, Anisoptera, Antiaris, Artocarpus, Bauhinia, Barringtonia, Bursera-Garuga, Calophyllum, Careya, Cassia, Cinnamomum-Dehasia, Cynometra, Diospyros, Dipterocarpus, Duabanga, Elaeocarpus, Echinocarpus, Gluta, Heritiera, Holigarna, Homalium, Kayea, Kingiodendron, Koompassia, Lagerstroemia, Lannea/Odina, Madhuca, Mangifera,* *Mallotus, Millettia, Ougeinia, Phyllanthus, Pometia, Sindora-Capaifera-Detarium, Shorea, Sterculia, Swintonia, Terminalia* and *Vitex*. These taxa are indicative of warm tropical rain forest condition during Neogene. Most of the taxa still exist in the area indicating thereby that climate has not much changed since Neogene period. Presence of *Anisoptera, Dipterocarpus, Koompassia, Pometia*, suggests migration of Indo-Malayan components in the flora.

The plant fossil reported from the Neogene period are comparable with modern taxa such as *Afzelia-Intsia, Anisoptera, Agathis-Araucaria, Calophyllum, Canarium, Careya, Cynometra, Dipterocarpus, Dracontomelum, Gluta, Kayea, Koompassia, Shorea*, etc. are indicative of warm tropical climate.

In Bihar fossil reports of *Dipterocarpus* and *Anisoptera* which were wide spread upto Pliocene in India are lacking. The family Dipterocarpaceae is represented by *Shorea robusta*, a taxa which grows relatively in dry habitats. The assemblage shows significant resemblance with the present day flora.

(iv) *Himalayan Neogene :*

Awasthi (1992), while discussing palaeoclimate and floral evolution based on review of Neogene of Himalaya concludes "The Himalayan foothills tropical forests with overwhelming majority of evergreen elements existed during Middle Miocene-Pliocene time .... The flora includes sizeable number of evergreen taxa of South East Asian distribution, e.g. *Anisoptera, Gluta, Koompassia, Sindora, Swintonia* and some species of *Dipterocarpus* and *Hopea*."

The rise of Himalaya resulted in conversion of area into land with number of water basins. As a sequal to this the foothills all along Himalayas became more warm and humid with high precipitation. The Indian Plate had already joined with Laurasia and leading to formation of land connections between India and neighbouring countries. Through these land connections the influx of numerous tropical moist evergreen to semi-evergreen species from South East Asia has taken place. The lead is taken by the dipterocarps through Myanmar and reached Himalayas as evidenced by fossil records.

On the higher slopes Sino-Japanese elements such as *Trachycarpus, Prunus* and *Populus* support the different floral pattern. The tropical forests mostly comprise taxa of Malayan and south-eastern distribution whereas subtropical and temperate forests had sizeable Sino-Japanese and Russian elements.

The luxuriant evergreen forests started dwindling towards the end of Middle Siwaliks, or beginning of Upper Siwaliks (Awasthi, 1992). Ultimately, these forests were replaced by deciduous elements such as *Clinogyne, Flacourtia, Milletia, Bauhinia, Breynia*, etc.

The Early Pleistocene Period witnessed the last phase of Himalayan uplift, progressive change of warm humid to drier and cooler climate. This change in climate had adverse effect, particularly on the dipterocarp community which has a luxuriant growth. Almost all the members disappeared from the Western and Central sectors of the Himalayan foothills. *Dipterocarpus* and *Shorea* are the sole survivor which has restricted distribution in Assam and Arunachal Pradesh. *Shorea robusta* is the only dipterocarp which occurs in Western and Central sectors of Himalayan foothills.

Awasthi (1992) presented a comprehensive review of palaeobotanical records from Neogene Himalaya and attempted to reconstruct the vegetation pattern through Siwalik Succession and interpret the palaeoclimate prevailing in the region during Siwalik period. The recovery of palynofossils from Kasauli and Dagshai formation is indicative of presence of subtropical to temperate vegetation in the upper regions of the newly uplift Himalayas. However, in contrast a rich assemblage of the megafossils from the Siwaliks is indicative of widespread occurrence of tropical to evergreen to moist deciduous mixed forests in the low land sub-Himalayan zone during middle Miocene-Pliocene. Awasthi (1992) further states "The assemblage is dominated by wet-evergreen dipterocarps and associated taxa, most of which are known to have entered the Indian sub-continent from South-East Asia during Miocene and subsequently spread all over and finally reached the lower slopes of sub-Himalaya. This has resulted increase in the diversity of tropical vegetation.

The post-Pliocene orogeny of Himalaya brought great changes in the topography and climate which adversely affected the vegetation pattern of the region. The early and Middle Siwaliks tropical evergreen forests whose chief components are *Anisoptera, Dipterocarpus, Hopea, Shorea*, (other than *Shorea robusta*), *Polyalthia, Calophyllum Aphanamixis, Dysoxylum, Gluta,* *Dracontomelum, Mangifera, Swintonia, Cynometra, Koompassia, Ormosia, Pongamia, Sindora, Duabanga, Diospyros* spp., *Myristica* etc. started dwindling towards the end of Middle Siwalik and subsequently disappeared from the western and central sectors, though a few taxa like *Mangifera, Litsea, Cinnamomum, Bauhinia, Dalbergia, Ficus,* etc. continued to adjust to the new climatic conditions. The extinction of tropical evergreen taxa and further rise of Himalaya gave way to proliferation and diversification of tropical and subtropical moist deciduous to dry deciduous to dry deciduous temperate vegetation in the lower and higher slopes, respectively as is also evidenced from palynological records."

The following three major sedimentary zones have been identified in the Himalayan orogenic belt

(i) The sub-Himalayan zone

(ii) The lesser Himalayan zone

(iii) The Tethys Himalayan zone

The sub-Himalayan zone represents the Siwalik rocks of Neogene age. These extend from Potwar Plateau in the west to Arunachal Pradesh in east, cover a distance of *ca* 2400 km in length. These are generally 20-25 km in width. These are formed by accumulation of alluvial detritus into long narrow foredeep derived from the rising Himalayas during Middle Miocene to Lower Pleistocene. The foredeep was formed as a sequel to the collision of Indian Plate with Laurasia and complete evacuation of Tethys sea during Oligocene. During the final phase of the rise of Himalaya in Pleistocene-Recent, the Siwalik sediments were also upheaved, folded and faulted forming a continuous mountain range of relatively low height ranging from 1000 to 1200 m above m.s.l.

A large number of fossiliferous localities from Palandri in the west to Pasighat in the east (Arunachal Pradesh) have been explored by various workers. The information generated by these exploration and and investigation of mega-fossils has helped a lot in deciphering palaeoecology and palaeogeography of the region.

Some stray reports one megafossils from foothills of Bengal and Arunachal Pradesh have been published. Pathak (1969) documented a few fragmentary leaves as *Castanopsis tribuloides, Cinnamomum tamala, Machilus villosa, Litsea polyantha, Bridelia stipularis, B. verrucosa, Mallotus philippensis* and *Rhododendron lapidotum* from the Middle Siwalik sediments of Mahanadi Section in the foot-hills of Darjeeling District. Awasthi (1982), however, doubts the generic and specific identification.

Singh and Prakash (1960) have reported leaves of *Zizyphus* and *Dioscorea* from Pasighat district, Siang (Arunachal Pradesh). Choudhury (1970) reported dicotyledonous leaves of uncertain affinities from the area. Awasthi (unpublished) has collected semisilicified and semicarbonised woods from Upper Subansiri (Subansiri district, Arunachal Pradesh) which are comparable to extant genera such as *Shorea, Euphorbia, Gluta, Albizia, Afzelia-Intsia, Cynometra, Cassia* and *Sindora*. These are mostly evergreen genera.

The small American elements comprising *Adenocaulon, Oxybaphus, Podophyllum, Meconopsis* Sect. *Stylopodium, Liquidamber, Gnetum, Lardizabala, Monotropa uniflora, Brassenia* and *Mitreola paniculata* perheps also arrived through the north east (Vishnu-Mittre, l.c.).

(iii) *Quaternary Period :*

The Quaternary period comprising Pleistocene and Holocene epoch covers a time from 1.64 m.y. B.P. to the present. The Pliocene orogeny brought about drastic changes in floristics. The geological events in the early Pleistocene resulted in the migration and establishment of Central Asian (Chinese and Euro-Siberian) taxa particularly in Himalayas. The Himalayan region which has been thoroughly investigated produced interesting results. During this period the wet tropical forests of western Himalaya occurring on the lower slopes vanished and temperate forests were transformed into dry and moist forest types. *Podocarpus* and Magnolia dispapeared by the end of Pliocene. *Cedrus* migrated from the Mediterranean. The emergence of the Himalayan taxa, during Pliocene/Early Pliestocene from Sino-Japanese genera, viz. *Abies spectabilis, Berberis lycium, Betula utilis, Cinnamomum tamala, Desmodium gangeticum, Juglans regia, Machilus duthie, Pinus wallichiana, Phoebe lanceolata, Rhamnus purpurea, Ulmus wallichiana* forms another interesting aspect of the floristic change. The other Pliocene/Pleistocene species recorded from Western Himalaya today occur in Western and Central region of China. Some of these taxa are *Abies oblongum, Alnus nepalensis, Berchemia floribunda, Betula alnoides, Castanopsis* sp., *Clematis montana, Cotoneaster microphylla, Cupressus torulosa, Desmodium laxiflorum, D. velutinum, Inula cappa, Litsea elongata, Mallotus philippensis, Meliosma pungens, Myrsine semi-serrata, Populus ciliata, Prunus cornuta, Pyrus pashia, Quercus glauca, Q. semicarpifolia, Rhamnus floribunda, Salix wallichiana, Woodfordia fruticosa*, etc.

The Sino-Japanese taxa predominated Pliocene and Pleistocene floristics of Himalaya. The Tropical African taxa such as *Ziziphus mauritiana* reaches the lower slopes of Himalaya in Pliocene times.

The early Pleistocene uplift of Himalaya and the associated mountains was equally effective in floristic changes. It resulted in development of arctic alpine belt into which migrated and established the Central Asian (Chinese-Euro-Siberian) taxa. The extinction and expansion of other floristic belts, the altitudinal and ecological delimitation of species and the emergence of Himalayan taxa from the migrants as a result of varying habitat and pulsating climatic fluctuation. The rising mountains acted as effective barriers to plant migration and also monsoon clouds, causing formation of inner dry valleys into which migrated taxa from the neighbouring dry regions. The pre-Pliocene summer higher rainfall in the Western Himalaya changed into a moderate or low rainfall with high winter precipitation in the form of snow, providing environment suitable for the Mediterranean flora to invade the region. Vishnu-Mittre (l.c.) states "the Himalayan flora developed secondarily from predominant Sino-Japanese floristics. When did the Saharo Sindhian floristics now skirting the hills and also occurring in Kashmir Valley and the Irano-Turarian elements migrate and become established?"

Karewa deposits of Kashmir contain large number of fossil leaves impressions which are comparable with the modern taxa. Their significance has been discussed elsewhere in the text.

The Pleistocene temperate and boreal species of Himalaya that spread during Pleistocene glaciation on the Himalayas, across the Aravalli Mountains to the Western Ghats and reached the extreme end of Peninsular India and in some cases to Sri Lanka, that was still connected with the mainland of Peninsula. With the retreat of the glaciers from the Himalayas in the post-Pleiostocene, they become isolated in the south from main range in Himalayas. The major bulk of these species is concentrated on the higher elevation of Nilgiris, Anamalai, Palani and Cardamom Hills in the southern part of the Western Ghats, but some of them may be found in Mahableshwar in the northern end of Western Ghats. Some of the Pleistocene relicts are :

Ranunculaceae	:	*Clematis* (Himalaya, Nilgiri and Anamalai Hills)., *Ranunculus* (Himalaya and South Indian Mountains).
Fumariaceae	:	*Corydalis lutea* and *Fumaria*
Cruciferae	:	*Cardamine* and *Capsella*
Violaceae	:	*Viola patrinis* (Siberia, Russia, Japan, Himalaya, Eastern and Western Ghats).
Polygalaceae	:	*Polygala siberica* (Himalaya, Khasi Hills, Siberia, China, Japan, Western Ghats from Nilgiris southwards to Sri Lanka).
Caryophyllaceae	:	*Silene gallica, Stellaria paniculata, S. media* and *S. saxatilis* (the last species occurs in Siberia, Japan, Khasi Hills, Himalaya and Nilgiris) and *Arenaria*, etc.
Geraniaceae	:	*Geranium nepalense* (Himalaya, Nilgiris and Sri Lanka).
Rhamnaceae	:	*Rhamnus virgatus* (China, Japan, Himalayas, Nilgiri and Palani).
Leguminosae	:	*Ulex europaeus, Cytisus scoparius, Trifolium, Parochaetus communis* and *Indigofera pulchella*.
Rosaceae	:	*Prinsepia utilis* (Himalaya, Khasi Hills, Nilgiris), *Fragaria, Potentilla* and *Alchemilla*

Umbelliferae	:	*Bupleurum* and *Heracleum*
Caprifoliaceae	:	*Viburnum* and *Lonicera*
Rubiaceae	:	*Galium*
Compositae	:	*Erigeron alpinus*, *E. canadense*
Primulaceae	:	*Lasymachia*
Gentianaceae	:	*Exacum* and *Swertia*
Scrophulariaceae	:	*Veronica* and *Pedicularis*
Labiatae	:	*Teucrium*
Euphorbiaceae	:	*Euphorbia helioscopia*
Ulmaceae	:	*Celtis*
Juncaceae	:	*Juncus*
Araceae	:	*Arisaema*

The configuration of the Himalayan mountains has largely been responsible for the concentration of the European and Siberian plants in the North-West Himalayas and Chinese and Japanese elements in the Eastern Himalayas. The small American elements comprising *Adenocaulon*, *Oxybaphus*, *Podophyllum*, *Meconopsis* sect. *Stylopodium*, *Liquidamber*, *Gnetum*, *Lardizabala*, *Monotropa uniflroa*, *Brassenia* and *Mitreola paniculata* perhaps also arrived through the north.

Diffusion of neotropical and extratropical new arrivals took place during the Quaternary largely governed by repeated climatic fluctuations. This has eventually resulted in the mixture of eastern elements in the west and of western in the east. The subtropical transitional belt between the temperate and tropical vegetation was also formed during this period. Some tropical elements on lofty mountains such as *Osbeckia, Agrostemma, Plectranthus*, members of Cyrtandraceae, Zingiberaceae, Araceae, Commelinaceae and orchids either continued to withstand, in nunataks, the onslaught of refrigeration of climate or advanced northwards during favourable period of climate. To this may be added the tropical genera *Menispermum* and *Gerbera* which occur in Siberia. Several of the extra tropical elements such as *Stellaria uliginosa, Circea alpina, Sanicula europea, Brunella vulgaris* and species of *Thalictrum, Cardamine, Geranium, Fragaria, Potentilla, Parnassia, Artemisia*, etc. were pushed down to the South Indian Hills by Quaternary climatic fluctuations. Amongst these the typical Himalayan genera such as *Berberis, Hypericum, Rubus, Pedicularis* and *Rhododendron* in South Indian Hills still provide testimony to such large scale floristic migration (Vishnu - Mittre, *l.c.*).

Quaternary palynological data is available from large number of localities, viz. Kashmir, Ladakh, Himachal Pradesh, Kumaon Himalayas, Eastern Himalaya (Darjeeling and Sikkim), Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, Southern India, Eastern India (Bengal basin and Assam) which vividly reflects the vegetational history of the region and palaeoclimate.

Holocene history of mangrove vegetation in India has been reviewed by Khandelwal (1991). Several deltic zones, viz. Gangetic Delta, Mahanadi Brahamani Delta and Godavari and Cauvery Deltas have been palynologically investigated. The results from Sundarban suggest that the climate of the recent past was almost same as today.

Kerala sediments indicate luxuriant growth of mangrove vegetation around 11000 yrs. B.P. However, 6000 yrs. B.P. the onwards the mangroves declined and could be equated with the existing mangrove ecosystem of Karela.

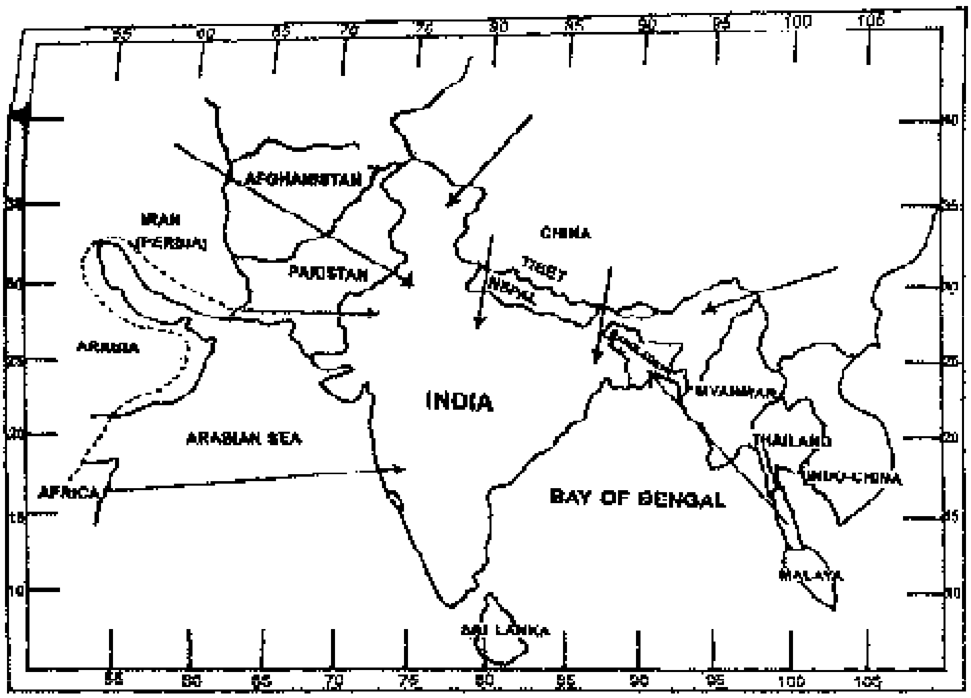
Currently, India with its land connections on three sides, viz. North, West and East has acquired fairly good number of plant speices from the neighbouring countries. The areas that have contributed most to the alien elements in the Indian flora are Myanmar, Malaysia, South-West China, Japan, Tibet, Siberia, West Asia, Europe and Africa. Hooker (1855) recognised the following principal elements in the Indian flora : (1) The Malaysia elements which are the most dominant; (2) The European Oriental elements; (3) the Africcan elements, (4) the Tibeto-Siberian elements and (5) Sino-Japanese elements. The Indian Subcontinent was considered meeting place of floras from the west, north and east, and with little botanical character of its own. This concept has been proved to be incorreet in the light of data on endemics available at present.

Wulff (1950), however, stated "thus Hooker (1855) finds in the flora of the Himalaya and Northern India a European element because the species forming it are likewise found in flora of Western Europe although, of course, it is perfectly clear that the centres of areas of these species lies precisely in the Himalayas, where in post-glacial times they spread to Europe. Hence this elements might be designated as Himalayan in flora of Europe but in no case as European elements in the flora of India."

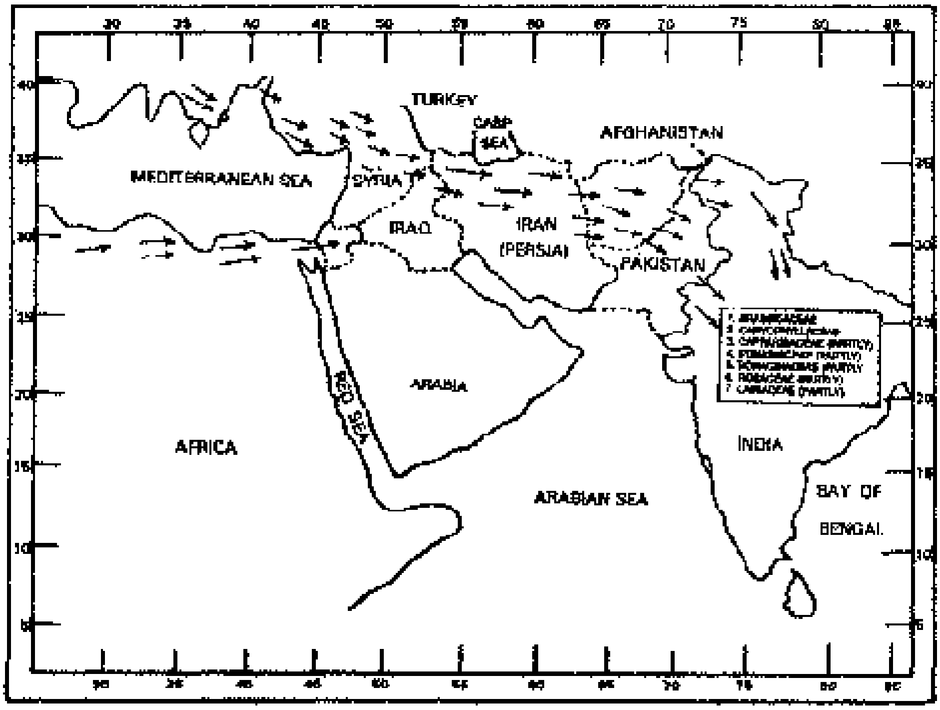
Ridley (1942) made certain observations on the Indian flora in reference to the ancient Oligocene flora of the world. The Magnoliaceae, Lauraceae, Hamamelidaceae, Cupuliferae, Salicaceae, Rosaceae, Umbellierae, Cornaceae, Primulaceae, Styraceae, Gentianaceae, Boraginaceae, Chenopodiaceae, *Engelhardtia, Carex* and some other plants had a wide distribution in the Cretaceous times over the entire northern part of the world upto the arctic region. In India, this flora is now practically limited to the Himalayas. Rarely, however, some representatives of the families are seen as far southward as mountains of Java and Sumatra.

A considerable flora in the tropical parts of India comprises chiefly tree and shrubs or rain forest type, extends from Malaysia through India to North Africa and reappears in Eastern South America. This flora seems to have originated in the Oligocene period, or atleast was in existence even then as far as north southern Europe.

The glacial oscillation and the upliftment of Himalayas and the migration of large number of plant species from the neighbouring countries has a tremendous impact on the composition of Indian flora. The migration has taken place both east and westwards (Map 11). The spread and naturalization of these taxa has changed the floristic and endemic scenario of the Indian subcontinent (Chatterjee, 1939; Mukherjee, 1940). The plant families such as Cruciferae, Caryophyllaceae, Capparidaceae, Fumariaceae (partly), Boraginaceae (partly), Rosaceae (partly), and Labiatae (partly) had their origin in East Mediterranean region (Map 12).



Map 11. Possible routes of the immigration of plants into India as shown by arrows (after Chatterjee, 1939).



Map 12. The influence of East Mediterranean flora on that of India, and possible route of the migration of plants from West-Asia and North-East Africa.

The North-East African or West Asian plant species migrated into India after the closing of the east end of Mediterranean probably considerably later than Miocene age and the desert formation of Arabia and Baluchistan, much of the west coast of India became xerophytic and sub-desertic. The desert elements hailing from Africa, Arabia, and the western parts of south Asia, invaded Rajasthan, Sindh, Bombay and went as far south as Kerala. The characteristic ones are : *Salvadora, Azima, Dodonaea, Acacia, Heliotropium, Indigofera, Farsetia, Malcolmia,* many crucifers, Zygophyllaceae, Capparidaceae, and grasses (Ridley, 1942).

In Western Himalaya the dry conditions prevailing towards the western ranges, particularly in the interior, have favourd the influx of species from the western and Middle Asian mountains. The *Artemisia* dominated steppes of extreme northwest include many genera, which have wide distribution in the Middle Asian Highlands. Some of the important components are; *Axyris, Eurotia, Kochia, Juniperus semiglobosoa* var. *turkistanica, Astragulus, Hippophae rhamnoides* ssp. *turkestanica* and *Acantholimon lycopodioides.* The species of Middle Asian genera viz., *Eremurus, Ferula* and *Prangos* are also present here. *Cedrus deodara* (Himalayan Cedrus) is distributed from Afghanistan to Nepal (Rau, 1974). Some of the western and Middle Asian components are distributed upto the extreme of Western Himalaya, some reaching only Kashmir and others extending to the length of Western Himalaya and such species are : *Thylacospermum rupifragum, Lamium rhomboideum* and *Physochlaina praealta.*

The second type of distribution includes species confined to North-Western Himalaya and extending upto Afghanistan viz. *Paeonia emodi, Christolea himalayensis, Epilobium* spp., *Primula floribunda* and *P. rosea.*

The third type of distribution is the species of West China, which are distributed all along Himalaya and reached Kashmir in the west. Such species are : Aletris pauciflora, *Anemone rupicola* and *A. vitifolia. Primula sikkimensis* and *Magnolia campbelli* species originate in Western China and reach Kumaon in the west. *Circaeaster agrestis,* curious little plant, which extends from north-west China across Tibet to Garhwal Himalaya.

Himalaya has served primarily as a route of migration and colonization from east and northwest, secondarily of endemic development (Stearn, 1969). *Anemone* *rivularis* a Himalayan plant reached Western Ghats and Sri Lanka (Jain, 1967). *Anemone vitifolia* extends from Himalaya to south China, Formosa and Luzon in Philippines. According to van Steenis (1934) this species has followed the Formosan - Luzon migratory track. *Sarcococca saligna* extends from Afghanistan and Himalaya to China, Formosa, Sumatra, Java and Lesser Soenda Islands, it is also found in Sri Lanka. *Primula prolifera*, a Khasi Mountain and Eastern Himalaya species, is also found in Malaysian mountains.

The Chinese mountains, being much older in age, have had considerable influence on the Himalayan flora, and many plants from these mountains have spread westwards to the younger Himalaya. During the Teritary period, a common flora must have covered the whole of East Asia, including Himalaya, China and Japan (Hara, 1966).

The spread and recession of Ice Sheet (Glacial and Interglacial period) must have exterminated some of the taxa during glaciation and provided suitable niche for influx of species from neighbouring areas during interglacial period (warmer period). The alternate movements of Ice sheet must have been responsible for isolation and disjunct distribition of many plant and animal species.

Rau (1974) while discussing the phytogeographical affinities of Himalayan flora states "In the Himalaya, the glaciation, however, did not affect the foothills, with the result that the vegetation of the lower belt was not affected. Migration of flora, survival of the relict, evolution of new species by an intermixing of different floras and acclimatisation of species from lower altitudes must have all had a role in as determining the present day composition and distribution of Himalayan flora of high altitude."

The Eastern Himalaya and North Eastern India provided corridor for the migration of large number of species from China, Japan, S.E. Asia, particularly Malaysia. A number of Euro-Siberian elements are common with that of Arunachal Pradesh. The region is very rich in endemics and floristic diversity. It is also considered as one of the centres of speciation. A number of primitive angiosperms viz. *Alnus nepalensis, Altingia excelsa, Betula alnoides, Exbucklandia populnea, Holboellia latifolia* var. *angustifolia, Houttuynia cordata, Magnolia griffithii, M. pterocarpa, Manglietia caveana, Talauma hodgsonii,* *Tetracentron sinense* are found in Arunachal Pradesh which give it a distinct phytogeographical status within Indian subcontinent.

A number of plant species from Siberia, China, Myanmar, Malacca and Tenasserim, Java, Japan, Sumatra, New Guinea, Sri Lanka, Bhutan, Perak, West Africa, Australia, Penang etc. entered Assam through the Eastern corridor. A detailed account is given elsewhere in the text. Janaki Ammal (1954) established that North-East India and South-West China are another source of plants for India. The extreme parts of Mishmi Hills in Assam and adjacent portion of China are centres of distribution for many of our Asian plants.

Species wise the Peninsular India is quite rich. Approximately 2045 species of Dicots and 500 species of Monocot are endemic to Peninsular India. A large number of species have migrated to this area as detailed elsewhere in the text. Peninsular India comprises four distinct zones :

(a) *Eastern drier zone of Deccan :* With typical deciduous forest components such as *Santalum album, Cedrela toona, Soymida febrifuga, Capparis, Grewia, Phyllanthus, Euphorbia neriifolia, Borassus flabellifer, Phoenix sylvestris, Flacourtia, Randia, Diospyros,* etc.

The tropical African, especially the East African and Madagascarian elements, constitute an important component of Deccan flora. Some elements from other countries such as Australia, Myanmar, Sri Lanka and Malaya have also been reported.

(b) *The Eastern Ghats :* They are rich in migrated species from number of neighbouring countries, viz. Sri Lanka, Malaysia, Myanmar, Tropical America, Africa, Madagascar, Australia, S.E. Asia, Middle East, China, Malacca, New Guinea, Philippines, Japan, Afghanistan, Pakistan, Indonesia, etc. the details of which are given elsewhere in the text. A number of East Himalaya elements are also found in the Eastern Ghats.

(c) *Malabar and Western Ghats :* Malabar flora is much richer in species and contain representative of such families as Dipterocarpaceae, Guttiferae, Palmae, Sterculiaceae, Myristicaceae, Myrtaceae, Anacardiaceae, etc. Many species of palms, bamboos, *Impatiens, Strobilanthes, Arisaema* are endemic to this region. This region has abundance of Malayan elements. *Podocarpus latifolia*, a Gymnosperm, is confined to hills of Tinnevelly (Tamil Nadu) and outside it is known from Myanmar and Malaya. Western Ghats show great affinity with that of Malesian region (Hooker, 1904; Subramanyam & Nayar, 1974). Indo-Malayan genus *Sarcandra* (Chloranthaceae) is represented by *S. chloranthoides* (Vesselless). *Kunstleria*, a prominent Malayan genus, is represented in Western Ghats.

A large number of Eastern Himalayan species are common with Malabar region.

A number of taxa are common with Sri Lanka. Monotypic genus *Kendrickia (K. walkeri)* is restricted to Anaimudi region of Anamalai and Adam's Peak of Sri Lanka.

A large number of orchidaceous elements common with Western Ghats and Africa have been reported by Abraham and Vatsala (1961). Mehrotra and Jain (1982) observed 52 species of Tribe Andropogoneae of Poaceae common with Africa.

Indo-Sri Lankan genus *Humboldtia* is represented by seven species.

(d) *Deccan* : The word Deccan as used by Mahabale (1966) loosely denotes any area to the south of Vindhyas right to the tip of Indian Peninsula. Mahabale (*l.c.*) "includes all the area to the South of Narmada and Mahanadi right upto Cavery basin. This area is bounded on eastern side by a discontinuous mountain chain, the Eastern Ghats, on the west by Sahyadris or the Western Ghats and encircled at the south by Nilgiris and Kodaikanal Hills. It forms a broad-based inverted triangle comprising a part of Madhya Pradesh, the whole of Maharashtra, a part of south Gujarat, Orissa, Mysore and Andhra Pradesh."

"On the hill side and on the plateau several genera of plants, including highly specialized rust fungi in point of host preference, are known to be common to East Africa, Madagascar and Western India, the latter are supposed to have migrated to Deccan through a long hazardous route from Abyssinia to Egypt, Syria, Palestine, Arabia, Iran, Baluchistan, Afghanistan and North-West frontier parts of India and Pakistan. They arrived through mountain passes into Indus valley from where they are supposed to have spreadout into Rajasthan, Northern Gujarat and adjacent country. They possibly migrated further to Deccan from these regions. An alternate route consisting of Monkey Bridge from Madagascar to the Western coast of India through Seychelles and Socotra Islands has been suggested but this has not found much favour with the plant geographers and palaeobotnists." Chatterjee (1940, 1962), Ridley (1942), Puri (1960), Legris (1963), Karnik (1961) have given list of some genera found in the Deccan region and other countries such as Africa, Australia, Myanmar, Sri Lanka, Malaya, Andamans, etc.

Another group of plants reached Deccan from the East by two or three alternate routes from Malaya, Java, Sumatra, Andaman, Sri Lanka, South India, Malabar and athence upto the Western Ghats and Deccan Plateau. The species of Podostemaceae, Bignoniaeceae, Dipterocarpaceae, Samydaceae, Combretaceae and Anacardiaceae are supposed to have reached by this route.

The second route is Myanmar, Assam, Eastern Ghats. Quite a number of tropical species from Malaya are supposed to have migrated by this route towards the Eastern Ghats and to plains lying to the south of the Mahanadi and Narmada. Most of these are moisture loving species as in Assam. They are now stabilized in pockets of Eastern and Western Ghats where climate is moist.

The third route has been proposed by Hora (1949,1950). It supposes that the migration of the flora and fauna from Malaya took place through Myanmar and Assam from where they migrated to Vindhyas and Satpura through Rajmahal Garo gap. They reached the extreme northerly end of the Western Ghats across the continent through Satpuras, moving from east to west, a little above the Narmada valley and migrated both towards Konkan and also to the main Deccan Plateau (Karnik, 1961). Those loving moisture migrated further Southwards till they reached Malabar region. Some of the migrated species lingered all along the Vindhya Satpura route before reaching Sahyadris. The Satpura thus served as a highway for the species to migrate from Malaya, Myanmar, Assam to Malabar and South India. Some moved south-eastwards to Eastern Ghats. Dr. Hora's *Satpura Hypothesis* envisages that there has not been much rise in temperature but slightly more humidity and rainfall atleast on an everage by 10-15" in Deccan. It also presupposes that Vindhyas were main watersheds of India then. There is another view of Pascoe that the main watersheds then could have been the Aravalis running North-East in which direction south-west monsoon move today.

Himalayas had not risen then, and therefore, only climatic zonation could have been mostly responsible for the moist tropical elements from Malaya, Myanmar, Sri Lanka, Andaman and Assam occurring on the hill tops of Peninsular India. In the subsequent climatic changes several of these species disappeared and were cut of from Malaya, Myanmar, Sri Lanka and other countries. Kingdon-Ward (1921), Burkill (1924), Auden (1949) and Razi (1956) favoured this view. After the Oligo-Miocene period Himalayas were rising and reached greatest heights in Pleistocene period. Many earlier moisture loving plants started moving northwards. In Pleistocene, temperature of Deccan went down still further, but nowhere snow was formed. Atleast four glacial and three interglacial period are known. Many significant changes took place in the composition of Indian flora in all these epochs. Several Oligo-Miocene elements from the Krystofovisch Flora of Middle East Asia came to India and spread in the Indo-Gangetic region (Ridley, 1942). Alpine flora invaded Himalayas and got settled there. Later both these elements spread to Deccan, the drier species on the plateau, and sub-temperate on the mountain tops of Western Ghats, Nilgiris, etc. Thus we find admixture of subtemperate plants with earlier tropical and sub-tropical species on the hill tops of Deccan and South India and not on the plateau (Mahabale, 1966).

Chatterjee (1939) observes that 61.5% dicotyledonous species of Indian flora and 18.2% of the flora of Peninsular India is endemic.

In the geological past during Oligo-Miocene period the Krystofovisch flora of Middle East came to India and spread in Indo-Gangetic region (Ridley, 1942). Today, the long stretch of dry desert and warm alluvium Indo-Gangetic Plain acts as a barrier for migration of Himalayan plants to south Indian hills and vice-versa. This area is under intensive cultivation. It is very poor in endemics. The south-eastern end of Gangetic Plain merges with littoral and mangrove region of Sundarbans where species of *Heritiera, Bruguiera, Sonneratia, Rhizophora* etc. pre-dominate the forest vegetation.

The invasion of the sea-shore or maritime plants of Indian coast was by a different route than the terrestrial ones. A large number of these plants (e.g., from Lauraceae, Guttiferae) were evolved in the Coral Islands of Polynesia and Malaysia and their seeds drifted along the south coast of Asia, settling on the eastern shores of India, rarely travelling upto the western coast. Typical examples are : *Mammea, Samadera, Xylocarpus granatum, Calubrina asiatica, Desmodium* *umbellatum*, *Derris uliginosa*, *Afzelia bijuga*, *Rhizophora conjugata*, *Bruguiera eriopetala*, *Pemphis*, *Scyphiphora*, *Guettardia*, *Wedelia biflora*, *Ochrosia*, *Tournfortia argentea*, *Avicennia officinalis*, *Cassytha*, *Hernandia*, *Flagellaria*, *Remirea maritima*, *Spinifex squarrosus*, etc. (Ridley, 1962).

Rao and Sastry (1974) while studying the strand vegetation of India and particularly Coromandel Coast reported that it comprises admixture of Afro-Perso-Arabian/Western and Indo-Malayan/Eastern elements or Polynesian. They further commented that the terrestrial esturaine flora distributed in esturine and tidal mangrove zone is derived chiefly from Malesian and Polynesian islands. Sri Lankan elements are well represented along southern shores of Tamilnadu and islands in Gulf of Mannar.

Hooker (1904) includes Lakshdweep Islands under Malabar and points out that vegetation is Malayan with no endemic species. An analysis of vegetation reveals that it is mixture of Malesian, Polynesian and Australian affinity. Many eastern elements occurring here extend upto South-western Peninsula from Malesian Islands through Malacca, Andaman and Nicobar Islands, Moulmein, Tennasserim, Sunderbans, Coromandel coast and Sri Lanka (Rao & Sastry, *l.c.*)

The Arakan Yoma-Indonesian are of hill range on which the Andaman and Nicobar Islands are situated in the north south direction has significantly contributed towards the distributional pattern of the plants in Andaman and Nicobar Islands. The Andaman group displays plants constituents of many Burmese origin whereas Nicobar group with Indonesian elements. The Great Nicobar and Indonesia share common families than with Indo-Myanmar-Thailand families.

Exotic weeds

The introduction of exotic species, weeds, (economic, horticultural elements, etc.) inadvertant seed adultration in imported cereals, better means of communication have facilitated introduction and wide spread of exotic weeds and other elements from the neighbouring and as well as from far of countries. These have become naturalized and form part of the regional flora. Some of these exotic weeds have become nuisance, health hazards and even chocke dams, rivers, etc. Some of the typical example are : *Lantana camara* var. *aculeata*, *Ipomoea angulata*, *Ageratum conyzoides*, *Eupatorium glandulosum*, *Helianthus annuus*, *Tithonia tagetiflora, T. diversifolia, Barleria cristata, Adhatoda zeylanica, Clitoria ternata, Jatropha gossypifolia, Pedilanthus tithymaloides, Eichhornia crassipes, Pepromia pallucida, Cryptostegia grandiflora, Agave angustifolia, Opuntia cochinellifera, Dioscorea alata, Croton bonplandianum, Eupatorium odoratum, Argemone mexicana, A. ochroleuca, Aeschynomene americana*, etc.

In addition to the migration of plants from various countries through North, North-Western, Western, North-Eastern, Eastern corridors, coastal areas and islands, etc. a large scale migration of plants within the country has taken place. This factor is also responsible for the change in the regional floristic composition. Phytogeographically the presence of Himalayan and North-Eastern and Eastern elements in Mahendragiri Hills, Chotanagpur ranges, Vindhyan and Satpura ranges, then South India to Western and Eastern Ghats is very interesting The Eastern Ghats elements in Western Ghats and *vice-a-versa* have also been reported in the past. The migration of large number of weeds from Punjab to Indira canal region in Rajasthan has been reported recently (Shetty & Singh, *l.c.*).

The recently carried out studies on the statistics of Indian flowering plants by Karthikeyan (unpublished) reveals existance of *ca* 17000 species. The species richness in each phytogeographical unit (*sensu lato*) is as follows :

Himalayas	8000 spp.
Eastern Ghats	2000 spp.
Western Ghats	4000 spp.
Deserts (Thar and Ladakh)	1000 spp.
Indo-Gangetic Plains	2000 spp.
Peninsular Plains	2000 spp.
N.E. India	5000 spp.
Islands	2000 spp.

The high Himalayan range is effectively isolated from the Northern Asia by the dry Tibetan plateau to the north and warmer alluvial plains to the south. Consequently the temperate and alpine vegetation of the Himalayas contains several species that have been unable to migrate either north or south. Peninsular India is bounded on the north by broad Indo-Gangaetic plain, and on three sides by the sea. Both these regions show high degree of endemicity. Maheshwari *et al.* (1964) state that in "the region as a whole, (including Pakistan and Burma), 61.5% of dicotyledons are endemic." They further state that "61.5% is rather a high figure for a continental areas like India with land connections in three directions, east, north and west. The two regions contributing most of this high endemic contents are the Himalayas with 3165 and Peninsular India with 2045 endemic species. The endemic species common to both regions are 533)."

The "Wides" totalling about 38.5% of the species, are widespread and extend to other countries. According to Chatterjee (*l.c.*) they fall under three categories (i) those which are chiefly tropical and subtropical and have fairly wide distribution in Asia and sometimes beyond it, (2) a considerable number extending just beyond the boundaries of our area into South-western China, Thailand, Tibet and Afghanistan; (3) cultivated and introduced plants.

Nayar (1982) observes that endemism in Indian flora works out to be around 33%. The Himalayan and Western Ghats in Peninsular India are two major areas where endemics are concentrated. To a lesser degree endemics also occur in N.E. region and Eastern Ghats and arid zone of Western India (Gujarat and Rajasthan).

No endemic family is known from India, however, 136 endemic genera have been discovered from India. Out of these 136 endemic genera 14 are spread throughout India, 57 are confined to to Peninsular region, 62 are restricted to the Himalayas and only 2 to the Andaman Islands.

Approximately 27 genera are common to Peninsular India and Sri Lanka.

According to Nayar (1982) there are 57 endemic genera and 2100 species of flowering plants in Peninsular India, most of which are confined to the Western Ghats. The occurrence of 57 endemic genera in Western Ghats as compared to the 84 from rest of India (Nayar, 1980) might indicate that it is an ancient flora. Most of the endemic species of Western Ghats are Palaeo-endemics.

The information on endemic species of the Eastern Ghats is very scanty. About 19 endemic taxa have been reported from Orissa and Andhra Pradesh.

Hooker (1907) opines that flora of India is merely a mixture of floras of the surrounding areas such as Malaya, orient, Africa, Tibet, China and Japan.

Champion and Trevor (1938) state "It is evident that there is no Indian flora as a separate entity but our vegetation is compounded of several elements which are present in very different proportion in the different areas."

However, Chatterjee (1940) while analysing the Dicot species found contrary to the expectation that India has high percentage of endemic species. He further states that "in fact the proportion of endemic species is so high that it can compare favourably with some of the oceanic islands". According to Chatterjee (*l.c.*) 50% flora of India is endemic.

Peninsular India and Himalayas show high degree of endemicity and hence floristic distinctiveness. Wulff (1950) feels Hooker's European elements in Indian flora contradictory. He feels that the Himalayan elements have gone to Europe in the Post-Glacial Period.

As stated earlier the Himalayan and Peninsular India share maximum of endemic species. The Indo-Gangetic plain is poor in endemics. The rough estimate is as follows

Endemic species

	Dicots	Monocots
Himalayas	3169	1000
Peninsular India	2045	500

The Peninsular India, bordered in the north by Bundelkhand and Rajmahal hills has characteristc true Indian flora which is reflected in its components. "It is palaeotropic flora derived from the original Gondwanaland" (Nayar 1987).

There are 58 endemic genera in Peninsular India, of which 47 are monotypic.

Sharma (1983) observed that 13% flora of S.E. Rajasthan is endemic. The number of endemic species, as reported by him, in each family is as follows - Acanthaceae (12), Ampelidaceae (2), Anacardiaceae (2), Annonaceae (1), Apiaceae (1), Asclepiadaceae (2), Asteraceae (9), Boraginaceae (2), Brassicaceae (1), Euphorbiaceae (2), Fabaceae (*sensu str.*, 12), Gentianaceae (3), Gesneriaceae (1), Lamiaceae (3), Oleaceae (1), Rubiaceae (1), etc.

Shah (1983) reported 168 species as endemic to South Gujarat. The distribution is as follows Dang Forest Division (97), Rajpipla Forest Division (14), Bulsar Forest Division (10) Dharampur Forest Division (7) and 2 each in Brauch and Surat.

Sabnis and Rao (1983) while investigatinig floristic analytical data of South Eastern Kutch revealed that phytogeographically, the area is more akin to Sind (Pakistan) and N.W. Rajasthan than any part of Gujarat State. The flora shows dominance of western elements over eastern or Indo-Malayan. Endemism is very low (2.4%) and few of the endemic plants are restricted only to Kutch and Saurashtra region while other endemics are comparatively widely distributed over the entire northern semi-arid zone.

Saxena and Brahmam (1983) observed that out of *ca* 2500 angiosperms and pteridophytes occurring in Orissa, 8 species, viz. *Acacia donaldii, Aglaia haslettiana, Aspidopteris hutchinsonii, Homonoia intermedia, Mucuna minima, Oryza jeyporensis, Tragia gagei* and *Uvaria eucinta* are endemic.

Dhar and Kachroo (1983) observed "In so far as the monocots (Gramineae excluded) are concerned the extent of endemism in Kashmir Himalaya seems to be negligible, extending not more than 15.94 on an average. The overall mean percentage of the endemic taxa in dicots amounts to 31.38% of the total flora" The percentage of endemism in alpine families is reported as Primulaceae (39.53), Saxifragaceae (53.57), Fumariaceae (52.00), Dipsacaceae (50.00), Scrophulariaceae (44.71), Asteraceae (39.82), Parnassiaceae (33.33), Gentianaceae (49.09).

Nayar (1996) has published comprehensive account of endemism in Indian flowering plants. According to his analysis there are 5725 endemic species which are distributed over 148 genera and 47 families.

Western Ghats have 1500 endemic species
Eastern Himalaya has 1808 endemic species
Western Himalaya has 1195 endemic species

Peninsular India has 2015 endemic species
Andaman & Nicobar Islands have 239 endemic species

Table-16. Percentage wise endemism in different plant groups in India

Taxon	No. of species	Percentage of endemics
Bryophyta	2700	29.0%
Pteridophyta	1022	24.5%
Gymnosperms	64	12.4%
Angiosperms	17000	33.5%

He has recognised 3 Mega endemic centres and 24 Micro endemic centres in India. The detail is given elsewhere in the text. On the basis of endemic concentrations and other factors he has proposed 20 phytogeographic division for India, Nepal and Bhutan.

From this analysis it is evident that only 33.5% angiospermic flora is endemic and the rest comprises migrants from various neighbouring and far flunged countries.

Nayar (1987), while analysing the flora of India, made the following observations on the affinities of flora with the neighbouring countries. In terms of percentage it comes to :

S.E. Asian and Malayan affinity	*ca* 35%
Temperate Asian	*ca* 8%
Steppes	*ca* 1%
African	*ca* 2%
Mediterranean-Iranian	*ca* 5%
Naturalized aliens	*ca* 18%

In addition to the deliberate introduction of the fruit trees, economic plants, ornamental plants, and escapes, etc., the naturalisation of some of these plants has tremendously changed floristic composition in many areas. A large number of exotic weeds have also entered Indian subcontinent and are fast spreading in all directions.

From the outgoing palaeobotanical evidences, presence of alien elements in Indian flora, and migration of plant species, phytogeographic distinctiveness, centres of speciation and high degree of endemicity it can easily be deduced that notwithstanding that Indian subcontinent is considered as a meeting ground for the flora of North, West and East, India does have flora of its own. In the light of discoveries of new taxa, new distributional records, monographic studies, additional floristic information and other relevant data it has become absolutely necessary to carry out intensive examination to find out exact position of the Indian flora and endemicity today.

The flora of India has undergone tremendous changes in the geological past as revealed by the recent palaeobotanical findings. The climatic and edaphic changes have exterminated many taxa and also opened opportunities for migration of many taxa to the isoclimatic regions.

Today, the picture of green vegetal cover is very gloomy. The wanton and unmindful felling of pristine and virgin forests all around for developmental works, mining operations, dam constructions, rapid urbanisation, rehabilitation in and around the forest areas, ever increasing population and its demand for forest produce, need and greed of human beings is destroying the habitats and fragile ecosystems at an alarming rate.

The damage done to the vegetation of the country by human beings is far greater than the natural catastrophies and disasters witnessed in the geological past. The people have not learned the lesson from the geological past and history. The plundering of the forests including the tropical rain forests continues unabated. The ramification of this unmindful devastation are very serious. The shrinking of natural forest cover and invasion by the non-indigenous elements, large scale cultivation of introduced species, has started showing the adverse effects. This is fast changing the biological spectrum of the subcontinent. A large number of plant and animal species have already become extinct. It is estimated that approximately 10% of the Indian flora is under threat. The total effect is creation of desertic conditions, which will in due coarse of time render this beautiful Indian subcontinent inhospitable for the living beings (plants and animals). The conservation, protection and afforestation efforts made by government and non-government organisations are not commennsurate with the damage done by anthropogenic activities and degradation of forests. According to F.A.O. 1981; Conserving the world Biological Diversity 1990 IUCN, Gland, India has 51,841 thousand ha of closed forest area, of which 0.3% area is deforested every year. This trend has to be reversed on top priority basis by the policy makers with constructive participatory management of the people who live in and around forest areas and depend solely on the forest produce for thier daily sustenance. Wood substitutes for timber and fire-wood on subsidised basis has to be provided to the concerned people so as to reduce dependibility on the forest wealth.

The destruction of wild natural habitats, denudation of mountains and dwindling of vegetal cover has started showing adverse effects. Sincere global efforts are required to check this menace, otherwise the time may not be far off which may result in global environmental changes and make the situation beyond human control. The posterity may witness the vast migration and disappearance of flora and fauna.

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7. A STATISTICAL ANALYSIS OF FLOWERING PLANTS OF INDIA

(S. Karthikeyan)

J.D. Hooker with the help of his associates had presented a consolidated taxonomic treatment of Indian Flowering Plants (J.D. Hooker, *et al.* 1872-1897). It is a common knowledge that this monumental work covered the *Flora of British Indian Empire*, i.e., India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Malayan Peninsula, Nepal, Tibet, etc. Hooker, *et al.* have described in this work, a total of 171 families, 2325 genera, 14312 species, 25 subspecies, 2302 varieties, 11 subvarieties and 9 forma. An analysis reveals that 170 families, 2073 genera, 10200 species, 17 subspecies, 1363 varieties, 4 subvarieties and 1 forma belonged to the political boundaries of present day India.

In the ensuing 124 years, many new genera, species, varieties, subvarieties forma and two families (*Clethraceae* and *Hydatellaceae*) have been described/ reported from India. Taxonomic work has been going on in a big way in almost all major botanical institutions involving Indian plants. This has thrown much light on the taxonomy and nomenclature of Indian plants which has resulted in a better understanding of them.

A tentative analysis based on contemporary knowledge is presented below. It should be noted that this kind of analysis can never be final and complete as the concept of species is subjective. In addition, constantly new taxa are being discovered and described or the already accepted genera or species are being reduced and merged, thanks to a better understanding of the group or groups as the case may be.

Number of various taxa of Indian Flowering Plants, as on date, has been shown in Tables 1 and 2:

TABLE-1

	Families	Genera	Species	Subspecies	Varieties	Subvarieties	Forma
Dicots	203	2282	12575	237	1771	30	50
Monocots*	44	702	4234	45	432	3	18
Total :	247	2984	16809	282	2203	33	68

*Figures based on Karthikeyan, *et al.* 1989.

TABLE-2

Sl. No.	Family	No. of Genera	No. of Species	No. of Subspecies	No. of Varieties/Subvarieties	No. of forma
1.	2.	3.	4.	5.	6.	7.
DICOTYLEDONES						
1.	Acanthaceae	92	500	–	84	–
2.	Aceraceae	1	25	–	4	–
3.	Actinidiaceae	2	10	–	1	–
4.	Aizoaceae	9	17	–	8	–
5.	Alangiaceae	1	7	–	–	–
6.	Amaranthaceae	20	60	3	18	–
7.	Anacardiaceae	21	70	–	8	–
8.	Ancistrocladaceae	1	4	–	–	–
9.	Annonaceae	24	120	–	4	–
10.	Apiaceae (Umbelliferae)	72	288	1	32	2
11.	Apocynaceae	47	119	–	21	–
12.	Aquifoliaceae	1	25	–	4	2
13.	Araliaceae	17	69	–	14	–
14.	Aristolochiaceae	5	25	–	5	–
15.	Asclepiadaceae	57	260	3	15	–
16.	Asteraceae (Compositae)	166	800	20	81	5
17.	Averrhoaceae	1	2	–	–	–
18.	Avicenniaceae	1	3	–	–	–
19.	Balanophoraceae	3	8	1	1	–
20.	Balsaminaceae	1	200	–	23	–
21.	Barclayaceae	1	1	–	–	–
22.	Barringtoniaceae	4	12	1	1	–
23.	Basellaceae	1	1	–	–	–
24.	Begoniaceae	1	55	–	6	–
25.	Berberidaceae	3	68	3	18	–
26.	Betulaceae	2	7	–	1	–
27.	Biebersteiniaceae	1	1	–	–	–
28.	Bignoniaceae	20	34	3	3	–
29.	Bixaceae	2	2	–	–	–
30.	Bombacaceae	3	5	–	–	–
31.	Boraginaceae	43	209	7	/30	–
32.	Brassicaceae (Cruciferae)	64	207	3	5	–
33.	Burseraceae	8	22	–	2	–

1.	2.	3.	4.	5.	6.	7.
34.	Buxaceae	2	6	--	2	--
35.	Cabombaceae	2	2	--	--	--
36.	Cactaceae	1	3	--	1	--
37.	Caesalpiniaceae	19	92	4	11	--
38.	Callitrichaceae	1	6	--	--	--
39.	Campanulaceae	12	46	--	6	--
40.	Capparaceae	7	55	2	4	--
41.	Caprifoliaceae	7	72	--	12	--
42.	Cardiopterygaceae	1	1	--	--	--
43	Carpinaceae	1	2	--	--	--
44.	Caryophyllaceae	25	122	1	11	3
45.	Casuarinaceae	1	2	--	--	--
46.	Celastraceae	16	102	1	8	1
47.	Ceratophyllaceae	1	2	1	2	1
48.	Chenopodiaceae	24	71	1	1	1
49.	Chloranthaceae	2	3	1	--	--
50.	Chrysobalanaceae	1	1	--	--	--
51.	Circaeasteraceae	1	1	--	--	--
52.	Clethraceae	1	1	--	--	--
53.	Clusiaceae (Guttiferae)	5	53	--	5	--
54.	Combretaceae	8	48	--	11	--
55.	Connaraceae	4	14	1	2	--
56.	Convolvulaceae	29	199	4	35	--
57.	Coriariaceae	1	2	--	1	--
58.	Cornaceae	7	15	2	1	--
59.	Corylaceae	1	2	--	--	--
60.	Crassulaceae	10	71	1	5	--
61.	Cucurbitaceae	39	99	2	22	2
62.	Datiscaceae	2	2	--	--	--
63.	Diapensiaceae	1	4	--	--	--
64.	Dichapetalaceae	1	5	1	--	--
65.	Dilleniaceae	3	12	--	--	--
66.	Dipsacaceae	4	10	--	--	--
67.	Dipterocarpaceae	5	30	--	1	--
68.	Droseraceae	2	4	--	1	--
69.	Ebenaceae	1	51	--	11	--
70.	Elaeagnaceae	2	19	4	6	--
71.	Elaeocarpaceae	2	33	--	1	--
72.	Elatinaceae	2	8	--	--	--
73.	Ericaceae	13	175	9	31	--
74.	Erythropalaceae	1	3	--	--	--
75.	Erythroxylaceae	1	6	--	--	--

1.	2.	3.	4.	5.	6.	7.
76.	Euphorbiaceae	84	527	1	71	1
77.	Eupteleaceae	1	1	--	--	--
78.	Fabaceae (Papilionaceae)	133	973	28	145	12
79.	Fagaceae	6	57	--	20	--
80.	Flacourtiaceae	10	38	--	--	--
81.	Flindersiaceae	1	1	--	--	--
82.	Frankeniaceae	1	1	--	--	--
83.	Fumariaceae	4	65	--	2	--
84.	Gentianaceae	24	190	--	36	1
85.	Geraniaceae	5	44	1	3	--
86.	Gesneriaceae	24	114	--	18	--
87.	Goodeniaceae	1	2	--	--	--
88.	Gyrocarpaceae	1	1	--	--	--
89.	Haloragaceae	4	12	--	1	--
90.	Hamamelidaceae	7	9	--	1	--
91.	Hernandiaceae	2	8	--	--	--
92.	Hippocastanaceae	1	2	--	--	--
93.	Hydrophyllaceae	2	2	--	--	--
94.	Hypecoaceae	1	2	--	--	--
95.	Hypericaceae	3	29	4	2	--
96.	Icacinaceae	12	22	--	5	--
97.	Illecebraceae	3	4	--	1	--
98.	Illiciaceae	1	4	--	--	--
99.	Ixonanthaceae	1	1	--	--	--
100.	Juglandaceae	2	2	--	3	--
101.	Lamiaceae (Labiatae)	72	435	--	88	--
102.	Lardizabalaceae	3	5	--	1	--
103.	Lauraceae	17	212	1	31	--
104.	Lecythidaceae	1	1	--	--	--
105.	Lentibulariaceae	2	36	--	--	--
106.	Linaceae	5	12	--	--	--
107.	Loganiaceae	11	44	--	5	--
108.	Loranthaceae	14	70	1	11	--
109.	Lythraceae	11	53	--	3	1
110.	Magnoliaceae	3	24	--	--	--
111.	Malpighiaceae	4	25	--	9	--
112.	Malvaceae	22	93	6	17	--
113.	Martyniaceae	1	1	--	--	--
114.	Melastomataceae	21	150	--	31	--
115.	Meliaceae	23	97	--	29	--
116.	Menispermaceae	22	43	--	2	--
117.	Menyanthaceae	1	4	--	--	--
118.	Mimosaceae	21	127	10	18	--

1.	2.	3.	4.	5.	6.	7.
119.	Monimiaceae	1	1	--	--	--
120.	Monotropaceae	4	5	--	--	--
121.	Moraceae	13	122	3	34	--
122.	Morinaceae	3	8	--	--	--
123.	Moringaceae	1	2	--	--	--
124.	Myricaceae	1	1	--	--	--
125.	Myristicaceae	5	25	2	2	--
126.	Myrsinaceae	12	109	--	17	--
127.	Myrtaceae	14	146	1	15	--
128.	Nepenthaceae	1	1	--	--	--
129.	Nelumbonaceae	1	1	--	--	--
130.	Nyctaginaceae	4	15	--	--	--
131.	Nymphaeaceae	2	7	--	—	--
132.	Nyssaceae	1	1	--	—	--
133.	Ochnaceae	4	6	--	--	--
134.	Olacaceae	5	15	--	1	--
135.	Oleaceae	10	99	4	34	1
136.	Opiliaceae	3	3	--	--	--
137.	Onagraceae	6	49	8	11	2
138.	Orobanchaceae	7	32	--	2	—
139.	Oxalidaceae	2	19	--	--	--
140.	Paeoniaceae	1	1	--	--	--
141.	Papaveraceae	5	27	--	--	1
142.	Parnassiaceae	1	13	1	--	—
143.	Passifloraceae	3	24	1	--	—
144.	Pedaliaceae	2	4	--	1	--
145.	Phytolaccaceae	4	6	--	--	--
146.	Piperaceae	4	101	9	1	--
147.	Pistaciaceae	1	1	1	--	--
148.	Pittosporaceae	1	11	--	1	--
149.	Plagiopteraceae	1	1	--	—	--
150.	Plantaginaceae	1	12	1	2	--
151.	Platanaceae	1	1	--	--	--
152.	Plumbaginaceae	6	10	--	--	--
153.	Podophyllaceae	1	2	--	1	--
154.	Podostemaceae	9	20	--	--	--
155.	Polemoniaceae	1	1	--	1	—
156.	Polygalaceae	4	31	--	8	--
157.	Polygonaceae	18	164	10	63	--
158.	Portulacaceae	2	8	--	1	--
159.	Primulaceae	10	183	4	34	2
160.	Proteaceae	2	7	--	--	--

1.	2.	3.	4.	5.	6.	7.
161.	Pyrolaceae	2	6	1	1	–
162.	Rafflesiaceae	2	2	–	–	–
163.	Ranunculaceae	28	193	3	21	–
164.	Resedaceae	3	5	–	–	–
165.	Rhamnaceae	15	68	–	6	–
166.	Rhizophoraceae	8	18	–	–	–
167.	Rosaceae	40	432	4	80	1
168.	Rubiaceae	113	616	9	67	3
169.	Rutaceae	29	114	1	22	–
170.	Sabiaceae	2	15	5	2	–
171.	Salicaceae	2	64	–	17	1
172.	Salvadoraceae	3	4	–	–	–
173.	Santalaceae	10	18	–	2	–
174.	Sapindaceae	21	55	–	5	–
175.	Sapotaceae	14	49	–	4	1
176.	Saxifragaceae	17	148	6	16	2
177.	Schisandraceae	2	6	–	1	–
178.	Scrophulariaceae	62	368	10	43	–
179.	Simaroubaceae	9	16	–	1	–
180.	Solanaceae	17	75	7	16	–
181.	Sonneratiaceae	2	4	–	–	–
182.	Stachyuraceae	1	1	–	–	–
183.	Sterculiaceae	19	68	–	3	–
184.	Stylidiaceae	1	2	–	1	–
185.	Styracaceae	5	49	7	12	–
186.	Symphoremataceae	1	2	–	2	–
187.	Tamaricaceae	3	16	–	–	–
188.	Tetracentraceae	1	1	–	1	–
189.	Theaceae	9	23	–	5	–
190.	Thymelaeaceae	14	23	1	1	–
191.	Tiliaceae	8	53	–	–	–
192.	Trapaceae	1	3	–	1	–
193.	Tropaeolaceae	1	1	–	–	–
194.	Turneraceae	1	2	–	–	–
195.	Ulmaceae	6	22	1	7	–
196.	Urticaceae	29	153	2	58	1
197.	Vacciniaceae	2	24	1	4	1
198.	Valerianaceae	5	27	–	2	–
199.	Verbenaceae	23	140	–	25	1
200.	Violaceae	3	41	1	2	1
201.	Vitaceae	11	109	1	5	–
202.	Xanthophyllaceae	1	4	–	1	–
203.	Zygophyllaceae	6	15	–	5	–

1.	2.	3.	4.	5.	6.	7.
	MONOCOTYLEDONES					
1.	Agavaceae	2	18	–	3	–
2.	Alismataceae	6	14	1	1	–
3.	Amaryllidaceae	5	24	–	6	1
4.	Aponogetonaceae	1	8	–	–	–
5.	Araceae	29	126	1	18	–
6.	Arecaceae (Palmae)	24	94	–	6	1
7.	Burmanniaceae	2	8	–	–	–
8.	Butomaceae	2	2	–	–	–
9.	Cannaceae	1	3	–	1	–
10.	Commelinaceae	14	90	2	7	–
11.	Cymodoceaceae	4	6	–	–	–
12.	Cyperaceae	38	545	13	93	1
13.	Dioscoreaceae	3	33	–	34	–
14.	Eriocaulaceae	1	70	–	–	–
15.	Flagellariaceae	1	1	–	–	–
16.	Hydatellaceae	1	1	–	–	–
17.	Hydrocharitaceae	9	18	1	1	–
18.	Hypoxidaceae	3	9	–	–	–
19.	Iridaceae	5	21	–	–	–
20.	Juncaceae	2	53	–	7	–
21.	Juncaginaceae	1	2	–	–	–
22.	Lemnaceae	4	13	–	–	–
23.	Liliaceae	45	214	2	28	4
24.	Marantaceae	6	14	–	–	–
25.	Musaceae	2	25	–	–	–
26.	Najadaceae	1	14	–	5	–
27.	Orchidaceae	184	1229	3	65	4
28.	Pandanaceae	2	17	–	–	–
29.	Philydraceae	1	1	–	–	–
30.	Poaceae (Gramineae)	263	1291	19	134/3	1
31.	Pontederiaceae	2	3	–	–	–
32.	Potamogetonaceae	1	18	2	2	–
33.	Ruppiaceae	1	1	1	–	–
34.	Smilacaceae	2	33	–	3	–
35.	Sparganiaceae	1	4	–	–	–
36.	Stemonaceae	2	2	–	2	–
37.	Taccaceae	1	3	–	–	–
38.	Trichopodaceae	1	1	–	–	–
39.	Trilliaceae	1	2	–	1	–

1.	2.	3.	4.	5.	6.	7.
40.	Triuridaceae	1	2	--	--	--
41.	Typhaceae	1	3	—	--	--
42.	Xyridaceae	1	6	--	--	--
43.	Zannichelliaceae	1	1	--	--	—
44.	Zingiberaceae	24	191	--	15	--

DICOTYLEDONES

I. Total number of families : 203

II. *The 27 families with 1 genus each and 1 species only :* Braclayaceae, Basellaceae, Biebersteiniaceae, Cardiopterygaceae, Chrysobalanaceae, Circaeasteraceae, Clethraceae, Eupteleaceae, Flindersiaceae, Frankeniaceae, Gyrocarpaceae, Ixonanthaceae, Lecythidaceae, Martyniaceae, Monimiaceae, Myricaceae, Nepenthaceae, Nelumbonaceae, Nyssaceae, Paeoniaceae, Pistaciaceae, Plagiopteraceae, Platanaceae, Polemoniaceae, Stachyuraceae, Tetracentraceae and Tropaeolaceae.

III. *The 35 families with 1 genus each with species ranging between 2 to 200**

Averrhoaceae (2), Carpinaceae (2), Casuarinaceae (2), Ceratophyllaceae (2), Coriariaceae (2), Corylaceae (2), Goodeniaceae (2), Hippocastanaceae (2), Hypecoaceae (2), Moringaceae (2), Podophyllaceae (2), Stylidiaceae (2), Symphoremataceae (2), Turneraceae (2), Avicenniaceae (3), Cactaceae (3), Erythropalaceae (3), Trapaceae (3), Ancistrocladaceae (4), Diapensiaceae (4), Illiciaceae (4), Menyanthaceae (4), Xanthophyllaceae (4), Dichapetalaceae (5), Callitrichaceae (6), Erythroxylaceae (6), Alangiaceae (7), Pittosporaceae (11), Plantaginaceae (12), Parnassiaceae (13), Aceraceae (25), Aquifoliaceae (25), Ebenaceae (51), Begoniaceae (55) and Balsaminaceae (200).

* Number of species indicated within brackets after the family names hereafter.

IV. *The 27 families with 2 genera each :*

Bixaceae (2), Cabombaceae (2), Datiscaceae (2), Hydrophyllaceae (2), Juglandaceae (2), Rafflesiaceae (2), Chloranthaceae (3), Droseraceae (4), Pedaliaceae (4), Sonneratiaceae (4), Buxaceae (6), Pyrolaceae (6), Schisandraceae (6), Betulaceae (7), Nymphaeaceae (7), Proteaceae (7), Elatinaceae (8), Hernandiaceae (8), Portulacaceae (8), Actinidiaceae (10), Sabiaceae (15), Elaeagnaceae (19), Oxalidaceae (19), Vacciniaceae (24), Elaeocarpaceae (33), Lentibulariaceae (36) and Salicaceae (64).

V. *The 15 families with 3 genera each :*

Opiliaceae (3), Illecebraceae (4), Salvadoraceae (4), Bombacaceae (5), Lardizabalaceae (5), Resedaceae (5), Balanophoraceae (8), Morinaceae (8), Dilleniaceae (12), Tamaricaceae (16), Magnoliaceae (24), Passifloraceae (24), Hypericaceae (29), Violaceae (41) and Berberidaceae (68).

VI. *The 12 families with 4 genera each :*

Monotropaceae (5), Ochnaceae (6), Phytolaccaceae (6), Dipsacaceae (10), Barringtoniaceae (12), Haloragaceae (12), Connaraceae (14), Nyctaginaceae (15), Malpighiaceae (25), Polygalaceae (31), Fumariaceae (65) and Piperaceae (101).

VII. *The 10 families with 5 genera each :*

Linaceae (12), Olacaceae (15), Aristolochiaceae (25), Myristicaceae (25), Papaveraceae (27), Valerianaceae (27), Dipterocarpaceae (30), Geraniaceae (44), Styracaceae (49) and Clusiaceae (Guttiferae) (53).

VIII. *The 5 families with 6 genera each :*

Plumbaginaceae (10), Zygophyllaceae (15), Ulmaceae (22), Onagraceae (49) and Fagaceae (57).

IX. *The 5 families with 7 genera each :*

Hamamelidaceae (9), Cornaceae (15), Orobanchaceae (32), Capparaceae (55) and Caprifoliaceae (72).

X. *The 4 families with 8 genera each :*

Rhizophoraceae (18), Burseraceae (22), Combretaceae (48) and Tiliaceae (53).

XI. *The 4 families with 9 genera each :*

Simaroubaceae (16), Aizoaceae (17), Podostemaceae (20) and Theaceae (23).

XII. *The 5 families with 10 genera each :*

Santalaceae (18), Flacourtiaceae (38), Crassulaceae (71), Oleaceae (99) and Primulaceae (183).

XIII. *The 3 families with 11 genera each :*

Loganiaceae (44), Lythraceae (53) and vitaceae (109).

XIV. *The 3 families with 12 genera each :*

Icacinaceae (22), Campanulaceae (46) and Myrsinaceae (109).

XV. *The 2 families with 13 genera each :*

Moraceae (122) and Ericaceae (175).

XVI. *The 4 families with 14 genera each :*

Thymelaeaceae (23), Sapotaceae (49), Loranthaceae (70) and Myrtaceae (146).

XVII. *The one family with 15 genera :*

Rhamnaceae (68).

XVIII. *The one family with 16 genera :*

Celastraceae (102)

XIX. *The 4 families with 17 genera each :*

Araliaceae (69), Solanaceae (75), Saxifragaceae (148) and Lauraceae (212)

XX. *The one family with 18 genera :*

Polygonaceae (164)

XXI. *The 2 families with 19 genera each :*

Sterculiaceae (68) and Caesalpiniaceae (92).

XXII. *The 2 families with 20 genera each :*

Bignoniaceae (34), and Amaranthaceae (60).

XXIII. *The 4 families with 21 genera each :*

Sapindaceae (55), Anacardiaceae (70), Mimosaceae (127) and Melastomataceae (150)

XXIV. *The 2 families with 22 genera each :*

Menispermaceae (43) and Malvaceae (93).

XXV. *The 2 families with 23 genera each :*

Meliaceae (97), and Verbenaceae (140).

XXVI. *The 4 families with 24 genera each :*

Chenopodiaceae (71), Gesneriaceae (114), Annonaceae (120) and Gentianaceae (190)

XXVII. *The one family with 25 genera :*

Caryophyllaceae (122).

XXVIII. *The one family with 28 genera :*

Ranunculaceae (193).

XXIX. *The 3 families with 29 genera each :*

Rutaceae (114), Urticaceae (153) and Convolvulaceae (199).

XXX. *The one family with 39 genera :*

Cucurbitaceae (99).

XXXI. *The one family with 40 genera :*

Rosaceae (432).

XXXII. *The one family with 43 genera :*

Boraginaceae (209).

XXXIII. *The one family with 47 genera :*

Apocynaceae (119).

XXXIV. *The one family with 57 genera :*

Asclepiadaceae (260).

XXXV. *The one family with 62 genera :*

Scrophulariaceae (368).

XXXVI. *The one family with 64 genera :*

Brassicaceae (Cruciferae) (207).

XXXVII. *The 2 families with 72 genera each :*

Apiaceae (288) and Lamiaceae (Labiatae) (435).

XXXVIII. *The one family with 84 genera :*

Euphorbiaceae (527).

XXXIX. *The one family with 92 genera :*

Acanthaceae (500).

XL. *The one family with 113 genera :*

Rubiaceae (616).

XXLI. *The one family with 133 genera :*

Fabaceae (Papilionaceae) (973).

XXLII. *The one family with 166 genera :*

Asteraceae (Compositae) (800)

The ten families having larger number of species :

Leguminosae (Fabaceae + Caesalpiniaceae + Mimosaceae) (1192), Asteraceae (800), Rubiaceae (616), Euphorbiaceae (527), Acanthaceae (500), Lamiaceae (435), Rosaceae (432), Scrophulariaceae (368), Apiaceae (288) and Asclepiadaceae (260).

Total number of genera	2282
Total number of species	12575
Total number of subspecies	237
Total number of varieties	1771
Total number of subvarieties	30
Total number of forma	50

Largest genus *Impatiens* (200)
Genera with only one species : 992

Some families with more number of genera with only one species are Asteraceae (84), Fabaceae (70) Rubiaceae (55), Acanthaceae (43), Brassicaceae (36), Apiaceae (34), Euphorbiaceae (31), Asclepiadaceae (30), Lamiaceae (29) and Scrophulariaceae (27).

The ten families which have genera with large number of species are Balsaminaceae (*Impatiens* 200 species), Fabaceae (*Crotalaria* 104 species), Scrophulariaceae (*Pedicularis* 98 species), Ericaceae (*Rhododendron* 97 species), Primulaceae (*Primula* 135 species), Myrtaceae (*Syzygium* 91 species) Moraceae (*Ficus* 100 species) Saxifragaceae (*Saxifraga* 89 species) and Piperaceae (*Piper* 88 species).

MONOCOTYLEDONES

Total number of families : 44

I. *The six families with 1 genus and 1 species only :*

Flagellariaceae, Hydatellaceae, Philydraceae, Ruppiaceae, Trichopodacee and Zannichelliaceae.

II. *The twelve families with 1 genus only with varying number of species :*

Juncaginaceae (2), Trilliaceae (2), Triuridaceae (2), Cannaceae (3), Taccaceae (3), Typhaceae (3), Sparganiaceae (4), Xyridaceae (6), Aponogetonaceae (8), Najadaceae (14), Potamogetonaceae (18) and Eriocaulaceae (70).

III. *The 9 families with 2 genera :*

Butomaceae (2), Stemonaceae (2), Pontederiaceae (3), Burmanniaceae (8), Pandanaceae (17), Agavaceae (18), Musaceae (25), Smilacaceae (33) and Juncaceae (53).

IV. *The 2 families with 3 genera each :*

Hypoxidaceae (9) and Dioscoreaceae (33).

V. *The 2 families with 4 genera each :*

Cymodoceaceae (6) and Lemnaceae (13).

VI. *The 2 families with 5 genera each :*

Iridaceae (21) and Amaryllidaceae (24).

VII. *The 2 families with 6 genera and 14 species each :*

Alismataceae and Marantaceae.

VIII. *The one family with 9 genera :*

Hydrocharitaceae (18).

IX. *The one family with 14 genera :*

Commelinaceae (90).

X. *The 2 families with 24 genera each :*

Arecaceae (Palmae) (94) and Zingiberaceae (191).

XI. The family Araceae has 29 genera and 126 species.

XII. The family Cyperaceae has 38 genera and 545 species.

XIII. The family Liliaceae has 45 genera and 214 species.

XIV. The family Orchidaceae has 184 genera and 1229 species.

XV. The family Poaceae has 263 genera and 1291 species.

The families with larger number of species in descending order are Poaceae (1291), Orchidaceae (1229), Cyperaceae (545), Liliaceae (214), Zingiberaceae (191), and Commelinaceae (90).

Total number of genera :	702
Total number of species	4234
Total number of subspecies	45
Total number of varieties	432
Total number of subvarieties	3
Total number of forma	18

Largest genus : *Carex* (160).

Genera with only one species-265.

Families with large number of genera with single species : Cyperaceae (15), Liliaceae (19) Orchidaceae (60) and Poaceae (111).

Approximate number of genera/species of different categories :

Endemic genera	141	
Endemic species	4500	
Herbs	1205	(Succulent herbs, 211)
Shrubs	2746	
Climbers (herbaceous as well as shrubby)	1735	
Trees	2863	
Branching palm	1	
Submerged marine Angiosperms	13	

Found only on sea shores of islands but not of that on mainland India, so far,: *Thuarea involuta* of Poaceae.

Foul smelling	62
Aromatic	254

Epiphytes	750
Mangroves	30
Saprophytes	7
Parasites and root parasites	309
Insectivorous/carnivorous	40
Stinging hairy	20
Salt marshy	26
Poisonous	2000
Economically useful (edible plants, cereals, pulses, fruits, vegetables, etc.)	5000
Fodder plants	1250

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8. WILD RELATIVES OF CULTIVATED PLANTS

(R.K. Arora)

INTRODUCTION

The wild relatives of cultivated plants constitute a rich reservoir of genetic variation of immense value to plant breeders. They have evolved to survive drought and floods, extreme heat and cold, and have been adapted to cope with many natural hazards (Hoyt, 1988). They have often developed resistance to pests and diseases and are thus crucial to crop improvement. They constitute a large array of diverse genepools which need to be tapped for their potential for innumerable promising characteristics.

Large variety of cultivated plants used by mankind today have been derived from the wild relatives through selection or hybridization. For bringing out desired improvements, a geneticist or a plant breeder needs to know the inherent qualities in the wild relatives of a particular plant or genepool. Thus, the scope of utilization of the wild relatives of our crop plants has been increasing day by day with our increasing capacity to study the genes responsible for various traits and their manipulation. Of late, science of genetic engineering has opened almost unlimited possibilities for the conservation and use of this unique wild plant wealth.

The contribution of wild relatives towards economic returns is well exemplified by crop plants such as rice, wheat, sugarcane, potato and tomato, besides several forages and other crops. Exploiting wild genepools requires intensive efforts and extensive knowledge of taxonomy, reproductive biology, cytogenetics, genetics and in many cases cell culture techniques (Stalker, 1989). Thus, good species collections must be obtained and studied accordingly to identify and incorporate their desirable attributes judiciously.

Unfortunately, changing land use patterns, rapidly increasing pressure on land both for agriculture and forestry development programmes as well as expanding demand for industrial and urban sectors have posed serious threat to the existing diversity in the wild relatives and related species. Hence special efforts are required to collect and conserve these resources for their current use and for posterity. An overall assessment of the nature and extent of this diversity occurring in India, and its distribution, ecology and potential use, is presented.

Classification of wild relatives

In classifying wild relatives of crop plants, it is necessary to sort out the intricate relationship of species, subspecies, varieties and ecotypes and group these according to degree of relationship in a given crop genepool (Hoyt, 1988). A crop genepool includes all the cultivars, wild relatives and related wild species containing all the genes available for breeding use. Each crop genepool (GP) can be divided/classified into three GP levels in genetic perspective (Harlan & de Wet, 1971; Hoyt, 1988):

GP1- Primary genepool	:	Crossing is easy in the primary genepool and hybrids are fertile; gene transfer is simple.
GP2- Secondary genepool	:	Can be crossed with GP1; hybrids are usually sterile but with some fertility; gene transfer is possible but may be difficult.
GP3- Tertiary genepool	:	Can be crossed with GP1; but hybrids are sterile; gene transfer may be possible with radical measures.

By and large, wild species in the primary genepools contribute germplasm more readily than those in the secondary genepool, while tertiary genepool can only be used for some crops for a limited numebr of genetic traits (Harlan, 1975). Thus, from the utilisation or exploitation view-point, wild genepools may be assigned to the following two categories :

Easy to exploit :

Wild progenitors	:	Closely related to crops; belong to primary genepool.
Other wild species	:	Relatively distantly related, cross compatible; belong to the secondary genepool.

Difficult to exploit :

Wild species	:	Distantly related/unrelated taxa of different genera (species), broadly falling into the tertiary genepool.

The understanding of weedy forms and wild progenitors is very important in the effective utilization of wild plant diversity. The taxonomy of a crop species is inseparable from that of the wild types and related wild species, overall range of the species variability is too much wider to reckon with and has necessitated the creation of infraspecific taxonomic categories to accommodate several groups. More than 65 infraspecific categories have been introduced (Jirasek, 1961; Hilu, 1989).

Species diversity

The estimated strength of wild relatives of crop plants and related taxa occurring in India is of about 320 species (Arora & Nayar, 1984) and based on the economic plant groups, category wise, the species of relevance to cultivated/crop plants may be grouped as follows :

Crop groups	*Species No.*
Cereals and millets	51
Legumes	31
Fruits	109
Vegetables	54
Oilseeds	12
Fibre plants	24
Spices and condiments	27
Others	26

This diversity belongs to 48 families and 116 genera. Botanically, this assemblage includes the Poaceae (Gramineae) (cereals and millets, bamboos, sugarcane), and Leguminosae (grain legumes/pulses/beans), with much diversity in fruit types occurring in Rosaceae, Rutaceae, Musaceae, Anacardiaceae, Rhamnaceae, Myrtaceae and Moraceae; for vegetable types in Malvaceae, Asteraceae (Compositae), Solanaceae and Cucurbitaceae; tuber types in Araceae and Dioscoreaceae; for oilseeds in Brassicaceae (Cruciferae) and Pedaliaceae; for fibre crops in Tiliaceae and Malvaceae; for spices and condiments in Liliaceae, Zingiberaceae and Piperaceae; and among other economic commodity groups, in Theaceae for wild relatives of tea and in Rubiaceae for wild types in coffee. Table 1 summarizes the floristic strength of wild relatives and related species occurring in India.

Table-1. Floristic strength of families and genera of wild relatives occurring in India.

Total strength	:	48 families, 116 genera and 320 species

Genetic richness by families

Genera (No.)	Families (No.)	Example
>20	1	Poaceae (Gramineae)
>10	1	Leguminosae
>5, <10	2	Rosaceae
4-5	2	Malvaceae, Zingiberaceae
3	4	Anacardiaceae
		Araceae
		Moraceae
		Sapotaceae
2	6	Brassicaceae (Cruciferae)
		Tiliaceae
		Rutaceae
		Asteraceae (Compositae)
		Musaceae
		Polygonaceae
1	32	Theaceae
		Lauraceae
		Solanaceae
		Lamiaceae (Labiatae)
		Amaranthaceae
		Chenopodiaceae
		Piperaceae
		Arecaceae (Palmae)
		Pedaliaceae
		Liliaceae

Floristic analysis of 116 genera of wild relatives points out the following pattern of species richness :

(i) Genera represented by one species only : *Aegle, Aegilops, Hygroryza, Trilobachne, Cicer, Lablab, Euphoria, Punica, Coccinia, Neoluffa, Colocasia and Myrica.*

(ii) Genera represented by two species : *Fagopyrum, Chionachne, Eleusine, Elymus, Narenga, Sclerostachya, Polytoca, Glycine, Docynia, Duchesnea, Brassica, Carthamus, Citrullus, Ensete, Mimusops and Carum.*

(iii) Genera represented by three to four species : *Coix, Hordeum, Mischanthus, Eremopyrum, Canavalia, Lepidium, Sesamum, Malus, Fragaria, Madhuca, Manilkara, Spondias, Linum and Urena.*

(iv) Genera represented by >5, <10 species : *Avena, Echinochloa, Dolichos, Lathyrus, Erianthus, Coffea, Camellia, Cucumis, Coleus, Phoenix, Pyrus, Morus, Elaeagnus, Amomum, Myristica (Knema), Malva, Momordica, Abelmoschus, Alpinia, Corchorus, Sorbus, Amaranthus* and *Chenopodium.*

(v) Genera represented by >10 or <20 species : *Prunus, Rubus, Cinnamomum, Curcuma, Zingiber, Rumex, Boehmeria, Zizyphus, Paspalum, Pennisetum, Setaria, Saccharum, Vigna, Atylosia, Mucuna, Trigonella, Artocarpus, Carissa, Citrus and Cordia.*

(vi) Genera with >20 <30 species : *Digitaria, Trichosanthes, Garcinia, Elaeocarpus, Maughania,* and *Allium.*

(vii) Genera with >30 <40 species : *Panicum and Hibiscus.*

(viii) Genera with more than 40 species : *Piper, Diospyros, Syzygium, Dioscorea, Rubus, Ficus, Grewia, Crotalaria and Solanum.*

The above diversity, vis-a-vis species richness, is shown in Fig. 1 (Arora, 1991). Among the 320 species, about 60 are endemic and/or rare taxa belonging to different economic plant categories as given in table 2 (Arora & Nayar, 1984).

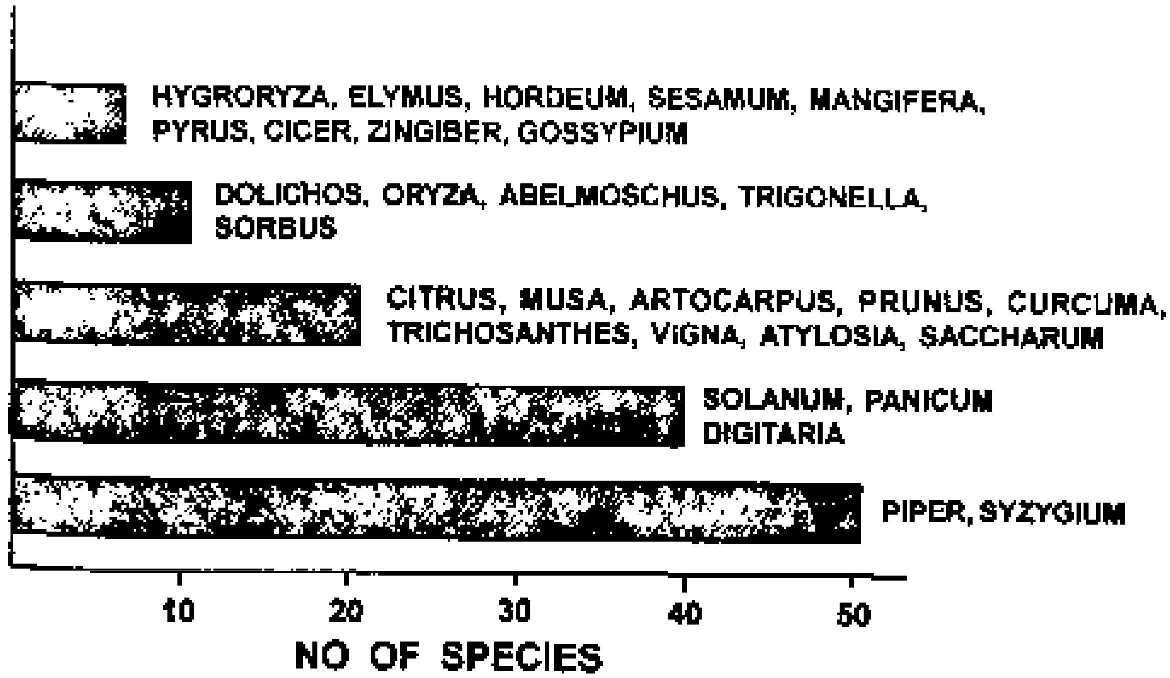


Fig. 2. The number of species in some important taxa of wild relatives of crop plants.

Table-2. Wild relatives and related endemic and/or rare species including endemic cultigens (Arora & Nayar, 1984).

Cereals and Millets :	*Coix lacryma-jobi* var. *ma-yuan*, *Digitaria cruciata* var. *esculenta*, *Digitaria sanguinalis* subsp. *aegyptiaca* var. *frumentacea*, *Oryza malampuzhaensis*.
Legumes :	*Atylosia cajanifolia*, *Atylosia grandiflora*, *Atylosia nivea*, *Canavalia stocksii*, *Cicer microphyllum*, *Dolichos bracteatus*, *Dolichos purpureus-wild lignosus forms*, *Lathyrus altaicus*, *Vigna mungo* var. *sylvestris*, *Vigna radiata (setulosus* forms), *Vigna grandis*, *Vigna vexillata* var. *stocksii/Vigna capensis*.
Fruit types :	*Citrus assamensis*, *Citrus ichangensis*, *Citrus indica*, *Citrus latipes*, *Docynia hookeriana*, *Malus baccata* var. *himalaica*, *Musa cheesmanii*, *Musa glauca*, *Musa flaviflora*, *Musa itinerans*, *Musa nagensium*, *Musa sikkimensis*, *Musa Mannii*, *Musa velutina*, *Prunus acuminata*, *Prunus jenkinsii*, *Prunus tomentosa*, *Pyrus kumaoni*, *Rubus lineatus*.
Vegetable types	*Abelmoschus tuberculatus*, *Allium rubellum*, *Cucumis hardwickii*, *Curcuma amarissima*, *Luffa hermaphrodita*, *Luffa umbellata*, *Maughania vestita*, *Neoluffa sikkimensis*, *Solanum melongena* var. *insanum*, *S. melongena* var. *potangi*, *Trichosanthes khasiana*,

	Trichosanthes majuscula, Trichosanthes ovata, Trichosanthes tomentosa, Zingiber intermedium.
Oilseed types :	*Sesamum laciniatum, S. prostratum.*
Miscellaneous :	*Bunium persicum, Camellia drupifera, Camellia lutescens. Lilium mackliniae, Linum perenne.*

Phytogeographical analysis

The phytogeographical distribution of 320 species of wild relatives and related taxa in different botanical regions pinpoints to the concentration of this genetic wealth in the warm humid tropical, sub-tropical regions and in the Western Himalayas, with low representation in the drier north-western region. The number of species occurring in each botanical Zone is as follows :

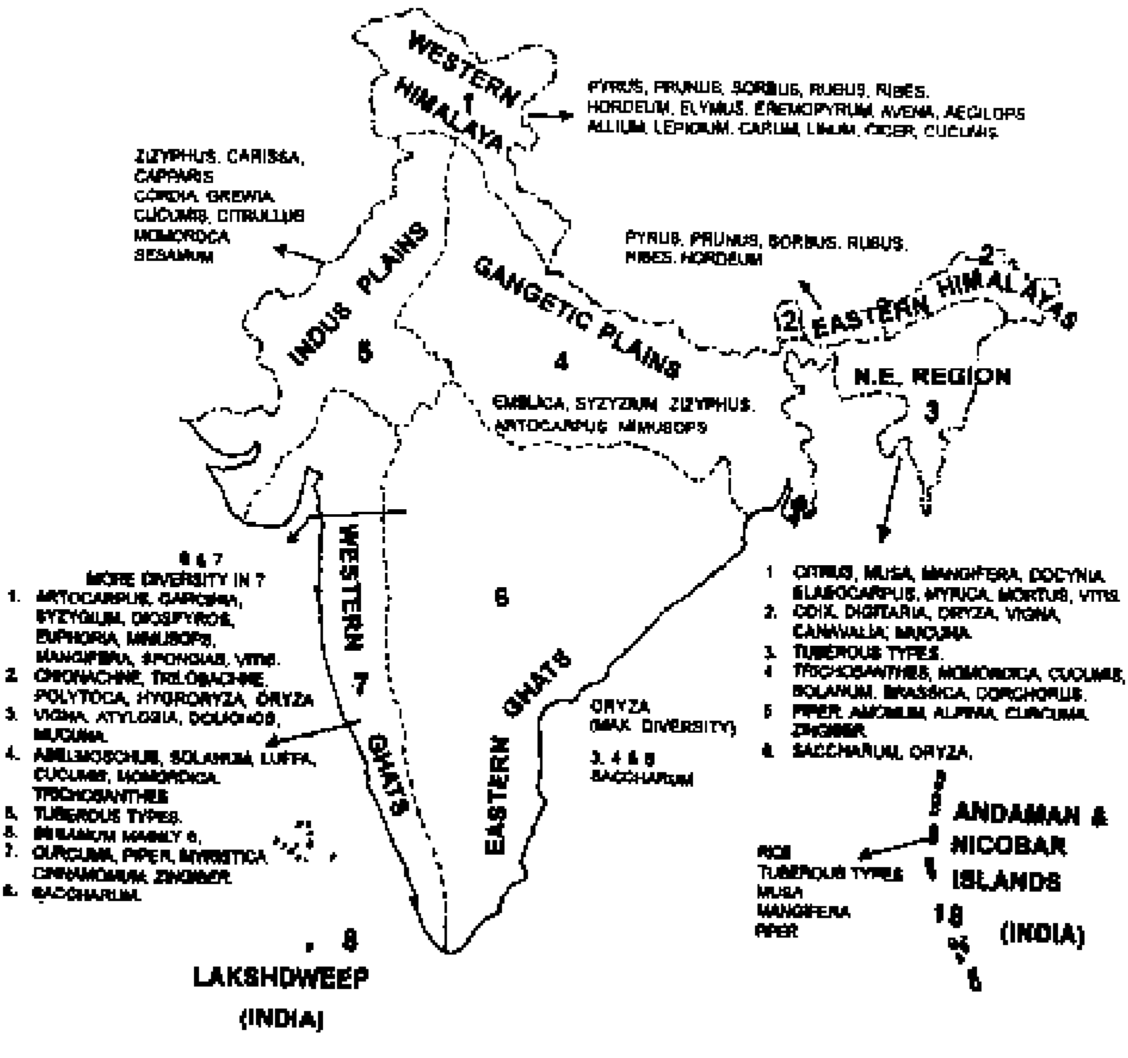
Phytogeographical Zone	Wild relatives (species no.)
Western Himalayas	125
Eastern Himalayas	82
North-eastern region	132
Gangetic plains	66
Indus plains (North-western plains)	45
Malabar/Western peninsular region/Western Ghats	145
Deccan/Eastern peninsular region/Eastern Ghats	91

The concentration of this diversity in wild relatives in different phytogeographical zones of India is shown in Map 13. (Arora, 1991).

Keeping in view the overall species richness, and the range of distribution of species, this diversity in wild relatives would fall in the following groups :

A. *Widely distributed taxa :*

Wider habitat range vis-a-vis diversity in number of species, e.g. *Solanum.*



Map 13. Distribution of diversity in wild relatives of crop plants in different phyto-geographical regions of India.

Wider habitat range but taxa with limited number of species, e.g. *Ablemoschus, Musa.*

Wider habitat range of taxa with single species adapted to more specific soil, climate regime; sporadic distribution within the geographical range, e.g. *Bunium persicum* in Western Himalaya.

B. *Endemic taxa :*

Narrow range of distribution, more localised; narrow ecological amplitude, e.g. *Cajanus Cajanifolius* in Belladilla range of Orissa, *Abelmoschus tuberculatus* in North-western drier plains of Uttar Pradesh, Rajasthan and Gujarat, and *Picrorhiza kurrooa* in Western Himalaya.

C. *Rare/endangered taxa :*

Extremely narrow range of distribution, low population density per site, such as in *Musa sikkimensis* and *Coptis teeta* in North-eastern region/Eastern Himalaya.

Wider distribution range, with over-exploited populations; natural habitat of species disturbed, such as in *Rauvolfia serpentina* in Western Ghats.

Ecology and distribution of diversity :

Ecologically, the wild relatives of crop plants occur as components (in specific habitats) of the different vegetation types, i.e. climatic, edaphic, biotic or bioedaphic dispersed within the different botanical regions (Map 2.) It is evident that :

1. The tropical moist evergreen/semi-evergreen forests in the western and eastern peninsular tracts and in North-eastern region possess rich diversity in wild relatives of perennial cultivated plants. Some of the major taxa available in such habitats are ;

   (a) Wild relatives of fruit trees, such as species of *Artocarpus, Citrus, Garcinia, Diospyros, Elaeocarpus, Euphoria/Nephelium, Syzygium, Spondias, Mimusops* and *Mangifera.*

   (b) Wild tree species of value as spices/condiments, like *Cinnamomum* and *Knema/Myristica* species.

(c) Wild species occurring as forest undergrowth, such as *Amomum, Piper, Zingiber* and others. *Piper,* being mostly viny, often occur on the outskirts of forest openings with several legumes, such as species of *Vigna, Pueraria, Canavalia, Atylosia, Maughania* and *Dolichos*; cucurbits, like *Luffa, Trichosanthes, Momordica, Cucumis and Coccinia* and others, like the non-tuberiferous *Solanum* spp., *Abelmoschus, Corchorus* and *Vitis.*

(d) The edaphic/bio edaphic plant communities in the above forests support wild types related to sugarcane *Saccharum* and related types, and species of *Carissa, Ziziphus, Capparis, Grewia, Phoenix, Solanum* and grasses, like *Digitaria, Polytoca, Chionachne, Trilobachne, Panicum and Setaria* species.

(e) Specialized habitats which are ecologically distinct, like the low lying water logged areas/ponds/lakes, etc. hold rich diversity in *Coix* species and related Maydeae, *Oryza nivara, O. rufipogon* and other species (particularly in the peninsular tract), *Echinochloa* spp. (Water logged habitat annual to perennial types) and *Canavalia virosa, Porteresia coarctata, Hygroryza aristata, Leersia* spp. in peninsular coastal tract in brackish water and *Vigna luteola* in beach forests (edaphically distinct). Besides, wild taxa of potential utility, such as *Coix gigantea,* etc. are also available here.

2. The dry tropical vegetation (mostly the deciduous forest types), as prevalent in southern peninsular tract and the northern plains, possesses diversity in fruit trees, like *Aegle marmelos, Feronia limonia, Salvadora persica, Cordia subcordata, Phyllanthus emblica, Diospyros, Morus* and *Grewia* spp.; thorny shrubs, like species of *Carissa, Capparis* and *Ziziphus,* and other components like *Solanum surattense* and *Sesamum indicum* and with viny types, like *Vitis* spp., *Momordica balsamina, Coccinia indica* and *Cucumis prophetarum* often along forest openings/edges.

3. Ecologically more distinct than the dry tropical vegetation is the semi-arid desert vegetation occurring in the Indus plains and in drier peninsular belt, marginal to the above type or even to the moist tropical deciduous type. Edaphically distinct habitats with specific flora of wild relatives/related types are met with, e.g. sand dune habitat, including rocky areas of North Western

drier plains with fruit tree types, like *Capparis decidua, Carissa congesta, C. spinarum, Ziziphus nummularia*, with *Grewia tenax* more common in rocky sites. Grasses include *Panicum* spp., *Eleusine compressa*, and other highly heat/drought tolerant types.

4. The montane sub-tropical vegetation as prevalent in the peninsular tract, particularly in the hills of Western Ghats and in the North-eastern region (1200-1800 m) holds diversity in temperate types well adapted to more humid tropical/sub-tropical climate :

   (a) Fruit tree components include *Prunus, Pyrus, Docynia* and *Elaeocarpus* species.

   (b) Rich undergrwoth of *Rubus, Solanum* and several species of genera listed above, under humid tropical type.

   (c) In the biotic vegetation type, i.e. Nilgiri sub-tropical hill savannah locally called *Sholas* (grasslands at 1800 m), more cold adaptable sub-tropical components occur, i.e. *Vigna, Atylosia/Cajanus, Trichosanthes, Abelmoschus, Solanum, Dolichos and Setaria*, with undergrowth of *Fragaria*.

5. The temperate vegetation types occurring in the Himalayan region possess rich diversity in:

   (a) Fruit tree types pome and stone fruits related to cultivated types *Pyrus, Prunus* and *Malus* and others like *Myrica* and *Morus* spp.

   (b) *Rubus and Ribes* spp. as small trees and undergrowth of *Fragaria, Lathyrus, Linum, Allium, Hordeum, Digitaria and Elymus* spp. as common components of bioedaphic/biotic temperate habitats.

   (c) *Vitis* spp. and cucurbits, such as *Cucumis pubescens, C. hardwickii* and *Trichosanthes* spp. occur in forest opening/outskirts.

6. In contrast to temperate vegetation, the alpine vegetation, characteristic of higher elevation zone of the Himalayas *ca* 2100-3300 m, is poor in wild

relatives and very few tree/shrubby components occur, *Sorbus, Prunus, Ribes* and *Rubus*. The alpine meadows and alpine scrub are bioedaphic types wherein occur *Allium, Avena, Aegilops, Eremopyrum, Elymus, Hordeum, Trigonella, Lathyrus* and *Cicer* species. These represent extremely cold-hardy/drought-tolerant germplasm.

Among the wild relatives death with above, *Hordeum* spp., *Elymus* and *Eremopyrum* occur as weeds in the North-western Himalayan region within and along barley fields; *Saccharum* cytotypes occur in the Indo-Gangetic plains, and the widely distributed and highly variable wild forms in *Vigna umbellata* and *V. radiata* var. *sublobata* occur in the tropical and sub-tropical zones.

From the above, it is evident that :

(i) Maximum variability in fruit tree components occurs in the humid tropical/subtropical zone of peninsular region and in the North-east, and for pome and stone fruits, in temperate forests of the Western and Eastern Himalayas.

(ii) A large proportion of diversity in wild relatives of cereals and millets occurs in biotic/bioedaphic habitats both in tropical/sub-tropical and temperate/alpine regions.

(iii) Maximum variability in legumes and cucurbits occurs in bioedaphic types either within the moist-tropical zone of peninsular region and in the north-eastern region, or along openings in the evergreen forests or in cleared secondary vegetation componets.

(iv) Several of these also occur as undergrowth in climax forest types, i.e. *Piper* spp. (climbing on *Garcinia* and others), *Curcuma, Zingiber, Dioscorea* and *Solanum* spp. in evergreen forests.

(v) Only a few species occur in specialized habitats as components of primary edaphic types, i.e. *Vigna luteola* in beach forest; *Oryza rufipogon* along margin of ponds; *Porteresia coarctata* and *Canavalia virosa* as components of brackish water and/or coastal strand vegetation.

(vi) There is more prevalence of wild relatives in disturbed, bioedaphic habitats.

In situ conservation of wild relatives

The above information on the phytogeographical and ecological synthesis of the wild relatives of crop plant can be appropriately used in adopting *in situ* conservation measures for this group of plants in national context. Examples may be cited considering the overall vegetational zones within each biosphere reserve, and the range of climate, soil, and physiography. Thus rich genetic wealth of wild relatives occurs in :

(a) Mysore Plateau-Wynad-Nilgiris : particularly for legumes, *Canavalia virosa*, *C. ensiformis*, *Dolichos uniflorus*, *D. bracteatus*, *Vigna radiata* var. *sublobata*, *V. dalzelliana*, *V. bourneae*, *V. wightii*, *V. umbellata*, *V. aconitifolia*, *V. trilobata*, *V. capensis*, *V. pilosa*; wild population of fruit trees, *Artocarpus heterophyllus*, *Mangifera indica*, *Euphoria longan*, *Ziziphus rugosa*, *Z. xylopyra*, and others; *Solanum* spp., *Momordica cochinchinensis*, *Trichosanthes* spp; tuberous types *Amorphophallus campanulatus* and *A. bulbifer*; oilseed types, *Sesamum laciniatum* and *S. prostratum*; and others, like *Cinnamomum zeylanicum*, *Knema attenuata*, *Curcuma zedoaria*, *Zingiber cassumunar*, *Saccharum* spp; *Coix gigantea*, *C. lacryma-jobi* and *Panicum psilopodium*.

(b) Similipal and Jeypore Hill Forsts (Orissa) : *Oryza nivara*, weedy *O. rufipogon*; legumes *Atylosia* spp., *Mucuna pruriens*, *M. utilis*, *Vigna umbellata*, *V. radiata* var. *sublobata*, *V. capensis*, *V. trilobata*, *V. aconitifolia*; species of *Syzygium*, *Ziziphus*, *Abelmoschus*, *Solanum* (including primitive *potangi* type), *Luffa*, *Saccharum* and related types.

(c) The biosphere reserve in the North-western Himalaya would hold diversity in *Elymus dahuricus*, *Hordeum spontaneum*, *Ficus palmata*, *Bunium persicum*, *Vigna umbellata*, *Cucumis hardwickii*, *C. pubescens* and species of *Eremopyrum*, *Setaria*, *Rubus*, *Ribes*, *Pyrus*, *Ziziphus*, *Solanum*, *Coleus*, *Linum*, *Amaranthus*, *Chenopodium* and *Allium*.

(d) The biosphere reserves in North-eastern region would hold rich diversity in *Mucuna bracteata, Vigna umbellata, V. pilosa, V. capensis, V. radiata* var. *sublobata, Citrus assamensis, C. indica* and other species, e.g. *Myrica esculenta, Musa* spp., and warm sub-temperate types like *Pyrus, Prunus, Rubus* and others. Rich variability would be available in certain endemic species of *Trichosanthes, Neoluffa sikkimensis* and others, like *Piper, Curcuma, Dioscorea, Alpinia* and *Camellia,* and wild types in *Alocasia* and *Colocasia.* Also the variability in *Saccharum, Erianthus* and related types is well represented here.

(e) In the Gulf of Mannar and in the Sundarbans occur *Vigna luteola, Oryza rufipogon, Porteresia coarctata* and *Hygroryza aristata.*

Economic potential of wild relatives

The wild species are important as possible donors of drought hardiness, adaptability to cold and to certain exacting edaphic situation, e.g. *Porteresia coarctata* in the brackish waters of Sundarban delta; *Oryza nivara*, the annual wild rice, for resistance to rice tungro virus; *Vigna mungo* var. *sylvestris* and *V. radiata* var. *sublobata* exhibiting tolerance to yellow mosaic virus; *Abelmoschus tuberculatus* has contributed one genome to our present day cultivars of *A. esculentus* and is important in providing material tolerant to yellow vein mosaic virus; wild type of *Sesamum laciniatum* has been used for studies in the disease resistance of sesame, *S. indicum. Saccharum* and related genera *Ripidium, Sclerostachya* and *Miscanthus* are likely sources of disease resistance and drought tolerance *Saccharum spontaneum* and *S. munja.*

As sources of potential rootstocks and as breeding materials, the rich diversity in wild fruits needs to be studied in detail. More important genetic resources are *Artocarpus, Mangifera, Citrus and Musa* species, e.g. *Musa balbisiana, M. acuminata, Citrus indica, Mangifera sylvatica* and *Artocarpus heterophyllus* in the sub-tropical belt, and of pome and stone fruits (*Docynia, Pyrus, Prunus, Rubus, Ribes, Sorbus,* etc.) in sub-temperate/temperate belt. *Musa* germplasm from North-eastern region could prove to be drought and fire resistant, being subject to high bioedaphic stress under *jhum* (shifting) cultivation.

Rich diversity occurs in the wild relatives of Maydeae (group to which maize belongs). This Asiatic group of species of *Coix, Polytoca, Trilobachne and Chionachne,* needs more thorough study for traits like adaptability and disease resistance. Equally important are the wild Triticeae, mainly occurring in the Himalayas, including *Elymus and Eremopyrum* and the wild species in *Hordeum.*

Among cucurbits, rich diversity in *Luffa, Cucumis, Momordica, Trichosanthes* spp. and others needs to be screened. Detailed studies are yet to be carried out for disease resistant traits. Similar emphasis needs to be given to wild species of tuberous crops, ginger, *Curcuma* and related Zingiberaceae of which rich diversity exists in India.

Besides, wild tea genetic stocks occurring in the forests of North-eastern region, species of *Camellia* and even *Eurya,* may be important. Some of these could provide hardy root-stocks and even be used as sources of cold tolerance. Wild species of coffee, *Coffea bengalensis* and others, from the humid tropical belt, also need to be assessed for their use.

Some general considerations

The above account demonstrates the richness in species diversity in wild relatives in the Indian subcontinent. In order to effectively utilize such genetic resources related to cultivated plants, the primary emphasis has to be on the collection and conservation of this plant wealth.

In national context, primarily the National Bureau of Plant Genetic Resources (NBPGR) and the Botanical Survey of India (BSI), have been engaged in collecting wild species diversity from different regions. The NBPGR seed bank holds representative variation of several wild relatives. Apart from such *ex situ* conservation measures, *in situ* measures have also been stressed at national level. The site of a sanctuary/biosphere reserve for conservation of *Citrus* germplasm in Garo Hills (Meghalaya) in the North-eastern region has been identified. Further, the horticultural/vegetatively propagated materials are held by relevant ICAR Institutes/Centres such as Indian Institute of Horticultural Research at Bangalore for *Citrus* and *Musa* spp.; Banana Research Station at Kannara near Trichur under the Kerala Agricultural University for *Musa;* Central Institute of Horticulture for Northern Plains at Lucknow for *Mangifera* and sugarcane Breeding Institute at Coimbatore for *Saccharum* and related diversity in *Eriantus* and *Narenga.*

Collections of some wild species are also being maintained by several crop-based institutes such as the Central Rice Research Institute, Cuttack, for *Oryza*. The Botanical Survey of India also maintains some wild relatives or related species, such as the newly described taxa - *Oryza indandamanica* and other threatened species at its Regional Stations and Botanical Gardens. Wild species related to ICRISAT mandated crops have been collected jointly by NBPGR-ICRISAT in collaborative explorations, thus augmenting diversity in wild *Cicer*, *Atylosia*, *Pennisetum* and other species.

Conservation and sustainbale management of range of diversity in wild relatives requires specific strategies and dynamic approaches. Both *ex situ* and *in situ* measures need to be integrated effectively and also economically. While *ex situ* conservation is being done using long-term seed storage facility and field gene-banks, efforts have also been made in recent years for *in situ* conservation of these valuable materials. The Ministry of Environment and Forests has now assigned high priority to establishment and management of biosphere reserves in the country. While 14 such reserves have been identified representing biological diversity in different eco-climatic zones, twelve are established also. It will be ideal to conserve wild species diversity in these reserves and allow them to co-exist and evolve in their natural environment. In case of endangered species (rare and endemic taxa), it would be desirable to maintain and conserve such diversity in experimental plots within the biosphere reserve or in other analogous ecological niches. Population studies and periodic monitoring of genepools will form an important part of this programme. There is also a need to establish genetic gardens in different eco-climatic zones and these may possibly be nearer to the relevant biosphere reserves so as to conserve genetic diversity of wild relatives and other useful species in environments similar to their original habitats.

Of equal concern in conservation of plant genetic wealth are the species listed in Table 2, the distributional area for many of which for various bio-edaphic/ecological/socio-economic reasons is shrinking fast. Rehabilitation of such flora by adopting *ex situ* measures or through protection of habitats etc., i.e. *in situ* measures, is important. Particular emphasis will have to be given to unique element of such flora/rare endemic species in particular zones, like *Citrus* and *Musa* spp., in North-eastern region. Thus, it is felt that this floristic treatment of wild relatives of cultivated/crop plants, would prove useful in sorting out the priority areas/plants, for conservation vis-a-vis management of conservation strategies in national perspective.

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9. LESS KNOWN ECONOMIC PLANTS

(K. Thothathri)

Plants have been useful to men and animals from time immemorial. The importance of earth's green mantle and its role in keeping the oxygen and carbondioxide balance cannot be over emphasised. A lot of references, right from vedic period on man utilising plants for his livelihood such as food, shelter, clothing, etc. are available. Man has domesticated plants similar to what he did with animals.

India has rich plant resources, occurring in different climatic conditions. There are about 17000 flowering plants, estimated for the Flora of India and hardly 3000-3500 plants are utilised by man. Of these, majority are medicinal (*ca* 1500-2000 species as mentioned in Wealth of India). Edible plants such as cereals, pulses, oil-seeds, vegetables, fruits, etc. number 1500. There are about 200-250 timber yielding plants, 200 fodder plants, and about 500 plants used in tanning, gum and resin industry. However, majority of the plant species still remain less known economically if we review their role vis-a-vis man's utilisation. There are hardly 20-25 species of cereals still used by man for his staple food and he has not tried others, whereas many potential species still exist in the wild. Similar is the case of pulses and oil-seeds which figure in our daily requirements of food. Only in the case of fruits and vegetables we have been experimenting with more and more less known plants.

Tribals in India have been using quite a number of plants to cure their ailments and their knowledge is passed on orally to only a few in their generation. Of late quite a number of these plants have been subjected to chemical screening and a number of active principles (alkaloids, etc.) have been recorded, which are experimented in diseases like cancer, heart ailments, etc.

Grasses and legumes are the more important groups of plants used by man. The family of legumes shows maximum promise for producing the vastly increased supplies of vegetable protein that the world will need in the near future. In developing countries cultivation of legumes is best and quickest way to augment the production of food proteins. Food legumes, particularly the grain legumes or pulses, are important foodstuff in all tropical and subtropical countries where they are second in importance only to cereals as source of protein. In India in fact they provide the only high protein component of average diet and over 10 million tonnes are consumed annually.

Grain legumes have a high total protein content (average 20-26 per cent) and can be considered as a natural supplement to cereals since, although they are usually deficient in the essential amino acids methionine and cystine, they contain adequate amount of lysine. Whereas, cereals are deficient in lysine but contain adequate amount of methionine and cystine. The toxic principles, if any, in grain legumes are usually removed by cooking.

In addtion to their value as foodstuff, food legumes are also important in cropping system because of their ability to produce nitrogen and increase soil fertility, thereby partially replacing the use of expensive nitrogenous fertilisers.

With current food shortage, winged bean (*Psophocarpus tetragonolobus* L.) is of considerable interest as a high protein, multi purpose crop particularly suitable for cultivation in humid tropics where the incidence of protein deficiency in human diet is difficult to remedy. All parts are edible. Like soya bean, this could be utilised as source of edible oil and has a potential as a substitute if commercial production could be developed. In future winged bean could become as important as soya bean in world agriculture.

As tuber crop some of the legumes, which are normally known for their edible seeds or tender pods as vegetable, produce tubers which are protein rich as they fix nitrogen. Hence their exploitation as staple food crop offers a way to integrate into established root tuber crop diet that are much more nutritious. The whole topic of leguminous root crops calls for concentrated research by anthropologists, botanists, agronomists, plant breeders, food scientists, nutritional experts, etc. Species such as *Vigna vexillata* (L.) A. Rich., *Vigna marina* (Burm.) Merr., *Flemingia vestita* Benth. ex Baker etc. (Wild in Himalayan hills, but cultivated in Assam) are such tuber crops. The small and juicy tubers of *F. vestita* are edible and are rich source of iron and phosphorus, containing more than 3 times the protein of cassava. *Pueraria tuberosa* DC. has edible tubers with 11% protein.

Less known plants which would play a vital role in the field of food, medicine, forestry industry etc. have been catalogued under the following heads:

I. Food Plants
   A. Cereals
   B. Pulses
   C. Tubers
   D. Oil-seeds
   E. Vegetables
   F. Fruits and Nuts

II. Timber/Wood/Fire wood/Paper pulp yielding Plants
III. Medicinal Plants
IV. Fibre Plants
V. Fodder Plants
VI. Tannin/Gums/Resin/Latex yielding Plants
VII. Miscellaneous Plants
VIII. Multi purpose Plants.

I. Food plants

Cereals, pulses, tubers, vegetables, oil-seeds fruits and nuts fall under this category. Important but less known plants under each category are enumerated with notes on their potential.

A. *Cereals* : *Coix lacryma-jobi* L. is a good substitute for rice. *Echinochloa frumentacea* Link is a good millet crop in Punjab and Gujrat. Edible starch is obtained from *Hitchenia caulina* Bak., the Indian arrow root plant widely used in hilly area. *Tacca leontopetaloides* (L.) Kuntze, the tahiti arrow root is the source of edible and nutritive starch used for preparing bread cake, porridge, etc.

B. *Pulses* : *Canavalia ensiformis* (L.) DC., commonly known as the 'sword bean', can be cultivated for the edible seeds. This has a considerable future because of its suitability for cultivation in areas of low altitude, high temperature and relative humidity unsuitable for other legumes. *C. gladiata* (Jacq.) DC. can be similarly tried as a good pulse crop. *Vigna aconitifolia* (Jacq.) Marechal, *V. umbellata* (Thunb.) Ohwi & Ohashi are the other potential pulse crops.

C. *Tubers* : Some of the legumes which are normally known for their edible seeds and tender pods are also a good source of protein rich tuber as they fix nitrogen. Hence their exploitation as staple food crop offers a way to integrate into established root crop diets. Such tubers are produced by *Vigna vexillata* (L.) A. Rich. and *V. marina* (Burm.) Merr. *Flemingia vestita* Benth. ex Baker, wild in the Himalayas, is cultivated in Assam for the juicy edible tubers, rich in iron and phosphorus and contain, 3 times more protein than in cassava plant. *Pueraria tuberosa* DC. is again another important tuberous crop, rich in protein (11%). The edible tubers of *Dioscorea esculenta* Burkill were once a good substitute for potato before the latter was introduced into India. Similarly the tubers of *D. hamiltonii* Hook.f. are edible. In both the cases the tubers are to be cooked well to remove the poisonous alkaloid. The rhizomes of *Nymphaea stellata* Willd. constitute another source of famine food. The starchy tubers of *Scirpus grossus* L. are the staple food of tribals. The rhizomes of *Nelumbo nucifera* are used as vegetables and for making pickles.

D. *Oil-seeds* : Edible oil as well as oil for industry are available from a number of plants. India is yet to reach selfsufficiency in oil seed production and has to depend on import of edible oil. This can be rectified if we pay attention to few of the less known oil yielding plants. *Diploknema butyracea* (Roxb.) Lam. (Indian butter), yields the 'Phulwara butter, used in the manufacture of margarine, soap, candles, etc. Edible oil can be obtained from the seeds of *Aphanamixis polystachya* (Wallich) Parker. Myrtel oil, used in soap industry, is obtained from *Myrtus communis* L. Seeds of *Xanthium strumarium* L. are a good source of vegetable oil for soap, paint and varnish industry.

E. *Vegetables* : Leaves of *Houttuynia cordata* Thunb., *Sauropus androgynous* Merr. and *Gerardinia* spp. are used as a substitute for vegetables in Eastern India. Pods of *Prosopis cineraria* Druce and *P. chilensis* Kuntze are edible.

F. *Fruits and Nuts* : Good number of wild palnts yield edible fruits/nuts but their yield and taste require improvement through breeding. Fruits of *Carissa carandas* L. are used in jelly industry. Edible berries (Indian star apple) are from *Chrysophyllum cainito* L. The fruits of *Diospyros kaki* L. f., *Elaeagnus latifolia* L. and *E. umbellata* Thunb. are edible. The fruits of *Euphoria longan* Steud. and *Nephelium lappaceum* L. are edible like litchi. *Gmelina* *arborea* Roxb. and *Hippophae rhamnoides* L. yield fruits which are rich in carotene and vitamin 'C'. Cheap but nutritive fruit, rich in Vitamin 'C' are obtained from *Ziziphus mauritiana* Lam. Berries of *Myrtus communis* L. are edible. The fruits of the genus *Spondias [S. axillaris* Roxb., *S. pinnata* (L.f.) Kurz, *S. mombin* L., *S. cytherea* Sonn.], are edible like mango and can be improved through breeding. Nuts of *Castanopsis hystrix* DC. and seeds of *Euryale ferox* Salisb., are edible.

II. Timber/Fire Wood/Paper Pulp Plants

Just like cereals, our timber resources are based on few selected species. Further there is the ever increasing demand of firewood since conventional energy resources, like coal and petroleum products are getting diminished in stock. In this connection the following plants deserve special attention: *Alangium salvifolium* (L.f.) Wang (wood for agricultural implements), *Aphanamixis polystachya* (Wallich) Parker (Wood for dugout canoes, furniture, etc.), *Calophyllum apetalum* Willd. (wood for buildings, boat making), *C. elatum* Bedd. (for rafters, ceiling boards, etc.), *C. soulattro* Burm.f. (for making dugout canoes) and *Carallia brachiata* (Lour.) Merr. (timber for house building, agricultural implements, etc.). *Chlorophora excelsa* Benth. & Hook., a native of America and Africa recently introduced in India (timber much valued for making gun carriages, fine furniture, panels, etc.), *Dillenia pentagyna* Roxb., *D. indica* L., *Dolichandrone stipulata* Benth. (wood durable and used in many ways), *Duabanga sonneratioides* Buch.-Ham. (wood light and durable), *Echinocarpus dasycarpus* Benth. and *E. assamicus* Benth. (wood for planking, making tea boxes), *Hesperethusa crenulata* (Roxb.) Roem. (wood for axles of carts and walking sticks), *Heterophragma adenophyllum* Seem (wood for furniture and cabinet making), *Hopea odorata* Roxb. (Wood for boat building, rail sleepers, etc.), *Hymenodictyon excelsum* Wallich (wood for tea chests, planking, cheap furniture), *Machilus macrantha* Nees (wood for house, boat building, cabinet making, rail sleepers, etc.), *Nauclea sessilifolia* Roxb. (timber for planking, house building), *Olax ferruginea* Royle (wood for tool handles, boat building, carving, etc.) and *Schrebera swietenioides* Roxb. (timber valuable and used for various purposes such as weaver's looms, agricultural implements, building construction, etc.) are the other species worth consideration.

Plants such as *Daphne oleoides* Schreb., *D. papyracea* Wallich ex Steud., *Hedychium coronarium* Koenig and *Themeda arundinacea* (Roxb.) Ridley are good source of paper pulp.

Fire wood Crops : Non renewable sources of energy such as coal and petroleum are getting depleted gradually and people will have to depend on plants as fuel for cooking and heating. Growth of human population is far outpacing the growth of new trees in social forestry. People in industrialised nations have no idea how important fire wood is to the less developed countries. In poor/developing countries 90% of people depend on fire wood as their chief source of fuel. Fire wood scarcity is most acute in India. There are a number of plants less known but potentially important as fire wood for fuel, such as *Leucaena latisiliqua* (L.) Gillis and *Sesbania grandiflora* (L.) Merr. etc. These plants are future sources of fuel energy and they can be developed through social forestry/energy plantations, etc. The following deserve mention as fuel yielding species; *Casuarina equisetifolia* L., *Pongamia pinnata* (L.) Pierre, *Gmelina arborea* Roxb., *Rhizophora mucronata* Poir., *Bruguiera gymmnorhiza* (L.) Savigny, *Ceriops tagal* Robbins, *Sesbania bispinosa* (Jacq.) F.W. Wight, *Syzygium cumini* (L.) Skeels, *Alnus nepalensis* D. Don, *Grevillea robusta* A. Cunn., *Acacia nilotica* (L.) Willd. ex Del., *Acacia senegal* (L.) Willd., *Adhatoda zeylanica* Medik, *Albizia lebbek* (L.) Benth., *Anogeissus latifolia* (Roxb. ex DC.) Wallich ex Guillemin Perrottet, *Azadirachta indica* A. Juss., *Cajanus cajan* (L.) Millsp., *Cassia siamea* Lam., *Parkinsonia aculeata* L., *Pithecellobium dulce*, (Roxb.) Benth., *Prosopis cineraria* (L.) Druce, *P. juliflora* (Swartz) DC. and *Ziziphus mauritiana* Lam.

III. Medicinal Plants

Native plants have been used as medicine in Siddha, Ayurveda and Unani preparations. Their role and importance have increased in recent times for their efficacy. The following are potential but less knwon plants of medicinal value: *Acalypha indica* L. (skin disorders), *Alhagi pseudalhagi* (Bieb.) Desv. ex Baker (decoction of twigs and roots), *Allamanda cathartica* L. (root extract as anticancer), *Alstonia scholaris* R. Br. (leaf and bark), *Brucea javanica* (L.) Merr. (fruit and leaves), *Cadaba farinosa* Forsk. *C. trifoliata* Wight. & Arn., *Caesalpinia crista* L., *Capsella bursa-pastoris* Moench, (for haemorrhage and blood pressure), *Clerodendrum serratum* Moon (fever, rheumatism), *Crateva nurvala* Buch.-Ham. (bark), *Cryptocoryne wightiana* Thw. (Leaf oil in elephantiasis), *Dichroa febrifuga* Lour. (root antimalarial), *Dictamnus albus* L. (root and bark), *Didymocarpus pedicellata* R. Br. (leaf for stones in kidney and bladder), *Entada phaseoloides* Merr. (seeds), *Ficus glomerata* Roxb. (leaves and fruits), *Hamiltonia suaveolens* Roxb. (root and bark) etc. The genus *Hedyotis* is highly medicinal where plant's extract of *H. corymbosa* Lam., *H. herbacea* L., *H. umbellata* Lam. and *H. auricularia* L. is given in dysentry and cholera. *Hernandia ovigera* L., *Holostemma annularis* Schum. (roots), *Ichnocarpus frutescens* R. Br. (roots), *Ipomoea nil* Roth (seeds), *Jatropha curcas* L. (rhizome), *Jussiaea suffruticosa* L., *Matricaria chamomilla* L., *Melia azedarach* L. (leaf and gum), *Naregamia alata* Wight and Arn. (root, stem & leaves), *Operuculina turpethum* (L.) Silva Manso (Indian Jalab or Turpeth), *Oxalis acetosella* L. (leaves), *Peganum harmala* L. (whole plant), *Psoralea corylifolia* L. (seed oil in leucoderma), *Salvadora persica* L. (fruit and stem bark), *Scoparia dulcis* L. (amelin from leaves reduce blood sugar), *Securinega virosa* (Roxb.) Pax. & Hoffm. (several alkaloids from plant parts medicinal), *Semecarpus anacardium* L.f. (fruits), *Solanum indicum* L. and *S. khasianum* C.B. Clarke (alkaloid solasodine and solasonine used as alternative sources of steriods for the preparation of cortisone and steroid sex hormones), *Sphaeranthus indicus* L., *Stellaria media* (L.) Vill., *Stephania glabra* Miers (alkaloids from tubers), *Symplocos racemosa* Roxb. (leaves and bark), *Toddalia asiatica* Juss. (root bark), *Xeromphis spinosa* Keay (bark and fruits) and *Taraxacum officinale* Weber ex Wiggers (roots and rhizome), etc. The seeds and fruits of *Syzygium cumini* (L.) Skeels are effective in diabetes.

IV. Fibre Yielding Plants

Apart from the traditional fibre plants like jute, cotton, sunhemp, coconut there are other plants whose parts can be well utilised for extracting fibre. Some of them are *Abutilon indicum* (L.) Sw., *A. theophrastii* Medik., *Debregeasia hypoleuca* Wedd., *D. longifolia* Wedd. (bark fibre), *Helicteres isora* L. (bark), *Oreocnide integrifolia* Miq. (bark fibre for cordage), *Sida acuta* Burm.f. and *S. cordifolia* L., *Yucca gloriosa* L., *Y. aloifolia* L. and *Urena lobata* L. yield excellent fibre which can very well compete with jute.

V. Fodder Plants

Fodder and pasture grasses are the natural food for cattle. Under this category the following deserve attention : *Dactylis glomerata* L., *Dichanthium annulatum* Stapf, *Indigofera hirsuta* L., *Ischaemum rugosum* Salisb., *Iseilema laxum* Hack. (best fodder grass), and *Melilotus indica* All. *Pueraria phaseoloides*

Benth. is a good forage crop in addition to its being a green manure. *Exbucklandia populnea* (R. Br. ex Griff.) R.W. Brown and species of *Ficus* also provide good fodder.

VI. Tannin/Gum/Resin/Latex

Tannin is the backbone of many industries, the most important being that of leather industry. Indian plants are excellent source of tannin such as species of *Acacia (A. leucophloea* (Roxb.) Willd., *A. mearnsii* Willd. 35% in bark), *Bruguiera gymnorhiza* Lam. (bark 25-65%), *Caesalpinia digyna* Rottl., *C. pulcherrima* (L.) Sw., *Osyris wightiana* Wallich ex Wight. (leaves 20%), *Rhus javanica* L. (leaf galls contain quality tannin), *Sonneratia apetala* Buch. & Ham. (fruit and bark), *Soymida febrifuga* A. Juss., *Tamarix aphylla* (L.) Karst. and *T. troupii* Hole (bark and leaf galls).

Canarium benghalense Roxb., *Hopea odorata* Roxb., *Kingiodendron pinnatum* Harms (oleoresin) and *Vateria indica* L. are some of less known plants, yielding good resin.

Elaeodendron glaucum Pers., yields good gum. Latex from plants, such as *Castilla elastica* Cerv., *Cryptostegia grandiflora* R. Br., *Palaquium* sp. (Indian guttapercha of commerce) find use in industry. Wax from *Rhus succedanea* L. obtained from the mesocarp of fruits, is used in candle industry.

VII. Multipurpose Plants

Ailanthus altissima (Mill.) Swingle : The bark is medicinal and useful in cardiac troubles, diarrhoea, dysentry and as antispasmodic; the wood of the plant is used for general constructions, furniture, etc.; fruits and leaves are also medicinal. *Diploknema butyracea* (Roxb.) Lam. : the flowers are the source of honey; seeds yield a fat called 'Phulwa' or Phulwara butter, used in the manufacture of margarine, soap and candle industry. *Alangium salvifolium* (L.f.) Wang : the root bark is medicinal and used in cutaneous affections. It is also antituberculár; leaves are hypoglycaemic and fruits are astringent; seeds are tonic and yield a fatty oil; the wood is used for making agricultural implements. *Aphanamixis polystachya* (Wallich) Parker : the timber is durable and used for making dugout canoes, furniture, etc.; seeds yield an essential oil; bark is astringent and used in liver and spleen diseases and rheumatism. *Arenga pinnata* (Wurmb) Merr. : the tender leaves and sweet pith are edible; a syrupy liquid from the male inflorescence is a source of sugar; the starch from the trunk is a source of sago. *Bauhinia variegata* L. : the leaves constitute good fodder; roots and bark are medicinal; leaves and pods are eaten as vegetable; flowers are laxative; leaves are used in bidi industry; seeds yield a fatty oil. *Gmelina arborea* Roxb. : the wood is valuable and usded in planking, furniture, shafts, axils, etc.; the root is an important ingredient in 'Dasamula' tonic. *Myrtus communis* L.: the leaves being aromatic are used as flavouring agent, as well as in medicine; the berries are edible; wood is used in tannery; leaves and flowers yield the 'Myrtel oil' used as a flavouring agent in soap industry; the seeds produce a fatty oil. *Nypa fruticans* Wurmb : This is an alround economic plant but not much utilised. The leaves are excellent material for thatching; the sweet sap, tapped from the male spadix, is used for making jaggery, sugar, alcohol and vinegar. The palm is ready for tapping after 5 years and tapping can be continued upto 50 years. A palm similar to *Nypa* is *Phoenix sylvestris* Roxb. It is tapped for the sap which is source of palm jaggery and sugar. The sap can be fermented for production of alcohol and vinegar.

Pongamia pinnata (L.) Pierre : the plant yields the 'Pongam" oil used in tannin and soap industry, burning and as medicine. *Sapindus laurifolius* Vahl is the South Indian soap nut tree. The fruits, root and bark are medicinal. Saponin, extracted from the fruits has wide applications in textile industry and the nuts are used as detergent.

The genus *Sesbania* with its 2 species *S. grandiflora* (L.) Poir. and *S. bispinosa* (Jacq.) W.F. Wight is a very useful plant. The former, due to its fast growth, is rated high as a forage, green manure as well as fire wood crop. Young leaves and the large flowers are used as vegetable, the leaves containing 36% protein with high mineral and vitamin contents. The seeds contain 40% protein and used as poorman's food. Gum idential to gaur gum is obtained from *S. bispinosa*. The stem is used as fire wood and forms an excellent source of paper pulp for fibre board, hard board and particle board. *Xanthium strumarium* L. is a weed throughout India. Several parts of the plant are used in medicine, edible oil, etc. Decoction of the herb is useful in chronic malaria, leucorrhoea, urinary diseases, and as diuretic and sedative. Oil from the seeds is used in soap, paint and varnish industry. The oil cake is a good organic manure as it contains higher nitrogen content (8-10%). The fruits are rich in Vitamn 'C' leaves are astringent, diuretic and antisyphylitic and the root is a bitter tonic in cancer.

VII. Plants of Miscellaneous Uses

Many species of *Cassia* are good ornamentals and serve as handsome avenue trees. *Spathodea campanulata* Beauv. *Cochlospermum religiosum* Alston and *Lagerstroemia parviflora* Roxb. are similar ornamental plants. The stem of *Clinogyne dichotoma* Salisb. can be used for making fine mats. *Croton sparsiflorus* Morong, another weed can profitably be used for compost manure as it is rich in potash and nitrogen. Species of *Desmodium* are good manure as well as cover crops in plantations. Species of *Iphigenia* are a good source of colchicine, used in drug industry for cortisone. Roots of *Derris elliptica* Benth. and *D. ferruginea* Benth. yield rotenone which is a good insecticide. *Pongamia pinnata, Sesbania speciosa* Taub., *Tephrosia candida* DC. *T. vogellii* Hook.f. and *T. Purpurea* Pers. are good green manure and cover crops in plantations.

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10. ENDEMISM IN THE INDIAN FLORA

(M. Ahmedullah)

Generally, when a taxonomic unit is found to occur in a restricted area which is isolated by geographical or temporal barriers it is called endemic. As such, the restricted distribution of an endemic taxon separates it from a widely distributed species or cosmopolitan species. Conventionally an endemic taxon is one which occurs in a small restricted area, i.e. an island, a peninsula, a phytogeographical area or a mountain range.

Endemic elements of a region throw light on the biogeography of the area, centres of speciation, areas of extinction, vicariance and adaptive evolution of the flora and fauna of the area. The biogeographic evolution of an area also is known to influence the extant pattern of distribution of plants and animals, including their endemism.

Wegener's theory of Continental Drift helps explain plant distribution and endemism to a certain extent. According to the Continental Drift theory the Indian plate of the Gondwanaland, which comprises the present peninsular Indian region, broke up from the main landmass during the Cretaceous and moved North-eastward by Middle Eocene to crash against laurasia. As the Indian plate moved northward (traversing about 5900 km) it was subjected to various climatic drift, followed by volcanic eruptions causing the flow of deccan lavas and resulting in the loss of many Gondwanaland floristic groups. Fossils representing the Glossopterian flora have been found. Anyway, as the Indian plate crashed against Laurasia, the impact caused the upliftment of a mountain range the Himalayas. The upliftment of the Himalayas was a major event that reflected on land formation, river systems, climatic systems, etc. So much so that the Himalayan law preside over the ecology and biogeography of the whole Indian region. This also resulted in the extinction of some vulnerable plant/animal groups, evolution of flora/fauna, their migration through the new corridors afforded by the mountain chains and adaptive radiation of species in new ecological niches and *refugia*. These events may also be responsible for the creation of endemic elements in India.

The Himalayan uplift from Middle Eocene to Pleo-plistocene afforded creation of mountain chains which acted as corridors for the species of temperate Central Asia the North Mediterranean elements from the West and Sino-

Japanese elements from the North-east, acting as the genetic stocks for the evolution of new species complexes in areas of climatic and ecological striffs and functioning as remnants of floras in the different microclimates of the mountain system.

Theoretical Aspects of Endemism

Endemic taxa restricted to a particular island, mountain peak or isolated mountain range or peninsula may well be remnants of an ancient flora, which in the course of geological and climatic changes got isolated/restricted to a particular geographical region. This antiquity can be judged by its taxonomic isolation, nature of its habitat and possible fossil history. The endemic taxa occurring in such isolated/restricted areas are possible survivors of their ancient stock that occurred in continental areas subjected to cataclysmic geological and climatic changes. Another School of thought contends that endemics are newly evolved species. The concepts of endemic are many.

Earlier Concepts

The term *Endemic area* was used by De Candole (1855) for an area of a taxonomic unit, especially species, which has a restricted distribution or habitat, isolated from its surrounding region through geographical, ecological or temporal barriers. According to Engler (1882) there are two kinds of endemics : one based on the preservation of ancient forms, which may have originated in entirely different region and the other on the development of entirely new forms.

Drude (1890) described *relics* as those taxa that occur in disjunct areas; the intermediate link being lost by environmental or geological changes. Such elements that form discontinuous or disjunct genera or species were also termed as *endemisme par conservation* by Briquet (1908), *conservative* by Diels (1908), *relic* or *ancient endemism* by Herzog (1926) and as *palaeoendemics* by *Chevalier* and *Guenot* (1925). The last mentioned term (palaeoendemics) has survived the passage of time and continue to be used even today.

Similarly different terminologies were used to describe endemics that were supposed to have been newly evolved primarily through speciation. The newly evolved endemics were called *autochthonous endemics* by Engler (1882), *secondary endemics* by Drude (1890), *endemisme par novation* by Briquet (1908), *progressive endemics* by Diels (1908), *neoendemics* by Herzog (1926), Braun-Blanquet (1923) and Chevalier and Guenot (1925). This last term is still popularly used today.

Later-day concepts

The concept of endemism received further attention in the period starting from 1950. According to Wulff (1950) due to the phenomenon of vicariance and adaptive radiation some endemics, which for all purposes should normally be considered as palaeoendemics, appear as an evolving group of species, called *Active epibiotics*. Epibiotic species are relict species that undergo diversification. Favarger and Contandriopoulos (1961) studied endemism applying cytotaxonomic methods because this can throw light on the relative age and mode of speciation of endemic taxon. According to them, endemics can be classified as below :

(a) *Palaeoendemics :* Which are taxonomically isolated, show no variation and occur in isolated refugia.

(b) *Schizoendemics :* Which are produced by gradual speciation having common origin, but isolated in different ecological niches. They usually have identical chromosomes.

(c) *Patroendemics :* Parent endemics, i.e. diploids which give rise to polyploids.

(d) *Apoendemics :* Which are polyploids usually of hybrid origin, arising from widely distributed diploids.

Bramwell (1972) detailed the concept of palaeoendemic elements and their nature. Richardson (1978) described various kinds of endemics that are now popularly used in phytogeography.

In modern usage the terms *Palaeoendemic, Neoendemic* and *Holoendemic* find a very broad acceptance. These are elucidated below :

Palaeoendemics : These are ancient endemics representing remnants of older floras and usually occurring in land masses of geological antiquity. A large number of endemics are supposed to be palaeoendemics or their derivatives. According to Bramwell (1972) the characteristic features of palaeoendemic elements are : (i) taxonomically isolated complements having no closely related species, (ii) presence of woody life forms in isolated taxa occurring in islands and mountain summits (iii) low level of polyploidy, (iv) major disjunction in the distribution and (v) possible fossil evidence.

Neoendemics : These are newly evolved endemic taxa of relatively recent origin possibly from an actively evolving genetic stock occurring in a particular ecotone. Neoendemics have closely related taxa occurring in the same area. They also develop through speciation. A high level of polyploidy is found among neoendemics. They generally have herbaceous or shrubby forms and occur in an area which are often subject to environmental or climatic stresses.

Holoendemics : These are endemics that are in an intermediate stage between neoendemics and palaeoendemics. All endemics start as neoendemics and end as palaeoendemics. Under favourable conditions neoendemics stabilize and diversify. This is the stage of holoendemics. The pathway of neoendemics becoming palaeoendemics is : origin, expansion, stabilization, diversification, migration, fragmentation, contraction and extinction. There is no time scale for this pathway and taxa pass along the evolutionary pathway at different rates and a holoendemic could only be one step removed from the ancestor of the group, i.e. have a few "advance" or "derived" characters, while a contemporaneous role would be many steps removed, with numerous such characters (Richardson, 1978).

Endemism in Indian Flora

By virtue of its varied physiognomy and climate, India harbours a rich flora with a fairly high degree of endemism. Being bounded on the North by the Himalayas and with its peninsular part surrounded by the different oceans, the isolation of the Indian flora is enough to give rise to endemism.

Chatterjee (1940) pioneered the work on endemism in the Indian context. According to him the "British India" had 133 endemic genera of Angiosperms. According to Chatterjee (1940) approximately 61.5% of the Indian flora are endemic. However, Chatterjee dealt with British India which included India, Pakistan, Myanmar, etc. According to Takhtajan (1969) the Indian floristic region has about 150 endemic genera. Rao (1972) listed 164 enedmic genera for the Indian floristic region including Myanmar and Sri Lanka. According to Nayar (1980) there are 141 endemic genera in India. Acanthaceae and Poaceae have the highest number of endemic genera (17 genera each). *Pteracanthus* and *Nilgirianthus* (Acanthaceae) have the largest number of endemic species, i.e. 20 species each. About 110 endemic genera are monotypic.

As many as 15 genera are found to be endemic (although by and large spread throughout) to India as a whole. The genera restricted to India as a whole are :

Amischophacelus R.S. Rao & Kammathy (Commelinaceae)
Bentinckia Berry ex Roxb. (Arecaceae)
Caesulia Roxb. (Asteraceae)
Colebrookea Sm. (Lamiaceae)
Glossocardia Cass. (Asteraceae)
Hoppea Willd. (Gentianaceae)
Indochloa Bor (Poaceae)
Indoneesiella Sreem. (Acanthaceae)
Indopiptadenia Brenan (Mimosaceae)
Lophopogon Hack. (Poaceae)
Octotropia Bedd. (Rubiaceae)
Ougeinia Benth. (Papilionaceae)
Plesmonium Schott. (Araceae)
Porteresia Tateoka (Poaceae)
Trichopus O.E. Schulz. (Dioscoreaceae)

The genera *Bentinckia* and *Octotropia* show disjunction in their distribution : the former is found in Kerala and Nicobar Island, while the latter is distributed from Western Ghats to Assam.

Apart from the above genera that occur throughout the Indian region there are genera that are restricted exclusively to two major regions i.e. The Himalaya and Peninsular India.

Endemism in the Himalayas

The distribution of high altitude Himalayan flora was described by Rau (1974) as one of migration of floras, survival of relics, evolution of new taxa by an interaction between different floras and acclimatisation of species from lower altitudes. A fairly good degree of endemism is found in all the altitudinal zones of the Himalayan vegetation. According to Nayar (1980), about 67 genera (Appendix-I) are found restricted to the Indian Himalayas. Many genera with restricted distribution extend to Tibet, S.W. China, N.E. India and Myanmar.

About 40 genera are confined to the Eastern Himalayas while 11 genera are confined to the W. Himalayas. *Jaeschkea* and *Parajaeschkea* are examples of two endemic pairs with species complements adapted to different climatic zones of the Himalayas. The monotypic *Drimycarpus* and *Parrotiopsis* represent tree genera. *Listrobanthes, Megacodon, Pseudoachranthera, Pseudostachyum, Pteracanthus, Sympagis* and *Triaenanthus* represent genera with shrubby elements.

Genera with both woody and shrubby elements are : *Catamixis, Lacaitaea, Physolena, Pottingeria, Roylea* and *Trachycarpus*. The rest of the 53 genera comprise herbs are twiners. The genus *Catamixis* is on the verge of depletion (Ahmedullah & Nayar, 1985).

At the species level there are as many as 3,161 endemics restricted to the Himalayas (Chatterjee, 1940). A large number of these are threatened.

Endemism in Peninsular India

Next to the Himalayas, Peninsular India harbours a high degree of endemism. According to Chatterjee (1940) there are 34 endemic dicotyledonous genera. However, some of the genera listed by him (*l.c.*) i.e. *Adenoon, Calacanthus, Decaschistia, Diotocanthus, Goniocaulon, Megenia, Nothopegia* and *Stenosiphonium* have been found to be distributed outside the Indian region as well. Similarly, the genera *Beddomea, Neopottandra, Prossonus, Solenocarpus*, which are found in Chatterjee's list of endemic genera, have been reduced to the synonym of *Aglaia, Meineckia, Margaritaria* and *Spondias* respectively through later-day taxonomic revisions.

Detailed studies on the endemism in the Peninsular Indian flora came out recently (Ahmedullah & Nayar, 1987). According to this study, there are 55 genera which are endemic to Peninsular India (Appendix-II). Of these, 47 are monotypic. The families Poaceae with 13 genera and Acanthaceae with 9 genera have the highest representation of endemic genera in Peninsular India.

The endemic genera of Peninsular India comprise herbs, succulent scapigerous plants, shrubs, climbers and trees. Tree species are mainly represented by the genera *Poeciloneuron, Blepharistemma, Pseudoglochidion, Meteoromyrtus, Otonephelium* and *Erinocarpus*. Such woody life forms are generally reckoned to be relictual in nature. The genus *Poeciloneuron* with two tree species, viz. *P. indicum* and *P. pauciflorum* occur in the evergreen forests of southern W. Ghats. The mangrove member *Blepharistemma* with a single species (*B. membranifolia*) is an interesting endemic genus as this inland mangrove species has adapted to the lowland forest conditions of the southern W. Ghats.

Carvia, Nilgirianthus, Phlebophyllum, Taeniandra and *Xenacanthus* are represented by shrubs/undershrubs that form the components of the tropical rain forest of W. Ghats. The monotypic genus *Moullava* with its scandent habit is found growing in the secondary forests of the foothills of northern and central W. Ghats. *Baeolepis, Decalepis, Janakia, Oianthus* and *Seshagiria* are endemic genera of twining undershrubs.

Some of the endemic genera are very interesting. The genus *Frerea* is a monotypic genus with very few populations in Junnar hill fort, Mahabaleshwar, Purandhar hills and other adjoining localities in the northern W. Ghats. *Frerea indica* has a very poor fruit formation. However, it has a remarkable capacity to tide over the drought period. The capacity to root vegetatively has helpd it survive so far. *Frerea indica* is a good example of a palaeoendemic on the verge of extinction due to habitat loss and poor fruit set. The same is the case with the monotypic genus *Utleria* that is restricted to the Anamalai hills. *Hubbardia* is another good example of an extinction-prone endemic genus. Any alteration in its balanced habitat conditions can cause its extinction (Ahmedullah & Nayar, 1987).

On the other hand, genera like *Moullava, Lamprachaenium, Nanothamnus* and *Carvia* have successfully established themselves. There are examples of endemics that show successful adaptations for survival and spread (Ahmedullah & Nayar, 1987).

The phenomenon of palaeoendemic species becoming epibotic through vicarious speciation in different ecological niches is seen in the endemic genera *Glyphochloa* and *Manisuris*. The endemic species of *Glyphochloa (G. ratnagirica* and *G. santapaui)* occurring in the windward side of W. Ghats on exposed laterite soils as vicariads are different from the species (*G. goaensis*) occurring in Goa and those species (*G. divergens*) occurring in the sheltered hills of Goa and the species of *Manisuris* commonly seen in the plains of Andhra Pradesh and Tamil Nadu (Ahmedullah & Nayar, 1987). At the species level Peninsular India harbours as many as 1932 taxa, including 1758 taxa at species level and 144 taxa at infraspecific level (Ahmedullah & Nayar, 1987). The bulk of these endemics are found in the W. Ghats region, while only 76 taxa are endemic to the E. Ghats region, where endemics like *Cycas beddomei* are endangered (Ahmedullah & Nayar, 1987). Of the 1932 endemic taxa, 1384 belong to dicotyledones while 548 taxa belong to the monocotyledones. Families, like Poaceae, Rubiaceae, Acanthaceae, Orchidaceae and Leguminosae have the largest representation of endemic taxa in the region.

As many as 27 genera are commonly endemic to Peninsular India and Sri Lanka reflecting past geolgical connection (Nayar & Ahmedullah, 1985).

Appendix-I : Endemic Genera of the Himalayas

1. *Aechmanthera* Nees (Acanthaceae)
   3 species of small shrubs; temperate Himalaya.

2. *Arcyosperma* Schulz (Brassicaceae)
   1 species of leafy herbs; W. Himalaya.

3. *Biswarea* Cogn. (Cucurbitaceae)
   1 species of scandent herbs; E. Himalaya.

4. *Brachystemma* D. Don (Caryophyllaceae)
   1 species of branching subscandent herbs; C. and E. Himalaya.

5. *Bryocarpum* Hook.f. & Thoms. (Primulaceae)
   1 species of scapigerous herbs; E. Himalaya.

6. *Catamixis* Thoms. (Asteraceae)
   1 species of erect undershrubs; W. Himalaya.

7. *Cautleya* Royle (Zingiberaceae)
   5 species of herbs; Himalaya.

8. *Caulokaempferia* K. Larsen (Zingiberaceae)
   2 species of herbs; Khasi & Jaintia Hills.

9. *Cavea* W.W. Smith & Small (Asteraceae)
   1 species of herbs; E. Himalaya.

10. *Chionocharis* I.M. Johnston (Boraginaceae)
    1 species of herbs; alpine Himalaya.

11. *Cleisocentron* Brühl. (Orchidaceae)
    1 species of epiphytic herbs; E. Himalaya and Assam.

12. *Cortia* Hook.f. (Apiaceae)
    1 species of herbs; Himalaya.

13. *Craniotome* Reichb. (Lamiaceae)
    1 species of herbs; temperate Himalaya.

14. *Cryptochilus* Wallich (Orchidaceae)
    2 species of epiphytic herbs; Temperate Himalaya.

15. *Curcumorpha* A.S. Rao & Verma (Zingiberaceae)
    1 species of herbs; E. Himalaya and Assam.

16. *Cyathopus* Stapf (Poaceae)
    1 species of herbs; E. Himalaya.

17. *Didiciea* King & Prain (Orchidaceae)
    1 species of herbs; Himalaya.

18. *Diplomeris* D. Don (Orchidaceae)
3. species of hebs; tropical to temperate Himalaya.

19. *Drimycarpus* Hook.f. (Anacardiaceae)
1 species of trees; E. Himalaya.

20. *Edgaria* C.B. Clarke (Cucurbitaceae)
1 species of scandent herbs; E. Himalaya.

21. *Eriophyton* Benth. (Lamiaceae)
1 species of herbs; Alpine Himalaya.

22. *Esmeralda* Reichb. f. (Orchidaceae)
3 species of epiphytic herbs; E. Himalaya.

23. *Hemiphragma* Wallich (Scrophulariaceae)
1 species of herb; temperate Himalaya and Assam.

24. *Indofevillea* Chatterjee (Cucurbitaceae)
1 species of woody climbers; Assam.

25. *Indopolysolenia* Hook.f. (Rubiaceae)
1 species of undershrubs; E. Himalaya.

26. *Jaeschkea* Kurz (Gentianaceae)
3 species of herbs; Himalaya.

27. *Kashmiria* D.Y. Hong (Scrophulariaceae)
1 species of herbs; W. Himalaya.

28. *Khasiaclunea* Ridsd. (Rubiaceae)
1 species of under shrubs; Assam, Khasia hills.

29. *Lacaitaea* Brand (Boraginaceae)
1 species of under shrubs; E. Himalaya.

30. *Lepidostemon* Hook.f. & Thoms. (Brassicaceae)
1 species of herbs; E. Himalaya.

31. *Leptocodon* Lem. (Campanulaceae)
1 species of twining herbs; E. Himalaya.

32. *Listerobanthes* Bremek. (Acanthaceae)
1 species of shrubs; E. Himalaya and Assam.

33. *Meeboldia* H. Wolff. (Apiaceae).
1 species of herbs; W. Himalaya.

34. *Megacodon* (Hemsl.) H. Smith (Gentianaceae)
1 species of shrubs; Himalaya.

35. *Micholitzia* NE. Br. (Asclepiadaceae)
1 species of climbers; Assam.

36. *Microschoenus* C.B. Clarke (Cyperaceae)
1 species of herbs, W. Himalaya.

37. *Milula* Prain (Alliaceae)
1 species of herbs; Himalaya.
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38. *Neoluffa* H.L. Chakraverty (Cucurbitaceae)
1 species of scandent herbs; E. Himalaya.

39. *Notochaete* benth. (Lamiaceae).
1 species of herbs; E. Himalaya.

40. *Parajaeschkea* Burkill (Gentianaceae)
1 species of herbs; E. Himalaya.

41. *Parakaemferia* A.S. Rao & Verma (Zingiberaceae)
1 species of herbs; Assam.

42. *Paroxygraphis* W.W. Smith (Ranunculaceae)
1 species of herbs; E. Himalaya.

43. *Parrotiopsis* (Neid.) Schmeid. (Hamamelidaceae)
1 species of small trees; W. Himalaya.

44. *Pauia* Deb & R. Dutta (Solanaceae)
1 species of herbs; E. Himalaya.

45. *Pedinogyne* Brand (Boraginaceae)
1 species of herbs; E. Himalaya.

46. *Pentabothra* Hook.f. (Asclepiadaceae)
1 species of herbs; Assam.

47. *Picrorhiza* Royle ex Benth. (Scrophulariaceae)
2 species of herbs; W. Himalaya.

48. *Platystemma* Wallich (Gesneriaceae)
1 species of herbs; temp; W. Himalaya.

49. *Pleurospermopsis* C. Norman (Apiaceae)

50. *Polyura* Hook.f. (Rubiaceae)
1 species of herbs; E. Himalaya.

51. *Pseudaechmanthera* Bremek. (Acanthaceae)
1 species of shrubs; Himalaya.

52. *Pseudodanthonia* Bor & C.E. Hubbard (Poaceae)
1 species of herbs; W. Himalaya.

53. *Pseudostachyum* Munro (Poaceae)
1 species of shrubs; E. Himalaya.

54. *Pteracanthus* (Nees) Bremek. (Acanthaceae)
20 species of shrubs; Himalayas.

55. *Pycnoplinthus* O.E. Schulz. (Brassicaceae)
1 species of herbs; Himalaya.

56. *Roylea* Wallich (Labiatae)
1 species of undershrubs; Himalayas.

57. *Semperviella* Dunn. (Crassulaceae)
4 species of herbs; W. Himalaya.

58. *Smithiella* Dunn (Urticaceae)
1 species of herbs; E. Himalaya.

59. *Stilbanthus* Hook.f. (Amaranthaceae)
1 species of woody climbers; E. Himalaya.

60. *Stiptanthus* (Benth.) Briq. (Lamiaceae)
1 species of herbs; E. Himalaya.

61. *Sympagis* (Nees) Bremek. (Acanthaceae)
5 species of shrubs; E. Himalaya.

62. *Tarphochlamys* Bremek. (Acanthaceae)
1 species of undershrubs; E. Himalaya and Assam.

63. *Theropogon* Maxim. (Liliaceae)
1 species of herbs; temperate Himalaya.

64. *Thomsonia* Wallich (Araceae)
2 species of herbs; Himalayas.

65. *Treutlera* Hook.f. (Asclepiadaceae)
1 species of twining herbs; E. Himalaya.

66. *Triaenanthus* Nees (Acanthaceae)
1 species of shrubs; E. Himalaya and Assam.

Appendix-II : Endemic Genera of Peninsular India

1. *Anapyllum* Schott. (Araceae)
1 species of tall herbs; plains to S.W. Ghats.

2. *Ascopholis* Fisch. (Cyperaceae)
1 species of erect herbs; C. and S.W. Ghats.

3. *Baeolepis* Decne. ex Moq. (Periplocaceae)
2 species of climbing undershrubs; S.W. Ghats.

4. *Bhidea* Stapf. (Poaceae)
1 species of herbs; N. W. ghats.

5. *Blepharistemma* Wight ex DC. (Rhizophoraceae)
1 species of trees; W. ghats.

6. *Bonnayodes* Blatt. & Hallb. (Scrophulariaceae)
1 species of herbs; N.W. ghats.

7. *Campbellia* Wight
1 species of parasitic herbs; southern W. ghats.

8. *Carvia* Bremek. (Acanthaceae)
1 species of shrubs; N.W. Ghats.

9. *Chandrasekharania* Nair, Ramch. and Sreekumar
1 species of herbs; W. Ghats

10. *Danthonidium* C.E. Hubb. (Poaceae)
1 species of herbs; N.W. Ghats.

11. *Decalepis* Wight & Arn. (Periplocaceae)
1 species of climbing shrubs; Peninsular India.

12. *Dicoelospermum* C.B. Clarke (Cucurbitaceae)
1 species of climbing herbs; W. peninsular region.

13. *Diplocentrum* Lindl. (Orchidaceae)
1 species of epiphytic herbs; S.W. Ghats.

14. *Erinocarpus* Nimmo ex J. Grah. (Tiliaceae)
1 species of trees; C. & N.W. Ghats.

15. *Frerea* Dalz. (Asclepiadaceae)
1 species of herbs; N.W. Ghats.

16. *Gantelbua* Bremek. (Acanthaceae)
1 species of herbs; Peninsular India.

17. *Glyphochloa* W.D. Clayton (Poaceae)
8 species of herbs; W. Ghats

18. *Griffithella* (Tul.) Warm. (Podostemaceae)
1 species of herbs; W. Ghats.

19. *Haplothismia* Airy-Shaw (Burmanniaceae)
1 species of herbs; S.W. Ghats.

20. *Helicanthes* Danser (Loranthaceae)
1 species of parasitic shrubs; W. Peninsula India (W. Ghats)

21. *Hubbardia* Bor (Poaceae)
1 species of delicate herbs; C.W. Ghats.

22. *Hyalisma* Champ. (Triuridaceae)
1 species of saprophytic herbs; S.W. ghats.

23. *Hydrobryopsis* Engl. (Podostemaceae)
1 species of herbs; W. and E. Ghats.

24. *Indobanalia* Henry & B. Roy (Amaranthaceae)
1 species of undershrubs; S.W. Ghats.

25. *Indopoa* Bor. (Poaceae)
1 species of herbs; W. Ghats.

26. *Indotristicha* van Royan (Podostemaceae)
1 species of herbs; S.W. Ghats.

27. *Janakia* Joseph & Chandrasekaran (Periplocaceae)
1 species of herbs; S.W. Ghats.

28. *Jerdonia* Wight (Gesneriaceae)
1 species of scapigerous herbs; S.W. Ghats.

29. *Kanjarum* Ramam. (Acanthaceae)
1 species of undershrubs; S.W. Ghats.

30. *Lamprachaenium* Benth. (Asteraceae)
1 species of herbs; Peninsular India.

31. *Limnopoa* C.E. Hubb. (Poaceae)
1 species of aquatic herbs; S.W. Ghats.

32. *Meteoromyrtus* Gamble (Myrtaceae)
1 species of small trees; S.W. Ghats.

33. *Manisuris* L. (Poaceae)
1 species of herbs; Peninsular India.

34. *Moullava* (Rheed) Adans. (Caesalpiniaceae)
1 species of scandent shrubs; W. Ghats.

35. *Nanothamnus* Thoms. (Asteraceae)
1 species of herbs; W. Ghats.

36. *Nilgirianthus* Bremek. (Acanthaceae)
20 species of shrub; W. Ghats.

37. *Normanboria* Butzin (Poaceae)
1 species of herbs; Tamil Nadu.

38. *Ochreinauclea* Ridsd. & Bakh.f. (Rubiaceae)
1 species of small trees; C. and S.W. Ghats.

39. *Olanthus* Benth. (Asclepiadaceae)
4 species of twining undershrubs; W. Ghats extending to E. Ghats.

40. *Otonephelium* Radlk. (Sapindaceae)
1 species of trees; S.W. ghats.

41. *Paracautleya* R.M. Smith (Zingiberaceae)
1 species of herbs; C.W. Ghats.

42. *Phlebophyllum* Nees (Acanthaceae)
    8 species of shrubs; W. and E. Ghats.

43. *Pleocaulus* Bremek. (Acanthaceae)
    3 species of small undershrubs; W. Ghats.

44. *Poeciloneuron* Bedd. (Bonnetiaceae)
    2 species of large trees; C. and S.W. Ghats.

45. *Pogonachne* Bor (Poaceae)
    1 species of herbs; coast of Maharashtra.

46. *Polyzygus* Dalz. (Apiaceae)
    1 species of herbs; C. and N.W. Ghats.

47. *Proteroceras* Joseph & Vajravelu (Orchidaceae)
    1 species of herbs; S.W. Ghats.

48. *Pseudodichanthium* Bor (Poaceae)
    1 species of herbs; N.W. Ghats

49. *Pseudoglochidion* Gamble (Euphorbiaceae)
    1 species of trees; S.W. Ghats (Annamalai)

50. *Santapaua* Balakr. & Subram. (Acanthaceae)
    1 species of herbs; Alayar hills.

51. *Seshagiria* Ansari & Hemadri (Asclepiadaceae)
    1 species of climbing undershrubs; N.W. Ghats.

52. *Silentvalleya* V.J. Nair *et al.* (Poaceae)
    1 species of herbs; S.W. Ghats (Silent Valley).

53. *Taeniandra* Bremek. (Acanthaceae)
    1 species of undershrubs; S.W. Ghats.

54. *Trilobachne* Schnek ex Henr. (Poaceae)
    1 species of herbs; W. Peninsular region.

55. *Triplopogon* Bor (Poaceae)
1 species of herbs; W. peninsular India.

56. *Utleria* Bedd. ex Benth. (Periplocaceae)
1 species of shrubs; S.W. Ghats.

57. *Vanasushava* Mukherjee & Constance (Apiaceae)
1 species of herbs; S.W. Ghats.

58. *Willisia* Warm. (Podostemaceae)
1 species of herbs; S.W. Ghats.

59. *Xenacanthus* Bremek. (Acanthaceae)
3 species of shrubs; S.W. Ghats.

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11. EXOTICS - INTRODUCED AND NATURAL IMMIGRANTS, WEEDS, CULTIVATED, ETC.

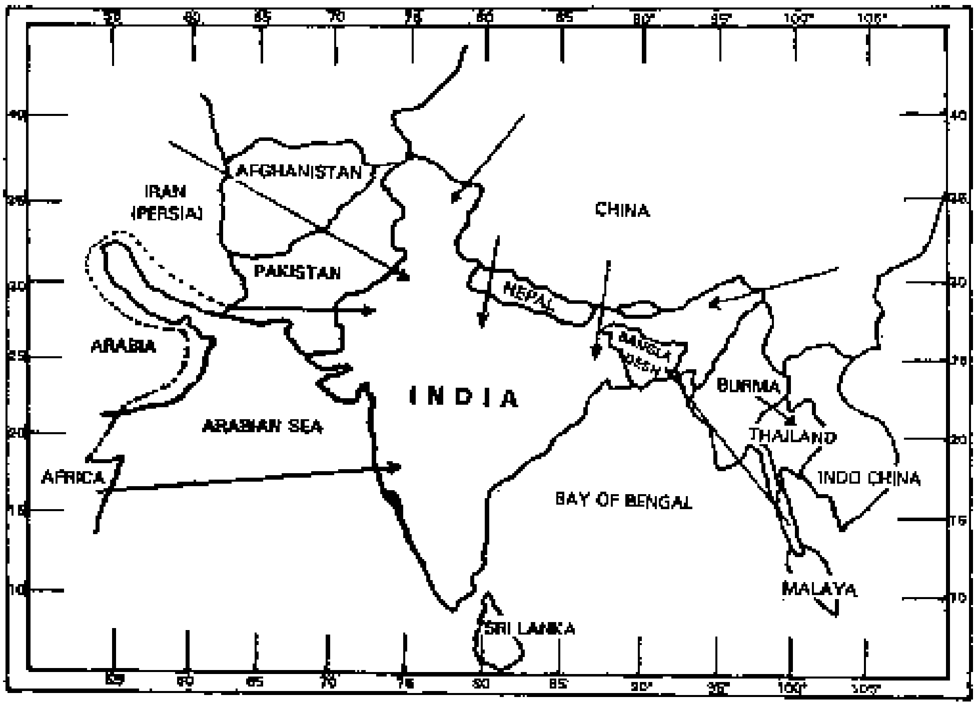
(D.S. Pandey)

The flora of India is very rich and varied on account of varied altitudinal, edaphic and climatic conditions. It has been considered that India is a region of the Indo-Malayan sub-kingdom under the palaeotropical kingdom (Good, 1947). Hooker (1904) and Champion and Trevor (1938) are of the view that flora of India is merely mixture of the surrounding countries, viz., Malaya, Africa, Tibet, China and Japan and there is no Indian flora as a separate entity. It is estimated that India has approximately 46,000 plant species, of which about 17,000 are vascular plants and ca 5,000 species are endemic (Nayar & Sastry, 1987). Indian flora shows ca 61.5% of endemism (Chatterjee, 1939), whereas Blasco (1971) considers only about 59% species endemic to India. Many species thought to be endemic are either reduced or located in the adjoining geographical territories (Nayar, 1977). The lofty mountain ranges in the North and presence of sea on its three sides provide an ideal situation for the preservation of an unique flora. However, Chatterjee (l.c.) considered that there was originally a typical Indian flora, which became masked by plant invasions from the surrounding countries.

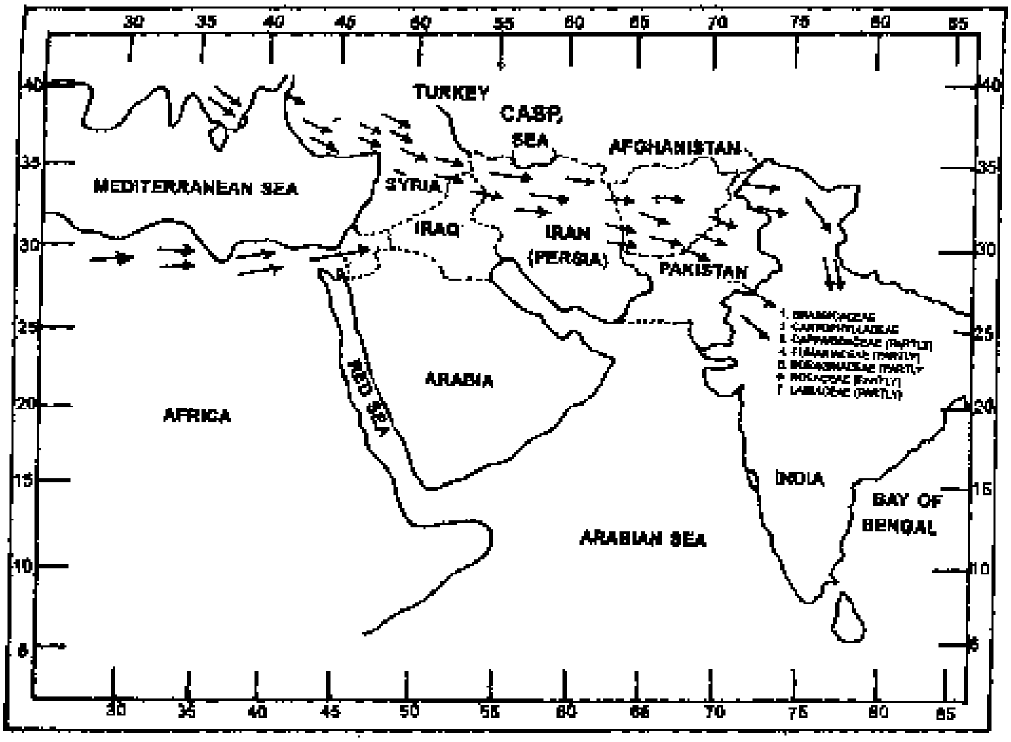
There are many foreign elements in Indian flora, brought mainly by Portuguese, Spaniards, Dutch, French and Englishmen either knowingly or unknowingly. Even prior to the settlement of Jesuit missionaries and early European explorers, a good number of economic plants were brought by the Aryan settlers from the countries lying North-west of India.

Although the great natural barriers (mountain ranges, sea and deserts) have protected the indigenous flora, yet land mass connections in the north and the west have provided migratory routes to many exotic elements from North-East Africa or West Asia, and South-West China by way of Arabia, Afghanistan, Kashmir and North Myanmar and North-East India respectively. the migration of flora might have occurred due to land bridge connections. Since all continents are or at least were connected during the Ice Age, through two wide terrestrial land bridges and one very wide insular isthmus, viz. the Panama isthmus linking the Americas, Beringia connecting North Asia and North America, and the Malaysian Archipelago joining Asia and Australia (van Steenis, 1962). In course of several years these elements got acclimatised, distributed gradually, from one place to other with the aids of wind, water and natural agencies, sometimes even eliminating the indigenous flora. As such, large number of species have come to India from the surrounding countries (Map 14), viz., Myanmar, Malaya, South-West China, Eastern China, Japan, West Asia, Sri Lanka and Africa. Although the vegetation of most of these regions is very different from India, none the less, the great influence of these countries on the flora of India is evident (Chatterjee, 1939; Mukerjee, 1940). Chatterjee (1947) is of the view that species originating in East Mediterranean regions, which had migrated both east and westwards mostly belong to the family Brassicaceae, Caryophyllaceae, Capparaceae, Fumariaceae, Boraginaceae, Rosaceae and Lamiaceae (Map 15). For example *Arabidopsis wallichii* (Hook.f. & Thoms.) N. Busch., *Arenaria serpyllifolia* L., *Brassica tournefortii* Gouan, *Capsella bursa-pastoris* Moench., *Cardamine impatiens* L., *Cerastium trigynum* Vill., *C. dahuricum* Fisch., *Descurainia sophia* (L.) Webb ex Prantl, *Dianthus caryophyllus* L., *D. orientalis* Adams, *D. crinitus* Sm., *Erophila verna* (L.) Besser, *Erysimum repandum* L., *Farsetia jacquemontii* Hook.f. & Thoms. ssp. *edgeworthii* (Hook.f. & Thoms.) Jafri, *Fortuynia aucheri* Schuttl., *Lepidium latifolium* L., *Lychnis apetala* L., *L. coronaria* Desr., *Malcolmia africana* Br.; *Matthiola odoratissima* R. Br., *Moricandia arvensis* DC., *Rorippa nasturtium-aquaticum* L., *Neslia paniculata* Desv., *Silene araenosa* C. Koch, *S. conoidea* L., *S. vulgaris* (Moench.) Garke, *Sisymbrium irio* L., *S. loeselii* L., *Stellaria aquatica* (L.) Scop., and *S. bulbosa* Wulfen. are some of the species which are found extending from West Asia to India.

East Brazilian, Mexican and African weeds might have got introduced into India through Portuguese ships. Mexican weeds began to get introduced into India when they touched and passed through Mexico. Later, these ships touched at the Cape of Good Hope to get supplies, as such many African weeds too got picked up. Many of South American, Mexican and African plants of economic value were brought by the Spaniards, Dutch, the French and European personnel and along with them many species of weeds came to India, established and sometimes got widely spread and ultimately became part of Indian flora. This process of introduction of alien weeds, initiated some 450 years back, is still active and will doubtlessly continue indefinitely. The modern man has thus become the greatest single agency in the distribution of plants throughout the world (Srivastava, 1964).



Map 14. Possible routes of migration of plants into India (after Chatterjee, 1939).



Map 15. Possible routes of migration of floristic elements from Middle-East Asia and North East Africa and its influence on Indian Flora (after Chatterjee, 1947).

A large number of exotic weeds have also been introduced, either intentionally as ornamental plants or accidentally with food grains, ballast, packing materials, seeds of economic plants or by adhering to clothing of men and hairs of domestic animals. Among such ornamental plants which were first introduced in the Indian Botanic Garden, Howrah and then became wild and naturalized are : Wild Morning-Glory, *Convolvulus arvensis* L. (Europe and continental Asia, introduced probably in 1804 by W. Hamilton Esq.); *Ipomoea carnea* ssp. *fistulosa* (Mart. ex Choisy) Austin (America, cultivated since 1879); Wild Sage, *Lantana camara* L. var. *aculeata* (L.) Mold. (South American Shrub, introduced in 1809 by W. Hamilton Esq.); Devil's-Claw, *Martynia annua* L. (Mexico, Brazil, Tropical America, introduced in 1802 by W. Hamilton Esq.); Rouge Plant, *Rivinia humilis* L. (South American plant, introduced during 1800 by W. Hamilton Esq.); Water Hyacinth, *Eichhornia crassipes* (Mart.) Solms. (Brazilian plant, first introduced in Dacca towards the 19th century as an ornamental plant now spread all over India); Carrot Weed, *Parthenium hysterophorus* L. (an American weed, appeared accidentally in the Indian Botanic Garden, Howrah in the year 1810 (Roxburgh, 1814); *Portulaca oleracea* L. and *Medicago lupulina* L. (European weed, introduced into India as impurity of vegetable seeds); *Gnaphalium purpureum* L. (tropical American weed, supposed to have been introduced with the American cotton seeds); *Anagallis arvensis* L. (European and Mediterranean region, introduced by the early Dutch settlers from the East Indies as impurity of vegetable seeds); *Croton bonplandianum* Baill. (reached into India through ballast of mud from South America in the year 1897), etc. have become common in Indian flora by natural means of dispersal (Ridley, 1930; Roxburgh, 1814; Maheshwari & Paul, 1975; Sharma & Pandey, 1984). Maheshwari (1962) considers that deforestation, faulty pasturage methods, shifting cultivation, faulty methods of harvesting, construction of roads and railway lines and continuous sowing of impure seeds are the main factors responsible for the spread and increase of alien plants in India. The first systematic enumeration of exotic weeds was given by Bruhl (1908) followed by others like, Kashyap (1924), Biswas (1934), Maheshwari (1961), Srivastava (1962), Rajagopal and Panigrahi (1965), Matthew (1969), Maheshwari and Paul (1975), Murti (1975), Maity and Guha Bakshi (1981) and Sharma and Pandey (1984). Chatterjee (1947) gives 38% of foreign plants which have naturalized in India. Maheshwari (1962, 1963) has stated 27% naturalized and introduced plants in the Flora of Delhi. Sharma and Pandey (1984) mentioned 38.16% of cultivated and aliens/exotics in the Flora of Allahabad District, whereas Maheshwari (1962) states that ca 40% of the flowering plants are foreign and naturalized in various parts of the country. Nayar (1977) states that ca 18% of Indian flora constitutes adventive aliens of which about 55% are American, 10% Asian, 20% Asian and Malesian and 15% European and Central Asian species.

These naturalized species, mostly weeds and other exotics, are grouped into the followirng categories :

I. Neo-Tropical
II. North-Temperate
III. North-African, Afro-Asian and Australian
IV. Tropical and South African
V. Austro-Asian
VI. Escape and run-wild from cultivation
VII. Recently introduced weeds
VIII. Other agri-horticultural, economic and medicinal plants

I. NEO-TROPICAL

(Mexico, Brazil, South America, Central America, Tropical America).

Species naturalized throughout India :

Acacia farnesiana (L.) Willd. (Tropical America), *Acanthospermum hispidum* DC. (South America), *Adenostemma lavenia* (L.) Kuntze (South America), *Ageratum conyzoides* L. (South America), *Aloe vivipara* L. (Central America), *Alternanthera ficoidea* (L.) R. Br. (South America and West Indies), *A. paronychioides* St. Hill (Brazil), *A. pungens* Kunth (Tropical America), *Argemone mexicana* L. (Mexico, Central America and West Indies), *Bidens pilosa* L. (probably America), *Blainvillea acmella* (L.) Philipson (South America), *Bromus unioloides* (South America), *Cardiospermum halicacabum* L. (South America), *Cassia hirsuta* L. (Tropical America), *C. occidentalis* L. (South America), *C. tora* L. (Tropical America), *Cissampelos pareira* L. (South America), *Chromolaena odorata* (L.) King & Robinson (Jamaica), *Conyza bonariensis* (L.) Cronq. (Tropical America and Argentina), *Coronopus didymus* (L.) Smith (Tropical America), *Crassocephalum crepidioides* (Benth.) Moore (Tropical America), *Croton bonplandianum* Baill. (Paraguay), *Datura innoxia* Mill. (Mexico), *D. metel* L. (Tropical America), *Desmanthus virgatus* (L.) Willd. (Tropical America)

Digitaria ciliaris (Retz.) Koel. (Tropical America), *Eichhornia crassipes* (Mart.) Solms. (Tropical and Sub-tropical America), *Eclipta prostrata* (L.) L. (South America), *Erigeron canadensis* L. (North America), *E. karvinskianus* DC. (Mexico to Panama), *Eupatorium trapezoideum* Kunth (probably Mexico), *Euphorbia heterophylla* L. (Tropical America), *E. hirta* L. (Tropical America), *E. thymifolia* L. (probably Tropical America), *Galinsoga parviflora* Cav. (Tropical America), *G. quadriradiata* Ruiz & Pavon (Mexico), *Gnaphalium purpureum* L. (Tropical America), *Heliotropium indicum* L. (America), *Ipomoea carnea* spp. *fistulosa* (Mart. ex Choisy) Austin (South America), *I. congesta* R. Br. (South America), *Jatropha heterophylla* Steud. (Tropical America), *J. gossypifolia* L. (Brazil), *Lantana camara* L. var. *aculeata* (L.) Mold. (South America), *Leonotis nepetaefolia* (L.) Ait. f. (probably Tropical America), *Lepidium virginicum* L. (North America), *Leucaena latisiliqua* (L.) Gills (Tropical America), *Martynia annua* L. (Mexico, Brazil, Tropical America), *Mimosa pudica* L. (Brazil), *Oenothera rosea* Ait. (Texas and Peru), *Opuntia dillenii* Ker-Gawl. (South America), *Oxalis corniculata* L. (South Europe and North America), *O. debilis* H.B. & K. var. *corymbosa* (DC.) Lourt. (Brazil), *O. latifolia* H.B. & K. (Brazil), *Parthenium hysterophorus* L. (West Indies, Central and North America), *Peperomia pellucida* (L.) H.B. & K. (Central America), *Pilea muscosa* Lindl. (Tropical America), *Pithecellobium dulce* (Roxb.) Benth. (Central America), *Scoparia dulcis* L. (South America), *Sida cordata* (Burm.f.) Borssum (Tropical America), *Tridax procumbens* L., and *Xanthium strumarium* L. (South America).

Species naturalized in some parts of India :

Abutilon cirspum (L.) Medik. (Tropical America), *Anacardium occidentale* L. (Brazil), *Ageratum houstonianum* Mill. (Mexico), *Agave angustifolia* Haw. (probably Central America), *Agave vera-cruz* Miller (Mexico), *Annona squamosa* L. (Tropical America and West Indies), *Aeschynomene americana* L. (America), *Argemone ochroleuca* L. (Mexico), *Bidens sulphurea* (Cav.) Sch.-Bip (Central America), *Calceolaria mexicana* Benth. (Mexico), *Cassia alata* L. (South America), *C. coluteoides* Collad. (South America), *C. sophera* L. (probably America), *C. tomentosa* L.f. (Tropical America), *Calpogonium muconoides* Desv. (America), *Centrosema pubescens* Benth. (Tropical America), *C. viriginianum* (L.) Benth. (Tropical America), *Cestrum diurnum* L. (West Indies), *C. fasciculatum* (Schlcht.) Miers. (Mexico), *Conyza sumatrensis* (Retz.) Walker (South America), *Chromolaena adorata* (L.) Robinson (Tropical America), *Corchorus aestuans* L.

(Tropical America), *Crotalaria anagyroides* Kunth (Tropical America), *Dahlia imperialis* Roezel (Mexico), *D. suaveolens* H.B. ex Willd. (Mexico), *D. tatula* L. (Central America), *Desmodium tortuosum* (Swartz) DC. (Tropical America), *Eruca vesicaria* (L.) Cav. ssp. *sativa* (Mill.) Thel. (South America), *Eupatorium capillifolium* (Lam.) Small (Tropical America), *E. glandulosum* H.B. & K. (South America), *E. ligustrinum* DC. (Central America), *Euphorbia geniculata* Orteg. (Tropical America), *E. prostrata* Ait. (Tropical America), *Evolvulus nummularius* L. (West Indies), *Flaveria trinervia* (Spreng.) Mohr. (Tropical America), *Fuchsia boliviana* Carr. var. *luxuriens* Johnston (Jamaica), *Furcraea foetida* (L.) Haw. (South America), *Helianthus cucumerifolius* Torr. & Gray (North America), *Heliotropium curassavicum* L. (West Indies), *Hyptis suaveolens* Poit. (South America), *Ipomoea coccinea* L. (Tropical America), *I. purpurea* Roth (Tropical America), *I. quamoclit* L. (Tropical America), *Iseilema laxum* Hack. (Tropical America), *Jatropha curcas* L. (Tropical America), *Lagascea mollis* Cav. (Mexico), *Lantana trifoliata* L. (Tropical America), *Lepidium virginicum* L. (North America), *Lippia javanica* (Burm.f.) Spreng. (Tropical America), *Malachra capitata* L. (Tropical America), *Malvastrum coromandelianum* (L.) Garcke (West Indies), *Mecardonia procumbens* (Miller) Small (Tropical America), *Mikania cordata* B.L. Robinson (Tropical America), *Mimosa diplotricha* C. Wright ex Sauv. var. *inermis* (Adelb.) Veldk. (South America), *M. invisa* C. Martius ex Colla (Tropical America), *Montanoa bipinnatifida* C. Koch (Mexico to Columbia), *Neptunia pleno* (L.) Benth. (Tropical America), *Nicotiana glauca* Graham (Tropical America), *N. plumbaginifolia* Viv. (Tropical America), *Oenothera odorata* Jacq. (South America), *O. rosea* Soland (Peru), *O. tetraptera* Cav. (Mexico and South America), *Opuntia vulgaris* Mill. (North America), *Oxalis deppei* Lodd. (Mexico), *O. pubescens* H.B. & K. (South America), *Parkinsonia aculeata* L. (Tropical America), *Passiflora subulata* Ortega (Mascarne Islands), *Passiflora mollissima* (H.B. & K.) Bailey (Western Tropical South America), *P. morifolia* Mast. (South America), *Physalis minima* L. (South America), *Prosopis glandulosa* Torrey (Tropical America), *P. juliflora* (Swartz) DC. var. *juliflora* (Tropiacl America), *P. juliflora* (Swartz) DC. var. *horrida* (Kunth) Burkart (Peru), *Psidium guajava* L. (Tropical South America), *Rivina humilis* L. (Tropical America), *Rauvolfia tetraphylla* L. (West Indies), *Romneya couteri* Harv. (South California and Mexico), *Ruellia tuberosa* L. (Tropical America), *Solanum hispidum* Pers. (Central America), *S. jasminoides* Paxt. (South America), *Solidago microglossa* DC. (Brazil), *Soliva anthemifolia* (Juss.) R. Br. ex Less (South America), *Sorghum halepense* (L.) Pers. (Tropical America and

Mediterranean regions), *Stachytarpheta indica* Vahl (South America), *Stylosanthes sundaica* Taub. (South America), *Stenolobium stans* Seem. (South America), *Synedrella nodiflora* Geartn. (Tropical America), *Tagetes minuta* L. (South America), *Tithonia rotundifolia* (Mill.) Blake (Central America), *T. tagetiflora* Desf. (Mexico), *Turnera ulmifolia* L. (Brazil), *Verbesina encelioides* (Cav.) Gray (Tropical America), *Vigna adenantha* (G.F. Meyer) Marechal *et al.* (South America), *Volvulopsis numularia* (L.) Roberty (Tropical America), *Wissadula periplocifolia* (L.) Presl. ex Thw. (Tropical America).

II. NORTH TEMPERATE

(Europe, Mediterranean regions, South Europe, Temperate region)

Species naturalized throughout India :

Anagallis arvensis L. (Europe and Mediterranean regions), *Capsella bursa-pastoris* (L.) Medik. (Temperate and Arctic Europe), *Convolvulus arvensis* L. (Europe, Continental Asia, Old World and Temperare region), *Digitalis purpurea* L. (Western and Central Europe), *Fumaria indica* (Hassk.) Pugsley (North Temperarte region), *Lathyrus aphaca* L. (Europe), *L. odoratus* L. (Italy and Sicily), *Malus sylvestris* (L.) Mill. (Europe and Temperate Asia), *Medicago polymorpha* L. (Europe), *Melilotus alba* Desr. (Europe and Temperate Asia) *M. indica* (L.) Ali (South Europe & South Western Asia), *Phalaris minor* Retz. (Mediterranean regions), *Silene gallica* L. (Europe), *Spergula arvensis* L. (Europe), *Stellaria media* (L.) Villars (Europe), *Trifolium dubium* Sibth. (Europe & Caucasus), *Vaccaria pyramidata* Medik. (Europe).

Species naturalised in some parts of India :

Briza minor L. (Mediterranean regions), *Chamaecytisus hirsutus* (L.) Link (Europe), *Hypochoeris glabra* L. (South Europe and Mediterranean regions), *Lepidium ruderale* L. (Europe), *Macroptilium lathyroides* (L.) Urban var. *lathyroides* (Europe), *Medicago lupulina* L. (Europe), *M. polymorpha* L. var. *apiculata* (Willd.) Van Dost & Reich. (Europe), *Poa annua* L. (Europe and Temperate Asia), *Polycarpon tetraphyllum* (L.) L. (Europe), *Polygonum hydropiper* L. (Temperate region), *Rhamnus persica* Boiss. (South Europe and North Africa), *Sarothamnus scoparius* (L.) Koch. (Europe), *Taraxacum officinale* Weber (Europe), *Teline monspessularia* (L.) K.H.E. Koch. (Europe), *Trifolium* *hybridum* L. (Europe and Continental Asia), *T. inacarnatum* L. (Europe), *T. subterraneum* L. (Mediterrancan regions), *T. tomentosum* L. (Europe), *Ulex europeus* L. (Europe), *Verbascum thapsus* L. (Europe and Asia), *V. virgatum* Stokes (Central and Western Europe), *Veronica anagallis-aquatica* L. (Temperate region), *Vicia villosa* Roth (Europe).

III. NORTH-AFRICAN, AFRO-ASIAN AND ARABIAN

Species naturalized throughout India :

Cleome monophylla L. (Afro-Asia), *Digera muricata* (L.) Mart. (Asia and Tropical Africa), *Emilia sonchifolia* (L.) DC. (Africa and Asia), *Eragrostis tenella* (L.) P. Beauv. ex R. & S. (Africa and Asia), *Laggera aurita* Sch.-Bip. (Afro Asia), *Merremia gangetica* (L.) Cufo. (Afro - Asia), *Portulaca oleracea* L. (North Africa), *Pupalia lappacea* (L.) Juss. (Afro-Asia), *Polypogon monspeliensis* (L.) Desf. (Temperate parts of Asia, Africa and Europe), *Sphaeranthus senegalensis* DC. (Africa), *Vicia hirsuta* Gray and *V. sativa* L. (West Africa and Europe).

Species naturalized in some parts of India :

Aristida adscensionsis L. (North Africa), *Cymbopogon martinii* (Roxb.) Wats. (Afro-Asia), *Indigofera linnaei* Ali (Afro-Asia), *Ipomoea carica* (L.) Sweet (Afro-Asia), *Jatropha glandulifera* Roxb. (Afro-Asia), *Lawsonia inermis* L. (Persia), *Micrococca mercurialis* (L.) Benth. (Afro-Asia), *Ocimum americanum* (L.) (Afro-Asia), *Punica granatum* L. (Afghanistan, Baluchistan and Persia), *Vigna trilobata* (L.) Verde. (Afro-Asia).

IV. TROPICAL AND SOUTH AFRICAN

Species naturalized throughout India :

Chloris inflata Link, *Cleome rutidosperma* DC., *Euphorbia tirucalli* L. (Tropical Africa), *Euphorbia prostrata* Ait. (West Africa and Mauritius).

Species naturalized in some parts of India :

Agapanthus africanus (L.) Hoffmgg. (South Africa), *Asparagus africanus* Lam. (Africa), *Corchorus olitorius* L. (Africa), *Dalbergia melanoxylon* Guilt. &

Perr. (Tropical Africa), *Guizotia abyssinica* (L.f.) Cass. (Tropical Africa), *Hibiscus ovalifolium* (Forssk.) Vahl (Africa), *Melianthus major* L. (South Africa), *Pennisetum clandestinum* Hoschst. (Tropical East Africa Mauritius), *Oxalis pes-ceprae* L. (Cape of Good Hope, South Africa), *O. variabilis* var. *rubra* Jacq. (South African).

IV. AUSTRO-ASIAN

Species naturalized throughout India :

Acacia distachya (Vent.) Macb. (Western Asia), *Althaea ludwigii* L. (West Asia, Mediterranean regions and South Africa), *Conyza bonariensis* (L.) Cronq. (Austro-Asia), *Crotalaria medicaginea* Lam., *Dimeria ornithopoda* Trin., *Desmodium microphyllum* (Thunb.) DC., *Indigofera glandulosa* Willd., *I. trifoliata* L. and *I. trita* L. (Austro-Asia), *Lobelia radicans* Thunb. (South and East Asia, probably Java) and *Ottelia alismoides* Pers. (Austro-Asia).

Species naturalized in some parts of India :

Acacia dealbata Link. (N.S. Wales, Victoria, Queensland and Tasmania), *A. longifolia* Willd. (Australia), *A. melanoxylon* R. Br. (South-East Australia), *Cassia planiticola* Domin (Australia), *Cassytha filiformis* L. (Australia), *Cytisus canariensis* Steud. (Canary Islands), *C. proliferus* L.f. (Teneriff Islands), *Eucalyptus globulus* Labill. (Tasmania, Victoria and N.S. Wales), *Hakea salicifolia* (Vent.) Burtt (Queensland and New South Wales), *Hardenbergia comptoniana* (Link.) Benth. (Western Australia), *Illicium cambodianum* Hance (Southern Indo-China and Southern Myanmar), *Lepidium sativum* L. (South Western Asia and North Africa), *Prunus armeniaca* L. (Siberia to China), *P. persica* Stokes (China), *Rosa multiflora* Thunb. (China and Japan), *Salvia plebeia* R. Br. (Austro-Asia), *Sporobolus diander* Beauv. (Austro-Asia), *Solanum blumei* Nees & Blume (Malaya), and *Wedelia calendulacea* Less. (Austro-Asia).

VI. ESCAPE AND RUN WILD FROM CULTIVATION

Occasionally, many of the introduced and cultivated plants get escaped from their cultivated site to a nearby area. Later, they form a part of the flora dominating over endemic species due to their easy propagation, dispersal, adaptations and favourable environmental conditions. Among such few species are: *Althaea rosea* (L.) Cav. (China), *Annona reticulata* L. (West Indies), *A. squamosa* L. (West Indies), *Antigonon leptopus* Hook. & Arn. (South America, Mexico), *Anthoxanthum odoratum* L. (Europe to temperate Asia), *Asclepias curassavica* L. (Tropical America), *Bauhinia rufescens* Lamk. (Tropical America), *Belamcanda chinensis* (L.) DC. (China), *Bellis perennis* L. (South Europe), *Briza maxima* L. (Mediterranean regions), *Bromus unoiloides* H.B. & K. (South America), *Buddleja madagascariensis* Lamk. (Madagascar), *Brugmansia suaveolens* (H.B.)- Bercht. (Mexico, Chile and Peru), *Capsicum annuum* L. (South America), *Cassia alata* L. (West Indies), *C. didymobotrya* Fresen (Tropical America), *Catharanthus roseus* (L.) G. Don (West Indies and Madagascar), *Cestrum aurantium* Lindl. (Guatemala), *Cichorium intybus* L. (Europe), *Clerodendrum aculeatum* Griseb. (Tropical America), *C. fragrans* var. *pleniflorum* Schauer (China and Japan), *Clitoria ternatea* L. (Tropical America), *Coffea arabica* L. (Arab), *Coriandrum sativum* L. (Southern Europe), *Cymbalaria muralis* (L.) Gaertn. (Europe), *Dactylis glomerata* L. (North Africa and Temperate Asia), *Erechtites valerianiifolia* (Wolf.) DC. (Tropical America), *Elscholtzia californica* Cham. (California), *Eupatorium conyzoides* Vahl (Tropical America), *Fagopyrum esculentum* Moench. (Central Europe and North Asia), *Fuchsia macrostemma* Ruiz. & Pav. (Chile), *Gomphocarpus fruticosus* (L.) Ait. (Cape of Good Hope), *Gomphrena globosa* L. (probably America), *Hibiscus sabdariffa* L. (America), *Lantana camara* L. (Jamaica and West Indies), *Linum usitatissimum* L. (Mediterranean regions), *Lycopersicon esculentum* (L.) Karst. (Tropical America), *Maurandia barclaina* Lindl. (Mexico), *Merremia dissecta* (Jacq.) Hallier f. (Tropical America and West Indies), *Mirabilis jalapa* L. (Tropical America), *Nicandra physalodes* (L.) Gaertn. (Peru), *Oenothera rosea* Soland. (Peru), *Opuntia elatior* Mill. (South America), *O. monocantha* Haw. (South America), *O. vulgaris* Mill. (North America), *Pachyrhizus roseus* (L.) Urban (Central America), *Panicum maximum* Jacq. (Tropical Africa), *Paspalum dilatatum* Poir. (South America), *Passiflora edulis* Sims. (Tropical South America), *Pergularia minor* Andr. (China), *Physalis peruviana* L. (Tropical America), *Ricinus communis* L. (Africa), *Rosa damascena* Mill. (Damascus), *Rumex acetosella* L. (Europe), *Santolina chamaecyparissus* L. (Mediterranean regions), *Sesbania sesban* (L.) Merr. (South Africa), *Solanum sisymbrifolium* Lamk. (Brazil), *Solidago canadensis* L. (South America), *Spartium junceum* L. (Mediterranean regions), *Spiraea cantoniensis* Lour. (China and Japan), *Thunbergia alata* Boj. (Tropical Africa), *Trifolium alexandrinum* L. (Egypt and Syria), *Tropaeolum majus* L. (Egypt and Syria), *Verbena bipinnatifida*

Schauer (Central U.S.A. and Mexico), *V. bonariensis* L. (Argentina, Brazil and Paraguay), *V. rigida* Spreng. (Brazil to Argentina), *Vinca major* L. (Europe), *Zantedeschia aethiopica* (L.) Spreng. (South Africa), *Zephyranthes aurea* Backer, *Z. tubispatha* Herb. (Peru) and *Z. rosea* Lindl. (Cuba).

VII. RECENTLY INTRODUCED WEEDS

A number of weeds have come into India recently and are spreading very fast to different regions of the country. Some of these are : *Agrostemma githago* L. (Europe), *Acanthospermum hispidum* DC. (South America), *Aeschynomene americana* L. (America), *Alternanthera paronychioides* St. Hill (South America), *A. pungens* H.B.& K. (Tropical America), *Apium leptophyllum* F. Muell. ex Benth. (Australia), *Argemone ochroleuca* Sweet (Mexico), *Asclepias curassavica* L. (Tropical America), *Asparagus africanus* Lam. (Africa), *Calceolaria mexicana* Benth. (Mexico), *Carthamus oxyacantha* Bieb. (Caucasus), *Chenopodium ambrosioides* L. (Mexico), *Chromolaena odorata* (L.) King & Robinson (Central America), *Cleome rutidosperma* DC. (Tropical Africa), *Conyza bonariensis* (L.) Cronq. (Western Asia), *Cotula australis* Hook.f. Australia), *Crassocephalum crepidioides* (Benth.) S. Moore (Tropical America), *Croton bonplandianum* Baill. (South America), *Datura suaveolens* H. & B. ex Willd. (Brazil), *D. quercifolia* H.B. & K. (Mexico), *Erigeron annuus* Pers. (Tropical America), *E. karvinskianus* DC. (Mexico to Panama), *Eupatorium glandulosum* H. B. & K. (Mexico), *E. ligustrinum* DC. (Central America), *Euphorbia graminea* Jacq. (Central America), *E. geniculata* Orteg. (Tropical America), *E. prostrata* Ait. (Tropical America), *Eichhornia crassipes* Solm. (Brazil), *Flaveria australasica* Hook. (Australia), *Galinsoga parviflora* Cav. (Tropical America), *G. quadriradiata* Ruiz & Pavon (Mexico), *Gnaphalium purpureum* L. (Tropical America), *Gomphrena celosioides* Mart. (Southern Brazil), *Hyptis suaveolens* Poit. (Tropical America), *Illicium cambodianum* Hance (Southern Indo-China, Southern Myanmar), *Jatropha gossypifolia* L. (Brazil), *Lagascea mollis* Cav. (Mexico), *Mecardonia dianthera* Pennell (Tropical America), *M. procumbens* (Mill.) Small (Tropical America), *Mikania cordata* B.L. Robinson (Tropical America), *Mitracarpus scabrum* Zucc. (Tropical Africa), *Nicotiana glauca* Graham (Tropical America), *N. plumbaginifolia* Viv. (Tropical America), *Oxalis latifolia* H.B. & K. (Mexico), *O. martiana* Zucc. (Brazil), *O. pes-caprae* L. (Cape of Good Hope), *Parthenium hysterophorus* L. (West Indies, Central and North America), *Peperomia pellucida* (L.) H.B. & K. (Central America), *Polycarpon tetraphyllum* (L.) L. (Europe), *Rivina humilis* L. (South America), *Ruellia tuberosa* L. (Tropical America), *Sagina apetala* L. (Europe), *Scoparia dulcis* L. (South America), *Solanum blumei* Nees & Blume (Malaya), *Soliva anthemifolia* (Juss.) R. Br. ex Less. (South America), *Synedrella nodiflora* Gaertn. (Tropical America), *Talinum paniculatum* Gaertn. (Tropical America), *Tithonia diversifolia* A. Gray (Mexico), *T. tagetiflora* Desf. (Mexico) and *Verbesina encelioides* Benth & Hook.f. ex A. Gray (America & Australia), (See Prain, 1890; Collet, 1902; Bruhl, 1908; Burkill, 1911; Calder, 1919; Gamble & Fischer, 1915-1936; Dudgeon, 1920; Kashyap, 1924; Jouget, 1928; Mayranathan, 1929; Fyson, 1915, 1932; Bor, 1934, 1973; Biswas, 1934; Kanjilal & Kanjilal, 1934; Kanjilal *et al.*, 1939, 1940; Raizada, 1935, 1936, 1950, 1959; Mukerjee, 1940; Sandwitch, 1946; Chaterjee & Raizada, 1948; Mooney, 1950; Datta, 1954; Tadulingam & Venkataratnam, 1955; Srivastava, 1955; Sundararaj, 1956; Pattnaik, 1956; Rao, 1956; Cook, 1958; Chaudhury, 1959; Duthie, 1960; Maheshwari, 1960, 1961, 1962; Mirashi, 1960; Chatterjee, 1960; Venkatesh, 1960; Haines, 1961; Backer & Brink, 1963; Rao & Kumari, 1963, 1964; Srivastava, 1964; Rajagopal & Panigrahi, 1965; Babu, 1966, 1969, 1977; Gupta, 1967, 1968; Matthew, 1959, 1969, 1981, 1983; Rao, 1969; Babu & Biswas, 1970; Yonzone *et al.*, 1970; Pandey, 1971, 1979; Maheshwari, 1972; Nair & Pandey, 1972; Maheshwari & Paul, 1975; Murti, 1975; Raizada, 1976; Srivastava, 1976; Nair, 1978; Saldhana & Nicholson, 1978; Bennet, 1979; Deb, 1981; Maiti & Guha Bakshi, 1981; Rao & Razi, 1981; Varma, 1981; Nair & Henry, 1983); Chowdhery & Wadhwa, 1984; Tiwari & Maity, 1984; Saldhana, 1984; Sharma & Pandey, 1984; Sharma *et al.*, 1984; Rothe, 1985; Verma *et al.*, 1985; Mukherjee, 1986; Henry *et al.*, 1987; Rao *et al.*, 1988; Panigrahi & Murti, 1989; Lakshminarasimhan & Sharma, 1991; Sanjappa, 1991; Sreekumar & Nair, 1991).

VIII. OTHER AGRI-HORTICULTURAL, ECONOMIC AND MEDICINAL PLANTS

Introduction of exotic plants into India was mainly for agri-horticultural and economic needs which included cereals, vegetables, edible-tubers, fruits, pasture and fodder, green manure and cover crops, fibre, timber, oil, gum, dye, tannin, spice and condiment, narcotic and hypnotic, beverage, masticatory, medicinal and for aesthetic value. Some of such plants are :

1. *Cereals* : Pearl Millet, *Pennisetum glaucum* (L.) R. Br. (Tropical Africa); Sorghum, *Sorghum vulgare* (L.) Pers. (Arabia); Maize, *Zea mays* L. (Central America).

2. *Pulses* : Pigeon Pea, *Cajanus cajan* (L.) Millsp. (Africa); Horse gram, *Macrotyloma uniflorum* (Lamk.) Verdc (Old World); Lima Bean, *Phaseolus lunatus* L. and Common Bean, *P. vulgaris* L. (Tropical America); Pea, *Pisum sativum* L. (Europe); Cow Pea, *Vigna sinensis* (L.) Savi ex Hassk. (Tropical Africa) and Scarlet Runner Bean, *Vigna unguiculata* (L.) Walp. (Central America).

3. *Vegetables* : Lady's Finger, *Abelmoschus esculentus* (L.) Moench. (Tropical Africa); Wax Gourd, *Benincasa hispida* (Thunb.) Cogn. (Java); Beat Root, *Beta vulgaris* L. (Europe); Cauliflower, *Brassica oleracea* L. var. *botrytis* L., Cabbage, *Brassica oleracea* L. var. *capitata* L., Brussels-Sprouts, *Brassica oleracea* L. var. *gemmifera* Zenk, knol khol, *Brassica oleracea* L. var. *gongyloides* L., Sprouting Broccoli, *Brassica oleracea* L. var. *italica* Plenck, and Turnip, *Brassica rapa* L. (Europe); Garden Cress, *Lepidium sativum* L. (West Asia); Tomato, *Lycopersicon esculentum* Mill. (Tropical America); Choyote, *Sechium edule* (Jacq.) Swartz (Mexico) and *Solanum melongena* L. var. *incanum* (L.) O. Kuntze (Tropical Africa).

4. *Edible tubers* : *Helianthus tuberosus* L. (China); Tapioca, *Manihot esculenta* Crantz (Tropical America); Potato, *Solanum tuberosum* L. (Temperate regions of America).

5. *Edible fruits* : Pine Apple, *Ananas comosus* (L.) Merr. and Cherimoya, *Annona cherimolia* Mill. (South America); Sour soup, *Annona muricata* L.; Bullock's Heart, *Annona reticulata* L. and Custard Apple, *Annona squamosa* L. (Tropical America); Bread Fruit, *Artocarpus altilis* (Park.) Fosberg (Polynesia); Bilimbi, *Averrhoa bilimbi* L. (Malaya); Carambola, *Averrhoa carambola* L. (Indonesia); Akee, *Blighia sapida* Koenig (West Africa); Papaya, *Carica papaya* L. (Central America); Netal, *Carissa grandiflora* A. DC. (South Europe); *Castanea sativa* Mill. (South Europe); Lime, *Citrus aurantifolia* (Christm.) Swing. (East Indies); Pummelo, *Citrus grandis* (L.) Osbeck. (Malaysia); Grape fruit, *Citrus paradisii* Macf. (West Indies); Mandarin, *Citrus reticulata* Blanco (China); Sweet Orange, *Citrus sinensis* (L.) Osbeck (South China); West Indian Star Apple, *Chrysophyllum cainito* L. (West Indies); Melon, *Cucumis melo* L. (Africa); Tree tomato, *Cyphomandra betacea* (Cav.) Sendt. (Peru); Chinese Loquot, *Eriobotrya japonica* (Thunb.) Lindl. (China); Java Apple, *Syzygium samarangens* (Blume) Merr. & Perry (Malaysia); Pitanga Cherry, *Eugenia uniflora* L.

(Brazil); Strawberry, *Fragaria vesca* L. (Europe and West Asia); *Garcinia livingstonei* T. Anders (East Africa); Litchi, *Litchi chinensis* Sonn. (China); Barbados cherry, *Malpighia glabra* L. (Tropical America); Mammey Apple, *Mammea americana* L. (Tropical America); Sapodilla, *Manilkara zapota* (L.) van Royen (Central America); White Mulberry, *Morus alba* L. (China); Rambutan, *Nephelium lappaceum* L. (Malaysia); Passion Fruit, *Passiflora edulis* L. (Brazil); Avacado, *Persea americana* Mill. (Central America); Othaheite Gooseberry, *Phyllanthus acidus* (L.) Skeels (Madagascar); Cape Gooseberry, *Physalis peruviana* L. (Tropical America); *Psidium friedrichsthelianum* (Berg.) Nied. (Central America); Guava, *Psidium guajava* L. and Guinea Guava, *Psidium guineense* Sw. (Tropical America); Strawberry Guava, *Psidium cattleyanum* Sabine (Brazil); Pomegranate, *Punica granatum* L. (Iran); Tamarind, *Tamarindus indica* L. (Tropical Africa); Common Apricot, *Prunus armeniaca* L. (Siberia to China); Common Plum, *Prunus domestica* ssp. *institia* (L.) Sch. (Southern Europe, America and South of Caucasus); Peach, *Prunus persica* (L.) Stokes (China); Common Pear, *Pyrus communis* L. (North Persia, Westward to South Europe); Japanese Pear, *Prunus pyrifolia* Nakai var. *cultra* Nakai (China); Manila Tamarind, *Pithecellobium dulce* (Roxb.) Benth. (Mexico); Great-Hog-Plum, *Spondias cytherea* Sonner. (Society Islands); Malay Apple, *Syzygium malaccense* (L.) Merr. & Perry (Malay Peninsula).

6. *Pasture and fodder* : Rescue Grass, *Bromus unioloides* H.B. & K. (South America); Rhodes Grass, *Chloris gayana* Kunth (Tropical Africa); Weeping Love Grass, *Eragrostis curvata* (Schrad.) Nees (Africa); Sheeps Fescue Grass, *Festuca ovina* L. (Temperate Asia); Guinea Grass, *Panicum maximum* Jacq. (Tropical Africa); Kikuya Grass, *Pennisetum clandestinum* Hoshst. (Tropical East Africa); Mesquite, *Prosopis chilensis* Stuntz (Tropical America and West Indies); Johnson Grass, *Sorghum halepense* (L.) Pers. (Tropical Africa); Egyptian Clover, *Trifolium alexandrinum* L. (Syria and Egypt); *Urochloa mosambicensis* (Hack.) Dandy (East Africa and Myanmar).

7. *Green manure and cover crops* : Joint Vetch, *Aeschynomene americana* L., *Centrosema plumieri* (Turp.) Benth., *Centrosema pubescens* Benth., Butter-Fly Pea, *Clitorea ternatea* L., *Phaseolus lathyroides* L. (Tropical America); Tropical Kutzu, *Pueraria phaseoloides* (Roxb.) Benth. (Malaya): Kudzu, *Pueraria thunbergiana* (Sieb. & Zucc.) Benth. (China); Common vetch,

Vicia sativa L. (Europe); Common Seaban, *Sesbania sesban* (L.) Merr. (South Africa); Egyptian Clover, *Trifolium alexandrinum* L. (Syria and Egypt).

8. *Fibre crops :* Century Plant, *Agave americana* L. (America); *Agave decipiens* Baker (Yucatan); Sisal, *Agave rigida* Mill. (Mexico); Ramie-Plant, *Boehmeria nivea* (L.) Gaud. (China, Japan and Malayan Isles); Kapok, *Ceiba pentandra* (L.) Gaertn. (Tropical America); White Jute, *Corchorus capsularis* L. (South China); Tussa Jute, *Corchorus olitorius* L. (Africa and Asia); Mauritius Hemp, *Furcraea gigantea* Vent. (South America); Cotton, *Gossypium hirsutum* L. (Mexico); *Malachra capitata* L. (Tropical America); African-Bow String, *Sansevieria trifasciata* Prain (West Africa); Spanish-Dagger, *Yucca gloriosa* L. (North America, Canada, Carolina and Peru) and *Wissadula periplocifolia* (L.) Presl ex Thw. (Tropical America).

9. *Timber :* Black Wood Acacia, *Acacia melanoxylon* R. Br. and Silver Oak, *Grevillea robusta* A. cunn. (Australia); *Nauclea orientalis* (L.) L. (Malaya, Myanmar and Sri Lanka); Jamaica Dog Wood, *Piscidia piscipula* (L.) Sarg. (Jamaica and Tropical America); Weeping Willow, *Salix babylonica* L. (Greece, Asia Minor and Nepal); *Swietenia macrophylla* King (Honduras); Mahogony, *Swietenia mahagonii* Jacq. (Jamaica and Central America); and Montezuma Cyperus, *Taxodium mucronatum* Tenore (Mexico).

10. *Oil :* Candle Nut, *Aleurites moluccana* (L.) (Malaya); Tung, *Aleurites cordata* Steud. (China and Japan); Cashew, *Anacardium occidentale* L. (Tropical America); Ground Nut, *Arachis hypogaea* L. (South America); Rape, *Brassica napus* L. (Mediterranean regions); Camphor, *Cinnamomum camphora* (L.) Nees & Eberm. (Eastern Asia); Palm Oil, *Elaeis guineensis* Jacq. (Tropical Africa); many species of *Eucalyptus* (Australia); Sun Flower, *Helianthus annuus* L. (North America); Punk Tree, *Melaleuca leucadendron* L. (Malaysia); Pepper Mint, *Mentha piperata* L. (Temperate regions); Camphor Basil, *Ocimum kilimandscharicum* Guerke (East Africa), Screw-Pine, *Pandanus odoratissimus* L.f. (Old World Tropics); All Spice Tree, *Pimenta dioica* (L.) Merr. (West Indies); Bay Trees, *Pimenta racemosa* (Mill.) J.W. Moore (West Indies and Tropical America); Castor, *Ricinus communis* L. (Africa); China rose, *Rosa chinensis* Jacq. (China) and Damask Rose, *Rosa damascena* Mill. (Syria).

11. *Gum, dye and tannin* : Silver Wattle, *Acacia dealbata* Link. and Green Wattle, *Acacia decurrens* (Wendl.) Willd. (Australia); Babul, *Acacia nilotica* ssp. *indica* (Benth.) Brenan and Gum Arabic, *Acacia senegal* (L.) Willd. (Africa); Camwood, *Baphia nitida* Afzel. ex Lodd. (West Africa); Annatto, *Bixa orellana* L. (Tropical America); Divi-Divi, *Caesalpinia coriaria* (Jacq.) Willd. (West Indies); Logwood, *Haematoxylon compechianum* L. (Jamaica); Rouge-Plant, *Rivina humilis* L. (South America) and Californian Pepper Tree, *Schinus molle* L. (South America).

12. *Spice and condiment* : White Mustard, *Brassica alba* (L.) Rabenh. (Mediterranean regions); Chillies, *Capsicum annuum* L. var. *acuminatum* Fingerh. and Bird Pepper, *Capsicum frutescens* L. (Tropical America); Padang Cassia, *Cinnamonum burmanii* Blume (Indonesia); Cassia, *Cinnamomum cassia* (Nees) Nees & Blume (Myanmar); Cinnamonum, *Cinnamomum zeylanicum* Blume (Sri Lanka) and Nutmeg, *Myristica fragrans* Houtt. (Moluccas).

13. *Narcotic and hypnotic* : *Datura arborea* L. (South America); Horn of Plenty, *Datura innoxia* Mill. (Mexico); *Datura sanguinea* Ruiz. & Pav.; Coca, *Erythroxylum coca* L.; Nicotine tobacco, *Nicotiana rustica* L; Tobacco, *Nicotiana tabacum* L. (South America) and *Turbina corymbosa* (L.) Rafin., (Mexico).

14. *Beverage* : Arabic Coffee, *Coffea arabica* L. (Ethiopia); Liberic Coffee, *Coffea liberica* Buill. ex Hiern. (Liberia); Congo Coffee, *Coffea robusta* Linden (Tropical Africa); Coffee, *Coffea stenophylla* G. Don (West Africa) and Cocoa, *Theobroma cacao* L. (South America).

15. *Masticatory* : Abata Kola, *Cola acuminata* (Beauv.) Schott & Endl. and Gbanja Kola, *Cola nitida* (Vent.) Cheval. (West Africa).

16. *Medicinal plants* : Barbados-Aloe, *Aloe barbadensis* Mill. (Mediterranean regions); garden Asparagus, *Asparagus officinalis* L. (Europe, North Africa and West Asia); Ipecacuanha, *Cephaelis ipecacuanha* (Stokes) Baill (Brazil); Quinine, *Cinchona calisaya* Wedd. and *Cissampelos pareira* L. (South America); Henbane, *Hyoscyamus niger* L. (Europe); Sensitive Plant Touch-me-not, *Mimosa pudica* L. and Balsam of Peru, *Myroxylon pereirae* (Royle) Klotzsch (South America); Opium Poppy, *Papaver somniferum* L. (South

Europe); *Rauvolfia tetraphylla* L. (West Indies); Rue, *Ruta graveolens* L. (Mediterranean regions); Sweet Broom Weed, *Scoparia dulcis* L. (Tropical America), Strophanthus, *Strophanthus hispidus* DC. (Tropical Africa); Milk Thistle, *Sonchus oleraceus* L. (Probably Europe); Black Eyed-Susan, *Thunbergia alata* Boj. ex Sims. (Tropical America) and *Withania somnifera* (L.) Dunal (Mediterranean regions).

17. *Ornamental trees, shrubs, climbers, foliage etc.* : Wattle, *Acacia baileyana* F. Muell. (Australia); Red-Hot-cat-Tail, *Acalypha hispida* Burm.f. (East Indies); Copper leaf, *Acalypha wilkesiana* Muell.-Arg. (Pacific); Queensland Kauri, *Agathis robusta* F. Muell. and *Agathis brownii* (Lam.) L.H. Bailey (Australia); *Agave victorae-reginae* (Mexico); Allamanda, *Allamanda cathartica* L. (South America); *Alternathera amoena* Voss. (Brazil); Alkanet, *Anchusa capensis* Thunb. (South Africa); Floss-flower, *Ageratum houstonianum* Mill. (Mexico); *Amaranthus caudatus* L. (Tropical Africa); Coral Creeper, *Antigonon leptopus* Hook.f. & Arn. (South America); Queen of the Flowering Tree, *Amherstia nobilis* Wallich (Myanmar); common Snap Dragon, *Antirrhinum majus* L. (Mediterranean regions); Rat-Tail Cactus, *Aporocactus flagelliformis* Lam. (Mexico, Central and South America); New Caledonian Pine, *Araucaria columnaris* (Forst.) Hook. (New Caledonia); Mr. Gunningham's Araucaria, *Araucaria cunninghamii* Sweet (Australia); Norfolk Islands Pine, *Araucaria excelsa* R. Br. [Norfolk Island (Australia)]; African Daisy, *Arctotis stoechadifolia* Berg. (South Africa); Fring-Flowered Aristolochia, *Aristolochia ciliata* Hook. (Buenos Aires); Calico Flower, *Aristolochia elegans* Mast. [Rio de Janerrio (Brazil)], Pilican-Flower, *Aristolochia grandiflora* Sw. (Guatemala), Livad-flowered Birthwort, *Aristolochia macroura* Gomezs, the Bird's Head Birthwort, *Aristolochia brasiliensis* Mart. & Zucc., *Aristolochia ridicula* N.E. Brown and *Aristolochia ringens* Vahl (Brazil); the Hairy Birthwort, *Aristolochia tomentosa* Sims. (North America); Partidge Breast, *Aloe variegata* L. (South Africa); Garden Asparagus, *Asparagus officinalis* L. (Europe, North Africa and Western Asia); the Fern Asparagus, *Asparagus plumosus* Baker (South Africa); *Banisteria laevifolia* A. Juss. (Brazil); *Barleria lupulina* Lindl. (Madagascar); Orchid Tree, *Bauhinia blakeana* Dunn (Hongkong); *Begonia manicata* Cels. (Mexico); Black-Berry Lily, *Belamcanda chinensis* (L.) DC. (China and Japan); Daisy-Flower, *Bellis perennis* L. (South Europe); Shrimp-Plant, *Beloperone guttata* Brandegee (Mexico); *Bignonia alliacea* Lam. (Brazil); Trumpet Flower, *Bignonia capreolata* L. (North America);

Bougainvillea, *Bougainvillea glabra* Choisy and *Bougainvillea spectabilis* Willd. (Brazil); *Brachycome iberidifolia* Butt. (Australia); Browallia, *Browallia viscosa* H.B. & K. (Tropical America); *Brownea coccinea* Jacq. (Venezuela); Lady-of-the-Night, *Brunfelsia americana* L. (West Indies); *Brunfelsia uniflora* Pohl & D. Don (Brazil); *Buddleja madagascariensis* L. (Madagascar); Pot Marigold, *Calendula officinalis* L. (South Europe and Australia); Sweet Sultan, *Centauria moschata* L. (Orientalis); Wall Flower, *Cheiranthus cheiri* L. (South Europe); Pride of Barbados, *Caesalpinia pulcherrima* (L.) Sw.; *Caladium bicolor* (Ait.) Vent., Pink Powder Puff, *Calliandra haematocephala* Hassk. (Tropical America); *Calliandra brevipes* Benth. & Hook. and *Calliandra tweedi* Benth. (Brazil); *Calliandra portoricensis* Benth. (West Indies); Bottle Brush, *Callistemon citrinus* (Curt.) Skeels and *Callistemon pollandii* Hort. (Australia); Aster, *Callistephus chinensis* (Cass.) Nees (China); Yellow Oleander, *Cascabela thevetia* (L.) Lippold (West Indies); Periwinkle, *Catharanthus roseus* (L.) G. Don (Tropical America); the Java Cassia, *Cassia javanica* L. (Sumatra and Java); *Cassia alata* L. (West Indies); Prickly Apple, *Catesboea spinosa* L. (West Indies); the Day Jasmine, *Cestrum diurnum* L. and Lady-of-the Night, *Cestrum nocturnum* L. (West Indies), chrysanthemum, *Chrysanthemum indicum* L. (China and Japan); Glory Pea, *Clianthus dampieri* Cunn. (Australia); *Cobaea scandens* Cav. (Mexico); Scarlet Cordia, *Cordia sebestina* L. (Cuba, West Indies and Florida); Cannon Ball Tree, *Couroupita guyanensis* Aubl. (Tropical South America); Rubber Vine, *Cryptostegia grandiflora* (Roxb.) R. Br. (Africa or Madagascar); Flamboyant, *Delonix regia* (Boj. ex Hook.) Faf. (Madagascar); Weeding Flower, *Dombeya wallichii* D. Jackson (Madagascar); White Lace Euphorbia, *Euphorbia leucocephala* Lotsy (Mexico); Poinsettia, *Euphorbia pulcherrima* Willd. ex Klotz. (Central America); Cape Jasmine, *Gardenia jasminoides* Ellis (China); Spotted Gliricidia, *Gliricidia sepium* (Jacq.) Walp. (Tropical South America); Hedgehog, *Gmelina philippensis* Cham. (Philippines); Stinkwood, *Gustavia augusta* L. (Brazil); Fire Bush, *Hamelia patens* Jacq. (Tropical America); Changeable Rose, *Hibiscus mutabilis* L., and Shoe Flower, *Hibiscus rosa-sinensis* L. (China), Fringed Hibiscus, *Hibiscus schizopetalus* (Mast.) Hook.f., (Tropical East Africa); Rose-of-Sharon, *Hibiscus syriacus* L. (Syria); Common Morning Glory, *Ipomoea purpurea* (L.) Roth (Tropical America); May-Flower, *Jacaranda acutifolia* Humb. & Bonpl. (Brazil and North-west Argentina); *Kalanchoe laciniata* (L.) Pers. (Acrica, Java, China and Japan); Cucumber Tree, *Kigelia africana* (Lam.) Benth. (Tropical

Africa); Pink Kopsia, *Kopsia fruticosa* A. DC. (Myanmar); Sweet Pea, *Lathyrus odoratus* L. (Europe); Horse Tamarind, *Leucaena latisiliqua* (L.) Gillis (Tropical America); Cat's claw, *Mcfadyena unguis-cati* (L.) Gentry (Argentina); Great Laurel Magnolia, *Magnolia grandiflora* L. (North America); Sleeping Mallow, *Malvaviscus arboreus* Cav. (Mexico); Moulmein Rosewood, *Millettia peguensis* Ali (Myanmar); Red Mussaenda, *Mussaenda erythrophylla* Schum. & Thonn. (Tropical Africa); Flag Bush, *Mussaenda philippica* A. Rich. (Philippines); Sacred Bamboo of China, *Nandina domestica* Thunb. (China and Japan); Nemophila, *Nemophila insignis* Benth. (California); Nemesia, *Nemesia versicolor* E. Mey and *Nemesia strumosa* Benth. (South Africa); Oleander, *Nerium oleander* L. (Mediterranean regions); Flowering tobacco, *Nicotiana alata* Link. & Otto var. *grandiflora* Comes (South Africa); Love-in-A-Mist, *Nigella damascena* L. (Mediterranean regions); Snake or Serpent Cactus, *Nyctocereus serpentinus* Britt. & Rose (Mexico); *Ochna atropurpurea* DC. (South Africa); *Olea europea* L. (Europe); Prickly Pear, *Opuntia elatior* Mill. (South America); Bunny Ears, *Opuntia microdasys* Pfeiff. (Mexico); *Opuntia tunicata* Hort. (Central America); Jerusalem thorn, *Parkinsonia aculeata* L. (Tropical America); Candle Tree, *Parmentiera cereifera* Seem. (Central America); Passion Flower, *Passiflora coerulea* L. (Brazil); Giant Granadilla, *Passiflora quadrangularis* L. (Tropical America); *Pentas lanceolata* (Forssk.) K. Schum. (Tropical America); Purple Wreath, *Petrea volubilis* L. (Tropical America), Petunia, *Petunia violacea* Lindl. (South America); *Plumeria alba* L. (West Indies); Pagoda Tree, *Plumeria rubra* L. (West Indies) and *Plumeria rubra* L. forma *acuminata* (Ait.) Sant. & Irani ex Shah (Mexico); Portlandia, *Portlandia grandiflora* L. (West Indies); Rose Moss, *Portulaca pilosa* L. ssp. *grandiflora* (Hook.f.) Geesink (South America); Speck-Boom, *Portulacaria afra* Jacq. (South Africa); Pomegranate, *Punica granatum* L. (Afghanistan, Baluchistan and Persia); Golden Shower, *Pyrostegia venusta* (Ker-Gawl.) Miers. (Brazil); *Pereskia bleo* DC. (New Grenada, Mexico); Phlox, *Phlox drummondii* W.J. Hook. (Texas); tube rose, *Polianthes tuberosa* L. (Mexico); Quassia, *Quassia amara* L. (Tropical America); Lemonia, *Ravenia spectabilis* Engl. (Cuba & Brazil); Traveller's Tree, *Ravenala madagascariensis* J.F. Gmel. (Madagascar); Mignonette, *Reseda alba* L. (South Europe); *Reseda luteola* L. (Europe); Common Mignonette, *Reseda odorata* L. (North Africa and Mediterranean regions); Pothos, *Rhaphidophora aurea* (Linden ex Andre) Furtado (Solomon Islands); Mosses-in-the-Cradle, *Rhoeo spathacea* (Sw.) W.T. Stearn (Central America);

Rondeletia odorata Jacq. (West Indies and Mexico); *Russelia equisetiformis* Schl. & Cham. and *Russelia sarmentosa* Jacq. (Mexico); Scarlet Salvia, *Salvia splendens* Ker-Gawl. (Brazil); *Sanchezia nobilis* Hook.f. (Equador); Red Saraca, *Saraca declinata* (Jacq.) Miq. (Sumatra); *Saritaea magnifica* (Bull) Dugand. (South America); Butter Fly Flower, *Schizanthus wisetonensis* Low. (South America); Florists' Cineraria, *Senecio cruentus* DC. (Canary Islands); *Serissa japonica* (Thunb.) Thunb. (China and Japan); Purple-Heart, *Setcreatea purpurea* L. (Mexico); Sweet William, *Silene armeria* L. (South Europe); Potato Tree, *Solanum grandiflorum* Ruiz. & Pav. (South America); Potato Creeper, *Solanum jasminoides* Paxt., and *Solanum seaforthianum* Ander. (Tropical America); Giant Patato-Vine, *Solanum wendlandii* Hook.f. (Tropical America); Tulip Tree, *Spathodea campanulata* Beauv. (Tropical Africa); Variable Flase Valerian, *Stachytarpheta jamaicensis* (L.) Vahl and *Stachytarpheta mutabilis* Vahl (Tropical America); Malay Apple, *Syzygium malaccense* (L.) Merr. & Perr. (Malay Peninsula); *Tabebuia argentea* Britt. (Paraguay); Golden Trumpet Tree, *Tabebuia chrysantha* (Jacq.) Nicholson (South America); Roble Blanco, *Tabebuia pentaphylla* Hemsl. (West Indies, Central America); Pink Pou, *Tabebuia rosea* DC. (Central and South America); African Marigold, *Tagetes erecta* L. (Africa or Mexico); French Marigold, *Tagetes patula* L. (Mexico); Fame-Flower, *Talinum calycinum* Engelm. (Mexico); Yellow Elder, *Tecoma stans* (L.) H.B. & K. (Tropical America); Bush-Clock-Vine, *Thunbergia erecta* (Benth.) Anders. (Tropical Africa); *Thryallis glauca* (Cav.) O. Kuntze (Tropical America); *Tithonia rotundifolia* (Mill.) Blake (Mexico); *Torenia fournieri* Linden ex Fourn. (Cochin China); Chinese Star Jasmine, *Trachelospermum divaricatum* (Thunb.) K. Schum. (China); *Tradescantia fluminensis* Vell. (Brazil); Nasturtium, *Tropaeolum majus* L. (South America); *Vaccaria pyramidata* Medik. var. *rosea* Hort. (Europe and Asia); Verbain, *Verbena bipinnatifida* Nutt. (California to Mexico); *Verbena peruviana* Britt. (Argentina and South Brazil); Monarch-of-the Veld, *Venidium fastuosum* Stapf (South Africa); Garden or Florist's Violet, *Viola odorata* L. (Europe, Africa and Asia); Pansy, *Viola tricolor* L. var. *hortensis* DC. (Europe); Blue-Acacia, *Wisteria sinensis* (Sims.) Sweet (China or Myanmar); *Xanthosoma lindenii* Engl. (Columbia); Spanish- Dagger, *Yucca gloriosa* L. (North America); Wandering Jaw, *Zebrina pendula* Schnizl. (Mexico); Zephyr-Flower, *Zephyranthes candida* Herb. (Peru); Common Zinnia, *Zinnia elegans* Jacq. (Mexico), etc. (See Connor, 1873; Gamble, 1902; Prain, 1903; Duthie, 1903, 1929; Troup, 1932; Benthall, 1946; Bailey, 1928, 1928b, 1949;

Vavilov, 1949/50, 1951; Blatter & Millard, 1954; Bor & Raizada, 1954; Santapau & Randeria, 1955; Coats, 1956; Booth, 1957, Bruggeman, 1957; Firminger, 1958; De Candolle, 1959; Pal, 1960; Gupta & Marlange, 1961; Desai, 1962; Haines, 1962; Mehra, 1965-1966; Backer & Brink, 1963, 1965, 1968; Maheshwari, 1963; Santapau, 1965; Gupta, 1967; Gamble & Fischer, 1915-1936; Purseglove, 1968, 1972; Singh, 1968; Matthew, 1969, 1981, 1983; Maheshwari & Paul, 1975; Bose, 1976; Srivastava, 1976; Nair, 1978; Saldhana & Nicholson, 1978; Bennet, 1979; Pandey, 1979; Jain & Sastry, 1980; Maity & Guha Bakshi, 1981; Nair & Henry, 1983; Sharma & Pandey, 1984; Pandey, 1984; Chakraverty & Jain, 1984; Rothe, 1985; Verma *et al.*, 1985; Ambasta *et al.*, 1986; Banerjee *et al.*, 1987; Henry *et al.*, 1987; Panigrahi & Murti, 1989; Pandey & Chakraverty, 1990; Lakshminarsimhan & Sharma, 1991; Sanjappa, 1991; Pandey *et al.*, 1991; Sreekumar & Nair, 1991; Chakraverty *et al.*, 1992 and Pandey & Chakraverty, 1992).

The establishment of Indian Botanic Garden, Howarh (formerly Royal Botanic Garden) in 1787, has played very important role for introduction, acclimatisation and distribution of many cultivated plants of agri-horticultural and economic/medicinal importance for which authentic records are available and hence, these deserve a separate mention. Some of the more important species first introduced to this garden are :

1. *Forage, food and Oil :* Soya Bean, *Glycine max* (L.) Merr. (Cochin China, Japan and Java from Moluccas); Cajeput Tree, *Melaleuca leucadendron* L. (Myanmar, Malaya Islands, around 1810 by Lt. M'Kenzi).

2. *Fodder :* Lucerne, *Medicago sativa* L. (Western temperate Asia, in 1796 by B. Boswell); Egyptian Clover, *Trifolium alexandrinum* L. (Syria and Egypt, in 1803 by T. Graham).

3. *Fruits :* Sour-Sop, *Annona muricata* L. (Tropical America, in 1811, by A. Roberts); Straw Berry, *Fragaria vesca* L. (Temperate Europe, Western Asia, and East of North America, before 1808); Black Mulberry, *Morus nigra* L. (Asia probably Persia, in 1795).

4. *Fibre :* Ramie-Rhea, *Boehmeria nivea* (L.) Gaud. (China, Japan and Malayan Isles, Roxborgh's period between 1793 to 1813).

5. *Timber :* Mahogony, *Swietenia mahogoni* (L.) Jacq., (Jamaica and Central America, in 1795 from West Indies), *Swietenia macrophylla* King (in 1872 from Honduras).

6. *Ornamental trees, shrubs, climbers, foliage etc. :* Allamanda, *Allamanda cathartica* L. (Brazil, during 1803 by W. Hamilton Esq. from Guinea); Partidge Breast, *Aloe vera* L. (South Africa, probably 1806); Queen-of-the flowering Tree, *Amherstia nobilis* Wallich (Myanmar, in 1826 by N. Wallich); Garden Asparagus, *Asparagus officinalis* L. (Europe, North Africa and Western Asia, probably before 1794); *Bambusa burmanica* Gamble (Myanmar, during 1876 by Oliver); Chinese Bamboo, *Bambusa glaucescens* (Willd.) Sieb. ex Munro (China and Japan, before 1794); Buddha's Bamboo, *Bambusa ventricosa* McClure (China and Japan, before 1913); *Bambusa vulgaris* Schrad. var. *striata* (Lindl.) Gamble (China and Japan, during 1863); Bougainvillea, *Bougainvillea spectabilis* Willd. (Brazil, during 1803 by W. Hamilton Esq. from Guinea); Australian-Pine, *Casuarina equisetifolia* J.R. & G. Forst. (Australia, Malaya and Pacific Islands, in 1798), Garden Croton, *Codiaeum variegatum* (L.) Bl. (Java to Australia and South Islands, during 1798 by C. Smith); *Colvillea racemosa* Boj. (Madagascar, during 1840); Butterfly-Pea, *Clitorea ternatea* L. (Tropical America, in 1814); Calbash tree, *Crescentia cujete* L. (Tropical America, during 1795 by W. Hamilton Esq.); *Dendrocalamus membranaceus* Munro (Myanmar, during 1892); Syrian Hibiscus, *Hibiscus syriacus* L. (Syria, before 1794), *Hibiscus tiliaceus* L. ssp. *hastatus* (L.f.) Borssum (Society Islands, during 1809 received by the missionaries brought by Lord Minto from Othaheite); Crape Myrtle, *Lagerstroemia indica* L. (China, before 1794); Double Coconut Tree, *Lodoicea maldivica* (Poir.) Pers. (Seycheles, in 1894); Sweet Scented Oleander, *Nerium indicum* Mill. (China, Cochin-China, before 1794); Jerusalem Thorn, *Parkinsonia aculeata* L. (West Indies and South America, in 1797 by W. Hamilton); Passion Flower, *Passiflora coerulea* L. (Brazil, during 1799); *Passiflora suberosa* L. (West Indies, during 1804); *Plumeria alba* L. (West Indies; during 1801 by W. Hamilton) Traveller's Tree, *Ravenala madagascariensis* J. F. Gmel. (Madagascar, Captain Tennant brought from the Islands of Mauritius, before 1832); China Rose, *Rosa chinensis* Jacq. (China, in about 1794 by William Roxburgh from China); Chinese-Arbor-Vitae, *Thuja orientalis* L. (China and Japan, before 1794); *Thyrsostachys oliveri* Gamble (Myanmar and Thailand, during 1892); *Thyrsostachys siamensis* Gamble (Myanmar and Thailand, before 1890);

Giant water Lily, *Victoria amazonica* (Poepp.) Sow, (Brazil, about 1873); Santa Cruz-Lily, *Victoria cruziana* d'Orb (Paraguay, during 1881); Spanish Dagger, *Yucca gloriosa* L. (North America, in 1799), Wandering-Jaw, *Zebrina pendula* Schnizl. (Mexico, in 1800 by W. Hamilton Esq.) etc.

7. *Seasonal flowers* : Pot Marigold, *Calendula officinalis* L. (South Europe, before 1814); Sweet Sultan, *Centaurea moschata* L. (probably Persia, before 1800 by Colonel Dyer); Wall Flower, *Cheiranthus cheiri* L. (South Europe, before 1840 by General Martin); Sun Flower, *Helianthus annuus* L. (Central America and Peru, before 1794); *Heliotropium peruvianum* L. (Peru, in 1801); Sweet Pea: *Lathyrus odoratus* L. (Italy, in 1799); Love-in-a-Mist, *Nigella damascena* L. (South Europe, probably before 1814 by Colonel Garstin), African Merigold, *Tagetes erecta* L. (Africa or Mexico, probably before 1794); French Merigold, *Tagetes patula* L. (Mexico, before 1794); Nasturtium, *Tropaeolum majus* L. (South America, in 1799). (See Roxburgh, 1814, 1820, 1824, 1832; Voight, 1845; Troup, 1932; Bailey, 1928, 1928b, 1949; Santapau, 1965; Sen & Naskar, 1965; Deb, 1977, 1982; Chakraverty & Mukhopadhyay, 1983; Saldanha, 1984; Sharma & Pandey, 1984; Bhattacharya *et al.*, 1986 and Bose *et al.*, 1987).

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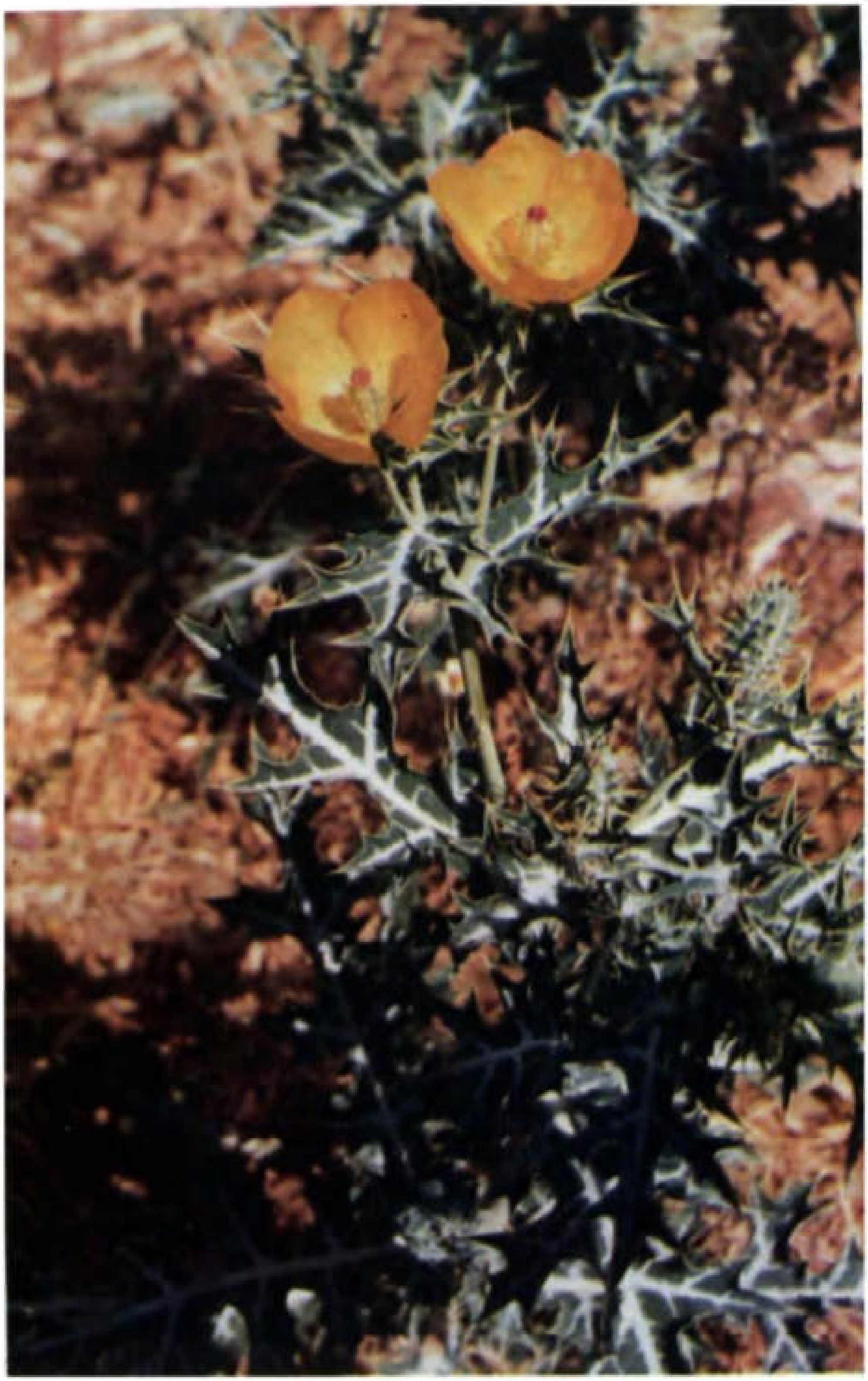

Plate 3. *Argemone mexicana* L. (BSI, IBG, Howrah)

Plate 4. *Prosopis juliflora* (Sw.) DC. (BSI, IBG, Howrah)

Plate 5. *Althaea rosea* Cav. (BSI, IBG, Howrah)

Plate 6. *Asclepias curassavica* L. (BSI, IBG, Howrah)

Plate 7. *Manilkara zapota* (L) van Royen (BSI, IBG, Howrah)

Plate 8. *Nicotiana tabacum* L. (BSI, IBG, Howrah)

Plate 9. *Catharanthus roseus* (L.) G. Don
(BSI, IBG, Howrah)

Plate 10. *Gliricidia sepium* (Jacq.) Kunth ex Walp.
(BSI, IBG, Howrah)

Plate 11. *Hibiscus rosa-sinensis* L. (BSI, IBG, Howrah)

Plate 12. *Saritaea magnifica* (Bull.) Dugand. (BSI, IBG, Howrah)

Plate 13. *Tabebuia argentea* Britt. (BSI, IBG, Howrah)

Plate 14. *Tabebuia pentaphylla* Hemsl. (BSI, IBG, Howrah)

Plate 15. *Tagetes patula* L. (BSI, IBG, Howrah)

Plate 16. *Parkinsonia aculeata* L. (BSI, IBG, Howrah)

12. ETHNOBOTANY IN INDIA

(D.C. Pal)

The unique empiric knowledge system about the use of the biological resources among the various human communities living close to nature is very ancient in India. This rich heritage of knowledge and age old wisdom of India might well be among the earliest in the world. According to 1991 census over 67.8 million tribal people, belonging to over 550 communities having 106 linguistic and 227 subsidiary dialects, constitute 8.08% of the population of the country. They live in about 5000 forest dominated villages which cover about 15% geographical area of a total of 3029 million hectares of Indian land mass (8°-4'-37°6' N and 68°7'-97°25' E). With these vastly diversified living ethnic groups and rich biological resources, India represents one of the great emporia of ethnobotanical wealth. In this perspective ethnobotanical studies may be highly profitable from academic, indigenous knowledge, local knowledge, community knowledge and folk knowledge point of view for planning and decision making prupose. There are some spatial aspects of aquired unique knowledge system of ethnic communities. The organised and systematic studies on ethnobotany as source of indigenous knowledge are very recent in India. However, up till now, the possible application of indigenous knowledge in planning and decision making has been unexplored. The present chapter focuses on the Ethnobotany in India which can facilitate the management of indigenous information and enhance its usefulness. In this respect a few important reference, on international studies, which have prompted Indian research in this field, have been referred. Ethnobotany in the realm of health care system, food, other agricultural crops improvement, conservation of genetic resources and the welfare of ethnic races with sustainable uses of plant resources have been emphasized in India.

Ethnobotany :

The term "Ethnobotany" is derived from two Greek syllables *Othnikos* or *ethnos*, meaning nation or race, and *botanikos* or *botane*, meaning plant. Thus etymologically the term "Ethnobotany" refers to the study of palnts of race(s). Dr. John W. Harshberger (1885), first coined the term "Ethnobotany" and applied it to the study of plants used by primitive and aboriginal people. He published it in the "Philadelphia Evening Telegram" and later under the heading "Some New Ideas" in 1896. Robbins, *et. al.* (1916), considered Ethnobotany as the study and evaluation of the knowledge of all the phases of plant life with primitive associates and of the effects of vegetal environment upon the life. Subsequently Jones (1941, 1962) interpreted Ethnobotany as "total relationship between primitive people and their surrounding plant wealth in the broader sense"

Faulks (1958) categorically stated that Ethnobotany encompassed the entire realm of "Economic Botany", including the modern use of plants. This view is not generally accepted now. Jain and De (1966) said that the relationship between the indigenous pepole and their plant surroundings forms the subject of "Ethnobotany" They specified that Ethnobotany includes the studies of plant wealth used by tribal people for their food, fodder, medicine (both human and veterinary), clothing, house building, oil seed, narcotic, beverage, fibre, dye, tan, agricultural instrument, hunting implements, material culture, magico-religious belief, taboo, totem, etc. and the impact of such usage on the survival of vegetation and of the individual plant species. Ford (1978) included the modern uses of plant also in the purview of Ethnobotany. Heiser (1920), interpreted Ethnobotany as studies of plants used by human communities in past and of present survivals at any level. Manilal (1988) stated that "Ethnobotany denotes the entire realm of useful relationship between plant and man". But harmful effects are also within the purview of ethnobotanical studies. Now Ethnobotany can be defined as direct total relationship of plants with man. This man-plant relationship can not be restricted to the limits of Economic Botany and Environmental studies only. The intimate relationship between plants and man the man of past, has come to us through surviving traditions only. So man-plant relation is multidimensional. Schultes (1962), pointed out that ethnobotamical studies require multidisciplinary and interdisciplinary approaches.

Jain (1987), broadly classified man-plant relationship into two groups, viz. (i) *Abstract*, and (ii) *Concrete*. The abstract relationship includes faith in the good or bad powers of plants, avoidance, sacred plants, worship, folklore, taboo, totem and other plants of aesthetic values. In literature similies and metaphor coming from plants and plant part(s) are also included within this realm.

The concrete relationship includes mainly the materialistic usage of plants, such as in food, medicine, shelter, etc. Jain (1989) categorised the *Abstract* and *Concrete* relationship between man and plants under four headings, viz. (a) Relationships useful both to man and plants (b) Relationships useful to man, harmful to plants (c) Relationships useful to plants, harmful to man (d)

Relationships harmful both to man and plants.

The relationships useful both to man and plants cover the realm of domestication of plants, agriculture, development of improved crop varieties, hybridisation, creation of hardy, diseases-resistant varieties, propagation, sustainable exploitation and conservation of wild plant resources. The relation useful to man but, harmful to plants include the areas of the practice of monoculture forestry, silviculture, usage of minor forest produces, etc. On the other hand relationships useful to plants but harmful to man include obnoxious weeds, like *Parthenium, Mikania, Eupatorium, Argemone* and the plants in pesticides.

The relationships harmful both to man and plants come under the purview of damage to environment, environmental pollution, deforestation, creation of waste lands by one way or the other, shifting cultivation, etc. The interesting area of work in Ethnobotany is the study of selection process brought about by the tribals in certain economic plants and conservation of germ plasm through patronage of land races.

Ethnobotany - A Multidisciplinary Science :

Ethnobotany plays a material role in the advancement of many aspects of other subjects, like Anthropology, Sociology, Agriculture, Horticulture, History, Archeology, Medicines, Ecology, Geography, Linguistics, etc. A comprehensive study combining all the above disciplines could only provide clue to the origin of cultivated plants, distribution of wild relatives, history, names, migration of human races, phonetics of different dialects of ethnic groups, etc. In this perspective the works of De Candolle (1886), a French Botanist, and Vavilov (1926, 1951), a Russian geneticist and agronomist, can be mentioned. They took the aid of Ethnobotany to acertain the centre of origin of economic plants in the world.

Ethnobotany - Its Interdisciplines and Subdisciplines :

The interdisciplinary and subdisciplinary realm of Ethnobotany are often been confused with each other. Ethnobotany itself is a multidisciplinary and inter-disciplinary science. It has many subdisciplines. With diversification of Ethnobotanical studies along new lines, more and more branches are being added to the subdiscipline of Ethnobotany.

Ethnobotany beyond its ordinary realm of botany has great significance for other branches of science, like meteorology, cosmetics, dietetics, music, toxicology, narcotics, pharmacology orthopaedics, gynaecology, paediatrics, ophthalmology, phytochemistry, etc. However, a distinct demarcation between the scope of related disciplines is often not possibe.

The study of various inter-disciplines of Ethnobotany, viz. ethnometeorology involves the weather forecasting through plant behaviour; ethnocosmetics involves traditional cosmetics; ethnodieteics for the study of food during sufferings and restrictions on consumption of edible plants in different seasons; ethnomusicology is related to plant used in instruments, referred to music; ethnotoxicology, ethnonarcotics referred to plants used by ethnic groups for hallucination and narcotic purpose; ethnopharmacology includes the pharmacology of ethnobotanical species; ethnoorthopaedics involves the study of traditional methods for healing of fractured bones and setting of dislocated joints; ethnoophthalmology included the study of plants used for curing eye diseases; ethnogynaecology covers the traditional methods of treatment of female diseases; ethnopaediatrics is the study of plants used for diseases amongst children, and so on. More and more new subjects are emerging in the inter-disciplinary approaches of ethnobotany.

On the other hand the studies dealing with the relationship of man with various subgroups of plant Kingdom, like algae, fungi, bryophytes, pteridophytes, lichens, etc. are called subdisciplines of ethnobotany and have been termed as ethnoalgology. ethnomycology, ethnobryology, ethnopteridology, ethnolichenology, ethnotaxonomy, ethnopalaeobotany, etc.

Ethnobotany - Its Relation to Folklore, Myths, Economic Botany and Traditional Medicine :

The word ethnobotany is sometimes interpreted with Folklore, Economic Botany and also considered as synonymous with traditional medicine. But the scope of the subject is much more than that. All the traditional systems of medicine today, which are well organised, distinct systems of diagnosis and cure for ailments in India, have their root in ethnobotany.

The usage of processed, improved plant products, their commerce and trade are termed as "Economic Botany".

Folklore deals with only unrecorded customs, beliefs, magic and rituals. Folklore practically recognised historical science in western countries. Whereas, myths have been defined as stories of anonymous origin prevalent among the people and accepted as true. Myth is said to be motivated not only by subjective wishful thinking, but also by the quests for an understanding of the significance of nature and life. Myth may be considered as primitive ethnobotany expressed in practice form.

Ethnicity of Indian Tribals :

The Indian tribals generally posses the characteristic feature of three great races of mankind, viz. Negroid, Cocasoid and Mongoloid. Anthropologically the term "Australoid", which was atributed to some Indian tribal groups, has been derived from the type "Negrito" under the great race Negroid.

Major Linguistic Classification of the Indian Tribals :

The Indian tribals may be classified under three major linguistic groups. The dialects of these groups have no written script. The Munda, Santal, Lodha, Kharia, Birhore, Ho, Asur, Gond and other tribes of central and eastern India belong to Australo-Asiatic linguistic group. The Oraon, Kondh, Toda, Balmaki, etc. of eastern, central and southern India speak Dravidian language. The Mech, Rabha, Toto, Nicobarese, Lepcha, Bhutia, Miris, Karbis, Nagas, Khasis, Monpa and other tribals of North-eastern India belong to Tibeto-Burman linguistic group, whereas Ongaes, Sompen, Great Andaminese, etc. have practically no specific dialects but have a good number of guttral sounds.

Historical Background :

Since the coining of the term "Ethnobotany" in 1895, the subject is now about hundred years old. Sicne then ethnobotany has had a wonderful history in U.S.A. While Harvard University has become a leading centre of ethnobotanical studies, the University of Michigan has established an ethnobotanical laboratory and many other universities of U.S.A. have included ethnobotany as a subject of study and research. Canada has instituted "Canadian Ethnobiology Service". It has become a major subject in Mexico, Brazil and other countries of South America.

In 1987, the department of Ethnobotany has been established at the Kunming Institute of Botany, Academia Sinicia. Ethnobotany has also been introduced as a subject of study along with Economic Botany in the university of Murcia, Spain. The subject has received considerable importance in Ethiopia, Ghana, Uganda, Kenya, South Africa, West Indies, Indonesia, Australia, New Zealand. It is the thrust area of research in Bangladesh and Nepal. In December 1994, an International Conference on Ethnobotany was held at Dhaka. The subject is receiving increasing attention in European countries as well, like U.K., France, Denmark, Portugal and others.

In India, with her vast heritage of vedic literature such as Rigveda (2500 B.C. 1600 B.C.), Atharva Veda (1500 B.C.-500 B.C.), Kautilya's Arthashastra (321 B.C.-186 B.C.), Vishnu Puran (500 A.D.), Agni Puran (500 A.D.-700 A.D), Vishnudharmottara Mahapuran (500 A.D.-700 A.D.), Apstanga Smriti (200 B.C.-200 A.D.), Brihat Samhita (500 A.D.), Upavanavinoda (1120 A.D.-1330 A.D.), etc., and with medieval literature in Sanskrit, Pali, Tamil, Persian and other regional languages, posses huge wealth of ethnobotanical information. Ascertaining of the botanical identity of large number of plants in ancient literature is one of the branch of investigation in ethnobotany. Starting from "Vihalyakarani" in Hindu epic Ramayana and "Soma" in vedas, more than one and a half dozen of plants have been attributed to different group of plants, varying from flowering plants, like *Tridax*, *Barleria* and *Sarcostemma* to fungus, like *Amanita muscaria*. Similar is the case with *Brahmi*, where plants vary from *Centella asiatica* to *Bacopa monnieri*, and in the case of *Bala* species varies from *Sida rhomboidea* to *Sida spinosa*. The names *jatamansi, punarnava,* etc., are also attributed to more than one taxa. Bodding (1925-1940) perhaps sown the seed of field investigation in ethnobotany through his pioneering contribution on *"Studies in Santal Medicine and Folklore"*. This was followed by an equally important contribution by late Prof. G.P. Majumdar (1938) through his publication - "Some Aspects of Indian culture (in plant perspective)". The Bulletin of Botanical Society of Bengal added the sub-title "Ethnobotanical studies in India" to it. Kirtikar and Basu (1933) stated "Ethnobotany is virtually a new field of research in India". They further remarked that ethnobotany will become a more important subject when its study would progress to a point where results could be studied comparatively. De (1968) also supported Kirtikar and Basu's view and stated that ethnobotany was a new science in India.

Botanical Survey of India : The Mother of Indian Ethnobotanical Research :

Botanical Survey of India was reorganised in 1954, to undertake the survey of plant resources of the country. Since the very inception, the Economic Botany section of the Central Botanical Laboratory of this Institution has undertaken studies on this subject. Late Janaki Ammal (1950), the person behind the reorganisation of the department, suggested the initiation of researches on ethnobotany in Central Botanical Laboratory with particular emphasis on documentation of subsistence food plants of certain tribals of South India, specially various prospects of genus *Dioscorea*. From 1960, Dr. S.K. Jain, initiated intensive ethnobotanical field studies among the Gond tribe of central India. In the Indian context he devised the methodology for the study of this subject in the field. The publications of Dr. Jain and his co-workers, like D.C. Pal, C.R. Tarafder, J.N. Dey, D.K. Banerjee and others in early sixties encouraged similar activities at many other centres, like National Botanical Research Institute (N.B.R.I.), Lucknow, National Bureau of Plant Genetic Resources (N.B.P.G.R), Delhi, Central Council for Research in Ayurveda and Siddha (C.C.R.A.S.); Central Council for Research in Unani Medicine (C.C.R.U.M.); Central Council for Research in Homoeopathy (C.C.R.H.) and Tropical Botanic Garden and Research Institute (T.B.G.R.I.), Thiruvananthpuram. In 1981, the Department of Sicence and Technology, Government of India, decided to set up an "All India Co-ordinated Research Project on Ethnobiology (A.I.C.R.P.E.) under the umbrella of "Man and Biosphere" programme. The proposal for the project was first floated by Dr. T.N. Khoshoo in July 1974. The project came into operation in July, 1982, with eighteen centers of studies. Simultaneously ethnobotany has been incorporated in the syllabus of Botany in many Universities, e.g. Manipur, Guwahati, Srinagar, Garhwal, Jaipur, Joypur, Calicut, Sagar, Bhagalpur, Darbhanga, Calcutta, Vidyasagar, etc. in Under as well as Post-graduate degree courses. This discipline has also been recognised for doctoral and post-doctoral research work by various academic institutions in India. These developments had tremendous impact on botanists, anthropologists, folklorists, traditional medicine practitioners, health conscious individuals with direct bearing on rural health care system and conservation of wild plants. Several Public Service Commissions have also included this subject in their syllabii. Botanical Survey of India itself has a separate section of ethnobotany with an ethnobotanical museum.

Botanical Survey of India organised a special session on "Plants in Folklore and Folklife" during XII International Congress on Anthropological and Ethnological Sciences, held at Delhi in 1978. Similar sessions were also organised by the department during Botanical Conferences of the Indian Botanical Society held at Calicut, Meerut and other places. It was followed up by the formation of a Society of Ethnobotanists in 1981 in India. Since then the society has been regularly organising seminars and workshops on ethnobotany in order to create awareness about recent researches in ethnobotany and to help evolve methodologies about studies on its different subbranches.

Founding of societies of Economic Botany, Ethnobotany and Ethnobiology and their regular publications have considerably popularised the subject. The IV International Congress of Ethnobiology held at Lucknow in 1994 has further helped in better understanding of the subject and its significance in contemporary world. Such advances ethnobotanical studies on various tribal communities notwithstanding, very little work has so far been done on textual resources and on comparative analysis of available information from various ethnic communities in India. The vast area of folkbotany, Folktaxonomy and the studies of plants used in various cultures remain more or less unattended. On the other hand ethnobotany of lower group of plants is almost totally untouched.

Area Covered Under Ethnobotanical Studies and the Tribal Communities Partly or wholly Studied by the Botanical Survey of India upto 1997 :

The scientist in Botanical Survey of India have undertaken ethnobotanical explorations in some areas of Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Bihar, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh and West Bengal. Besides, several other Research Institutions and universities have also undertaken ethnobotanical studies in other geographical areas, like Himachal Pradesh, Gujrat, Kashmir, etc. The Department has research wings at its different regional circles to carry out ethnobotanical studies as a part of this regular research programme.

The major ethnic groups studied during the course of these investigations are: Asur, Balmikis, Bhils, Bhumij, Bhutias, Chenchus, Garos, Gonds, Great Andamanese, Hoes, Jaintia, Karbis (Mikirs), Khasis, Kharias, Khonds, Khols, Lepchas, Lodhas, Mahlis, Mundas, Meech, Maria, Mishmees, Monpas, Miris, Nicobarese, Onges, Oraons, Paarias, Rathas, Reddhis, Saoras, Santals, Shompens, Toda, Totos, etc.

Impact :

The Impact of these studies are seen in many areas of plant science including conservation of biodiversity, forest vegetation as sacred groves, non-timber forest produce, etc. So far it has resulted into the documentation of about 9500 species used both for human and veterinary medicine, food, fodder, fiber, housebuilding materials, gum, resin, dye, fuel, oil seeds, narcotics, beverage, poision, pesticides, musical instruments, material culture, source of germplasm, incense, perfumes and magico religious purpose. It is seen that a quite good number of wild, semi-wild plant species have been found with new information regarding their usefulness. Over 3500 species posses medicinal or aromatic properties. But the scientific verification of these informations has so far been done in 3% cases only. It is estimated that about 1523 wild plants have so far been botanically identified as wild edible plants for human consumption. Recent ethnobotanical investigations and discovery of remarkable medicinal properties, such as cortisone precursors from sapogenins of plants, like *Costus*, *Solanum*, *Dioscorea*; hypertensive agents from *Veratrum*; cytotoxic principles from *Podophyllum*; ephedrine from *Ephedra*; ginseng from *Panax*; guggulipid from *Commiphora*; taxol from *Taxus*; cocain from *Erythroxylon*; antimalarial drug from *Artemisia*; vincristine and vinblastine from *Catharanthus*; khellin from *Ammi visnaga*; reserpine from *Rauvolfia*; hesperidin from *Citrus* plants; bishydroxycoumarine from *Melilotus officinalis*, etc. have given new impetus to the study of the subject. Modern medicine is paying increasing attention to the medicinal plants used by the tribals. Perhaps at present a quarter of modern pharmaceutical products such as analgesic, antibiotic, diuretic, laxative, tranquilizer (reserpine) or a cough pastille, amongst a long list of other items (Soedigdo, *et al.*, 1980) originated from plant extracts. The commercial value of these medicines and drugs, and other pharmaceuticals, now amounts to some US $ 40 billion a year (Myers, 1983). It has been estimated that the total export of medicinal plants from wild Indian sources has increased from about Rs. 220 million in 1974-1975 to Rs. 5000 million in 1980 (Chatterjee, 1980).

India and Africa are the cradles of psychoactive drugs that may have some promise in experimental psyschiatrics (Schultes, 1996). The ethnic communities of these countries are the custodians of traditional knowledge about these psychoactive drugs.

In India, during last three decades about 450 scientific papers and one and half dozen books on ethnobotany have been published by about 160 research workers covering about 3023 plant species of ethnomedicinal importance. All these plants have been systematically screened to ascertain their biological active principles. A broad based biological screening of these species, belonging to 1400 genera and 265 famileis, has confirmed the field information, on different biological activities, viz. antibacterial, antifungual, antihelminthic, antiprotozoal, antiviral, antifertility, hypoglycaemic, antilipaenic effect on cardio-vascular system (CVS), anti-inflammatory, etc. (Mehrotra, 1989). Most of these plants belong to Angiosperm and are known for thier usefulness for about 4000 drug industries of various systems of medicine in India.

Distinguishing Features of Tribal Medicine :

(a) The tribal system of medicine is primarily a system of compound drug.
(b) Rice beer, country liquor, mauha liquor, water, etc. are considered as carrier of medicine.
(c) Long pepper, round pepper, ginger, betel leaf, etc. are regarded as agents for bio-assimilation of medicine.
(d) There is no written formula due to want of written language script.
(e) No specific written pharmacopoea and standarisation exists.
(f) Very specified and systematised medicine.
(g) Preference is given to fresh and living plants.
(h) An age old system of medicine guided by experience.
(i) There is no measuring scale and unit, thus only approximity.

The Scopes and Implications of Ethnobotany :

The ethnobotanical studies conducted so far on different areas of its sub-disciplines and interdisciplines has hardly covered 10-15% of the tasks involved in India. Except for the listing of plants used by the specific ethnic groups of a particular geographical region, no attempt has so far been made to integrate all the sub- as well as interdisciplinary approaches of the subject together. The subject has very recently been included in the research programmes of rural health care system, emergency food plants and life supporting drug potents. In India the vastness of the scope of the subject has been indicated by Sarin (1989) and Rao (1989). Other than helping in planning of economic development in rural and tribal area the folklore studies may give new thoughts for rewriting history. It may increase the stock of words for enriching literature. It may help judge the social and economic conditions of the people. Rituals, legends, religious ceremonies, tales, proverbs, riddles, etc. can help in national integration, solve village disputes, environmental protection, etc. It can give clue for revitalisation of folk artisans. It also can be deployed for the evaluation of the commercial aspects for sustainable use of locally available raw materials in respect of development and planning, forest management and conservation of native plant genetic resources.

Food :

Tanaka (1976), Uphof (1968), Zeven (1975), etc. documented about 3000 important plant species and 1000 potentially useful plants which are meeting the present human needs. Ambasta *et al.* (1994) mentioned nearly 5223 plant species as useful plants in India. Arora (1991), Singh and Arora (1978), Bhandari (1974), Roy Chaudhari and Pal (1978) and many others have made notable contribution in this regard. For example the plants like *Piper peeploides, Parkia roxburghii, Moghania vestita,* etc. are unknown or less known for their usefulness but used as vegetable in North-eastern states. Similarly *Hodgsonia heteroclita,* a cucurbit, is used by Mizos as oil-seed and *Digitaria cruciata* var. *esculenta* as cereal by Khasis. Several other plants like species of *Alocasia, Colocasia, Amorphophallus, Dioscorea,* etc. are cultivated by various ethnic communities.

Medicine :

In recent years, the special uses of plants in ancient times by the primitive societies have caught a greater attention. The discovery of plants as source of hallucination and narcotics by Schultes (1973, 1996), Schultes and Hofmann (1980, 1987), Prance (1970), Rubin (1975), Marlin (1984), Wasson (1969), Jain *et al.* (1994) has created a global sensation on psychoactive drugs. The recent ethnobotanical studies in India have resulted into documentation of about 3500 species as against 1800 known earlier. The efficacy of contraceptives derived from sapogenous plants, like *Abrus precatorius* (white seeded), *Helicteres isora* (fruits), *Dendrophthoe falcata* (host parasite junction), *Entada phaseoloides* (seed), used by the tribals in India, has been established. Similarly *Aegle marmelos* (young leaves) and *Coccinia grandis* (fruits and leaves) are used to cure diabetes amongest children. *Argyreia nervosa* (roots), *Atylosia scarabaeoides* (seeds), *Drosera burmanni* (leaf traps), *Cassia fistula* (roots), *Curculigo orchioides* (roots), *Schrebera swietenioides* (fruits) are used in veterinary medicine. The plants, like *Phyllanthus fraternus* (whole plant) is used in jaundice and *Clausena excavata* (whole plant) and *Coptis teeta* (roots) are used in malarial fever.

Folklore :

Plants, like *Achyranthes aspera* and *Plumbago zeylanica* are used for expediting childbirth, and *Viscum album*, a parasite, is used for keeping the evil eyes away.

Narcotic :

The usefulness of plants, like *Paspalum scrobiculatum* (seed coats), *Rivea hypocrateriformis* (seeds), *Grewia microcos* (leaves), *Streblus asper* (wood powder for Myanmar cigarette), *Terminalia bellirica* (cotyledons) as sources of narcotics is unknown or little known.

Poison :

In India, starting from *Aconitum* a good number of plants are used as poison. But tribals normally use *Cleistanthus collinus* (roots), *Derris scandens* (seeds), *Aconitum* (roots), *Gloriosa superba* (tubers), *strychnos-nux-vomica* (seeds) for poisoning of the arrow heads.

Beverage :

Various starchy plant saps, leaves, seeds and flowers are used as raw material for preparation of beverages. Besides, tea and coffee, *Heritiera littoralis* (leaf tea), *Caryota urens* (sap), *Nypa fruticans* (sap), *Madhuca indica* (flowers), *Rhododendron* (flowers), etc. are used by the Indian tribals for both alocholic and nonalcoholic beverages.

Arms and Instruments :

Bow and arrow are common arms of the tribals. The plants, like *Bambusa bambos* (stem), *Manilkara littoralis* (stem), *Dendrocalamus strictus* (stem), etc. are used for making bows. Similarly *Anodendron paniculatum* (fibre), *Bauhinia vahlii* (bast fibre), etc. are used for preparing bow strings. *Ancistrocladus extensus* (stem), *Arundo donax* (stem), *Dendrocalamus strictus* (branches), etc. are used for making shaft for arrows.

Fibre :

More than 150 plant species of both wild and cultivated origin are known to yield fiber. The plants, like *Calamus viminalis* (stem), *Calamus palustris* (stem), *Donax cannaeformis* (leaves), *Borassus flabellifer* (leaves and petiole fibre), *Combretum roxburghii* (stem), *Eulaliopsis binata* (leaves), etc. are used by different tribals for obtaining fibre.

Magico Religious Belief :

There are uses of plants for various magico religious beliefs as well. It may be for treating ailments, securing luck, detecting missing pets, etc. In these perspectives *Clerodendrum serratum* (stem) is used for curing viral disease, like "Naranga" which is manifested by blisters on stem. Similarly, white flowered *Clitoria ternatea* (leaves) juice is applied for curing eye cataract.

Taboo and Totem :

There are toboo and totemic palnts. *Haldina cordifolia, Dioscorea* spp., *Lagerstroemia speciosa*, etc. are the few examples of such plants.

Sacred Plants :

Every human community has some sacred plants and flowers. Few examples of such plants are *Adansonia digitata* (Buddhists), *Aegle marmelos* (Hindus), *Ficus* spp. (Christians), *Phoenix* (Muslims), *Haldina cordifolia* (Tribals), *Cannabis* (Tribals). The flowers, like *Calotropis procera, Hibiscus rosa-sinensis, Clitoria ternatea, Nyctanthes arbor-tristis, Nelumbo nucifera, Datura metel, Saraca asoca,* etc. are regarded as sacred. Similarly, some patches of vegetation are regarded as sacred groves. According to Gadgil and Vartak (1981), in Maharashtra alone there are about 400 sacred groves which cover about 3,570 hactares of land. These patches of vegetation have been dedicated to some deity. Hajra (1981), and Maheshwari *et al.* (1981), have done good work on this aspect in North-east and central India respectively.

Some areas of Prioritisation in Ethnobotany for 21st Century :

Jones (1941, 1962) and Jain (1989) observed that ethnobotany is actually the reciprocal and dynamic aspect of human interactions with plants. But, Ford (1978) stated that ethnobotany has been applied to the solution of modern world problems where ecological perspectives have dominated both resarch and policy decisions. For ecological studies scientists are dependent on ethnobotany. Very recently it has been realised that ethnobotany is the vital discipline for ecological studies. Even biochemistry, despite its identity as a highly speciallised scientific discipline, has become a prominent approach to ethnobotany. It has been redefined as integrated discipline that draws intellectual strength from plant science and anthropology. The following are the major thrust areas :

1. Scientific confirmation of the ethnobotanical information already received.
2. Field studies on the basis of geographical areas and tirbal groups.
3. Museum and herbarium studies.
4. Studies of folklore and folk taxonomy.
5. Studies of paleoethnobotany.
6. Studies of total ethnobotany covering all aspects of the sjubject into a single species, or genus or family.
7. Comparative analysis of information already received.
8. Study of ancient and medieval literature.
9. Role of tribal participation in forest management.
10. Role of tribal participation in environmental management and conservation of nature.
11. Study of folk medicine, veterinary medicine and house hold remeldies.
12. Looking for new chemical compounds in already known medicinal palnts.
13. Looking for the new uses of known ethnobotanically important plants.
14. Looking for newer and newer genetic resources in respect of food, medicine and other economic plants.
15. Ascertaining the range of palnt diversity in respect of usefulness.

16. Study of ethnobotany in respect of gymnosperms and lower groups of plants like algae, fungi, lichen, liverworts, mosses and pteridophytes
17. The cultural recognition of plants.
18. Symbolic representation of plants to cultural understaning.
19. Intelectual property right and royalties from marketable plant products.
20. Social differentiation of plantlore and communications about plants.
21. Gender differences in plant based knowledge.

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13. PLANT-BASED INDUSTRIES

(G. Sen Gupta)

INTRODUCTION

Plants provide man with his basic needs of food, shelter and clothing. Moreover, many essential and daily requirements are also obtained from plants. To provide us with our requirements all kinds of industries, small and large, have gradually been established. As newer uses for plants and their derivatives, byproducts or waste products of other plant based industries are being discovered more and more new plant based industries are coming up. India has made rapid strides in industrialisation with the result that today there are many plant-based industries.

1. TEXTILE INDUSTRIES

The textile industry is one of India's oldest industries, being well over a hundred years old. Of the total industrial output of India, the textile industries' share is approximately 20-25%. The total employment in textile sector is estimated about 64.20 million in 1995-96 against 30 million in 1990. The total exports of the textile industry during 1998-99 amounted to Rs. 52,720.78 crore i.e. nearly 25% of our total export.

I. Cotton (races of *Gossypium arboreum, herbaceum* and *hirsutum*) :

Among cotton-producing countries, India has the largest area under cultivation. There was a record production of 114 lakh bales (of 170 kg each) of cotton in 1990. India is now in a position to export cotton yarn and textiles earning valuable foreign exchange. India is also the first country to have commercial cultivation of cotton hybrids. The cotton textile industry comprised the hand-spun, hand-woven khadi sector, the medium-scale powerloom sector and the high-tech sector. The number of cotton/man made fibre mills has increased from 378 in 1951 to 1782 till March, 1998. Out of these, 192 are in the public sector, 151 mills in corporation sector and 1439 mills are in the private sector. Cloth production in the mill sector in 1990 was 27810 lakh sq m, in the powerloom sector (including hosiery) it was 114040 lakh sq. m and in the handloom sector (excluding khadi, woollen and silk fabrics) it was 45370 lakh sq. m. In the unorganised sector, cloth production in the handloom sector was 350.8 crore m and in the powerloom sector it was 645.7 crore m. In 1990-91, the powerloom sector cloth production was valued at Rs. 10,988 crore, while exports were valued at Rs. 5,233.30 crore. Over 80% of the powerlooms were in the decentralised sector, accounting for more than half the total cloth produced and employing 55.5 lakh people. During 1998-99, the cotton production in the country reached 127.7 lakh bales.

II. Jute (*Corchorus capsularis* and *olitorius*) :

The jute industry is also more than a hundred years old. India is the world's principal jute producing country and it also is one of the biggest foreign exchange earners. The total production reached about 101 lakhs bales (each of 180 kg) in 1997-98. The industry employs about 2.5 lakh people and also supports 40 lakh jute farmers. In 1980, the total number of looms were 44,516. In 1989-90 there were 73 jute mills and the total production of jute was 71.12 lakh bales (of 80 kg each) while that of jute goods was 13.04 lakh tonnes, out of which 2.36 lakh tonnes were exported. The industry is facing competition from synthetic and non-synthetic substitute fibres. The industry is, therefore, reorienting itself to meet this challenge by paying more attention on increasing yield, diversification of jute products and products mix, improving quality and in streamlining and modernising marketing procedure for both internal and external trade. Jute is blended with cotton or these in turn are blended with rayon, silk and synthetic fibres and woven into fabrics.

III. Other fibres :

Plant fibres other than jute and cotton are obtained from coconut *(Cocos nucifera)*, which is coir, and sisal hemp *(Agave sisalana)*, flax *(Linum usitatissimum)*, mesta *(Hibiscus cannabinus)* (production of mesta in 1997-98 was 12.39 lakh bales of 180 kg. each), 'sunn' hemp *(Crotalaria juncea)* (production of 'sunn' in 1989-90 being 40 million tonnes), sabai *(Eulaliopsis binata)* etc. Man-made non-synthetic fibres like rayon, acetate rayon, viscose rayon are usually obtained from the pulp of cotton linters, *Bambusa arundinacea, Dendrocalamus strictus, Eucalyptus globulus, Gossypium arboreum, Acacia* spp., etc.

IV. Products of textile industry :

There is a wide range of products which most industries themselves are manufacturing. Mention may be made of yarns, threads, fabrics, readymade garments, laces, tapes, embroideries, union fabrics or blended fabrics, twines, ropes, cords, sacking, hessian, canvas rugs, carpets, waterproof cloths, roofing fabrics, linoleum, blankets, hosiery, furnishing clothes and upholstery, industrial fabrics, etc. In 1987-88 cotton yarn, fabrics and made up articles worth Rs. 1063.78 crore were exported, while jute products, including twist and yarn worth Rs. 242.82 crore were exported. In 1988-89 production of jute goods was 13.88 lakh tonnes. In 1987-88 the readymade garment sector earned Rs. 1792 crores in foreign exchange, while in 1990-91 it earned Rs. 4640 crore. There is vast scope for increasing trade in readymade garments.

V. Handloom sector :

This sector presents one of the oldest cottage industries. This industry provides livelihood to about 15.6 lakh people. In 1989-90, there were over 70 lakh handloom-weaving households. Production of cloth by 38 lakh working looms was 7170 m sq. mtrs, during 1998-99. During the same period exports of handloom products fetched Rs. 807 croere. It is essentially a rural-oriented indusrty and the Government has been encouraging weavers to form co-operatives, by giving them incentives, in order to safeguard their interests and for their welfare. The need to standardise, improve quality and design, cater to the fashion requirements of importing countries and at the same time countinue to maintain the regional diversities of weaving patterns are all receiving the attention of concerned authorities. Traditionally, handloom fabrics were woven from cotton and silk, but now man-made fabrics and jute are also being used. Handloom products are becoming increasingly popular both within and outside the country. The future of this industry is very bright.

2. FOOD GRAINS

Food grains are mostly produced in the unorganised sector and farmers retain a portion of their produce for themselves. In 1998-99, food grain production was 202.54 m tonnes.

I. Rice (*Oryza sativa*) :

Our principal food grains is rice and in 1998-99 the production figure was

84.74 m tonnes. Rice mills dehusk the grains and remove the outer bran from it. Of the total rice produced, nearly 55% is dehusked in the nearly 34,680 modern rice mills. Handpounding to remove the husk is still practised in rural India even today. Basmati rice which is a variety with non-sticky grains and a superior aroma, has a good demand in the international market, specially the middle-east. In 1996-97, the export of this item earned Rs. 3172 crore.

The byproducts of rice milling are - husk, bran and polish. The rice husk has many uses, such as paper pulp for manufacture of various packing and insulating materials and as ingredient for breakfast foods. The bran is the most important byproduct and is used as cattle feed and for extraction of fatty oil. It is also used in manufacture of rice bran oil and in the soap industry and also gives an edible oil.

Processed rice products are flaked or beaten rice *(chura, aval)*, parched or expanded rice *(murmury)*, parched paddy *(keel)*, ground parched rice *(sattu)*, deep fried crispies from rice or along with pulses, and fermented pudding *(idli)* and pancake *(dosa)*.

II. **Wheat** (*Triticum aestivum*) :

Wheat is the next most important crop and its production in 1998-99 reached 71.01 m tonnes. Wheat is ground in flour mills to give wholemeal flour or *atta*. Stone mills driven by hands, bullocks or camel are still to be found in rural north-west India. Roller-flour mill industry is a very large one in the organised sector. In these mills wheat is converted into wheat flour *(maida)* and semolina *(suji)*. They also produce *atta*.

Nearly 10.5 m tonnes of wheat is converted into various wheat products by about 820 roller flour mills. The flour is utilised by the bakery industry to produce bread and other bakery products. Various protein food formulations are prepared with flour which is mixed with groundnut *(Arachis hypogaea)* flour and tapioca *(Manihot esculenta)* flour. Semolina is used in preparation of breakfast foods. Puffed wheat flavoured with malt *(Sorghum bicolor)* and cocoa *(Theobroma cacao)* and coated with sugar is also produced. The byproducts of wheat milling, are also the constituents of livestock feed.

Apart from the rice and wheat, the production of different course cereals together reached 30.94 m tonnes during 1998-99.

III. Jowar (varieties and races of *Sorghum bicolor, cernuum, durra* and others):

This crop occupies more area under cultivation than any other crop except rice. In 1998-99, production was 8.53 m tonnes. Sorghum grain is malted and is used in the food and brewery industries. Starch is a byproduct of jowar and is used in the textile industry and for preparing adhesives. Gluten meal, another product, is used as cattle feed.

IV. Maize *(Zea mays)* :

The production of maize in 1998-99 was 10.78 m tonnes. From the wet-milling industry of maize is obtained starch while the other subsidiary products are maize oil and residues. The maize oil is mostly used in various industries and for manufacture of soap, while the residues is converted into animal feed. maize is valued as a green fodder for live-stock and the grains as poultry feed. Maize bran is also used as livestock feed. Other products are dextrose, corn syrup (liquid glucose) and sorbitol used in food processing industry (cakes, cookies, icings and fillings) and the pharmaceutical industry. The products of dry milling are used for the manufacture of cornflakes, popcorn, etc.

V. Bajra *(Pennisetum typhoides)* :

Its production in 1998-99 was 6.88 m tonnes. The husked grain is ground to give flour. The grains yield malt and is a source of diastase. The plant is utilised as a green fodder.

VI. Groundnut *(Arachis hypogaea)* :

In 1997-98, production of groundnut was 7.85 m tonnes, out of which 80.9% of the crop was utilised for production of groundnut oil. In 1979-80, 349 tonnes of groundnut in shell, worth Rs. 12.76 lakh, and 22,776 tonnes of groundnut kernel worth Rs. 13.45 crore were exported. After extraction of oil, the oilcake is used as livestock feed. Techniques have been developed to produce edible protein-rich flours and protein isolates from oilcakes. These are used as protein sources or protein supplements to food. Products of groundnut include roasted or salted ground nuts, groundnut (peanut) butter, groundnut candies, groundnut brittle, chocolate-coated kernels, etc. Some of these are used in formulations with other proteinaceous ingredients and skim milk powder. The shells are used for manufacture of particle boards and as roughage in cattle feed.

VII. **Bengal Gram** *(Cicer arietinum)* :

In 1997-98 production was 6.12 m tonnes. Products of gram are daal, gram atta, sattu, etc.

IX. **Pulses** :

Production of pulses during 1998-99 has been 15.85 m tonnes which recorded a 21% increase over the previous year's.

3. FOOD AND AGRO-BASED INDUSTRIES, INCLUDING HORTICULTURE and FLORICULTURE

The industries which come under this category have a vast potential for expansion of trade. The export of horticultural products including processed foods amounts to Rs. 722 crore today, while that of processed foods alone in 1989-90 was Rs. 368.09 crore. Inspite of the rich resources of crops, the area put under cultivation of horticultural crops is barely 6% of the total cultivated area in India, and that too mostly in the cottage and small-scale sector. Our global trade of this item is only 1%, while the unutilised capacity is as high as 62% and the wastage of fruits and vegetables is nearly 30%. Inspite of that India is the second largest producer of vegetables and the third largest producer of fruits.

Lack of proper links between the producing and the processing centres, inadequate or non-scientific storage facilities, lack of transportation services and the absence of effective marketing skills continue to plague not only the horticultural industry, but a vast number of other Indian Industries as well, specially in the unorganised or small-scale sector. These constraints act as bottlenecks in exploitation of this highly promising sector of the Indian economy.

To minimise wastage of fresh fruits and vegetables, the industry is encouraged now to take advantage of the techniques of irradiation, by gamma rays, of perishables to considerably extend the shelf-life and freshness of the products. This technique is absolutely harmless contrary to popular belief, and is being encouraged by the United Nations and our Government. The Bhabha Atomic Energy Centre have successfully tested over the last 25 years the lasting quality of potatoes, onions, mangoes, bananas, wheat and wheat products, spices, etc. Till now, the Indian Government has approved irradiation of onion, spices, etc. meant for export and is actively considering domestic clearance for spices, potatoes and onions. Suitable packaging and cryogenic techniques go a long way in prolonging retention of the freshness of perishables or its shelf life. Tissue culture techniques for rapid multiplication of uniform quality coconuts, oil palm, papaya etc. have been standardised.

I. Fresh fruits and vegetables :

The production of fruits in 1989-90 was 265 lakh tonnes and that of vegetables 495.3 lakh tonnes. Interestingly, over 55% of export earnings in fresh fruits came from export of mango (*Mangifera indica*) alone, whose production in 1990 was 95 lakh tonnes. Production figures of other fruits in 1990 are bananas 62 lakh tonnes, oranges -18.54 lakh tonnes and apples -9.78 lakh tonnes. Of vegetables, it is seen that onion *(Allium cepa)* constitutes the single largest item of export, followed by potato *(Solanum tuberosum)*. In 1990 production figures of several vegetables are as follows-potato-150 lakh tonnes, lentils *(Lens culinaris)* 7.03 lakh tonnes, dry beans *(Phaseolus vulgaris)*-40 lakh tonnes. Among the fruits in which there is trade mention may be made of grapes *(Vitis labrusca and vinifera)*, pomegranate *(Punica granatum)*, papaya *(Carica papaya)*, banana *(Musa paradisiaca)*, ber *(Ziziphus mauritiana)*, aonla *(Phyllanthus emblica)*, lime *(Citrus aurantifolia)*, mandarin *(C. reticulata)*, apple *(Malus pumila)*, pineapple *(Ananas comosus)*, custard apple *(Anona squamosa)*, guava *(Psidium guajava)*, chikoo *(Manilkara achras)*, etc.

II. Dried fruits (including dehydrated and frozen fruits and vegetables) :

Under this, mention may be made of the following almond *(Prunus amygdalus)*, walnut *(Juglans regia)*, cashewnut *(Anacardium occidentale)*, peas *(Pisum sativum)*, groundnut etc. Dehydrated fruits include banana, mango, dates *(Phoenix sylvestris)*, figs *(Ficus carica)*, pomegranate, onions, potato, peas, cauliflower *(Brassica oleracea* var. *botrytis)*, okra *(Abelmoschus esculentus)*, carrots *(Daucus carota)*, etc.

III. **Processed fruits and vegetables :**

In this sector there were 5112 (Jan. 1999) licensed units, with production off processed fruits and vegetables amounting to 9.4 lakh tonnes in 1998-99. Of the items being exported it may be mentioned that over 60% earnings came from export of mango pulp and juice, pineapple and other fruit juices, jams and jellies, mango pickles, dehydrated onions, garlic *(Allium sativum)* powder and mango-based products. Some of the other fruits are apple, guava, palmyra palm *(Borassus flabellifer)*, sweet lime *(Citrus limettoides)*, banana, papaya, strawberry *(Fragaria chiloensis)*, tomato *(Lycopersicon esculentum)*, Jackfruit *(Artocarpus heterophyllus)*, pear *(Pyrus communis)*, peach *(Prunus persica)*, cherry *(P. avium)*, olive *(Olea europaea)*, aonla, litchi *(Litchi chinensis)*, groundnut, etc. Items like the sweet, jelly-like endosperm of immature seeds of the palmyra palm have tremendous export potentiality as its canned is syrup already being exported, from Thailand to the ever-increasing Asian markets and USA.

The bottling and the canning industries are intimately linked to this sector. Soft drink production in 1998-99 was 5670 m bottles.

IV. **Floriculture :**

This sector is now a booming industry. In the year 1995 flower trade at the retail level in India almost touched Rs. 300 crores. The principal items are the red roses *(Rosa* hybrids), followed closely by chrysanthemums *(Chrysanthemum* spp. and cultivars) and carnations *(Dianthus caryophyllus)*. Orchids, gladioli *(Gladiolus* spp.), dahlias *(Dahlia* spp.) are also very much in demand. A Rs. 30 crore Central Government project for the development and export of orchids and other flowers over a 3 year period in four southern/western states on completion, would earn foreign exchange worth Rs. 100 crore in place of the present Rs. 8 crore. The project when fully implemented would also provide employment to 50,000 persons in each of the four states.

For interior decoration, crotons *(Codiaeum variegatum)*, Indian rubber tree *(Ficus elastica)*, palms, cacti, succulents and other ornamentals which are shade-tolerant are commonly used.

With the realisation of the vast potential of trade in horticultural products special emphasis has been given in developing temperate, sub-tropical and tropical fruits, vegetables, ornamentals, coconut *(Cocos nucifera)*, areca nut *(Areca catechu)* cashewnuts, spices, mushrooms, etc. The use of tissue-culture technology has found application in the floriculture industry for large scale multiplication of orchids and other species.

VI. **Processed foods :**

Consumer industries manufacturing bakery products, breakfast foods, biscuits, confectionery and other ready-to-eat-foods which come under this category are rapidly expanding. Manufacturers of malt extracts and beverages, chocolate and cocoa powder, instant food blends, protein foods, weaning and invalid foods also have a bright future.

Production of ready-to eat-foods went up in 1998-99 to 30 lakh tonnes, cocoa products to 34,000 tonnes and high-protein foods to 8,900 tonnes. The importance given to this sector can be gauged from the fact that in 1988 a separate Ministry of Processing Industries was established.

With the creation of a conducive industrial atmosphere following the Governments liberalised economic policy it is expected that major foreign investments are likely to be made in the food processing industries. Several export-oriented units in the fruit and vegetable processing sector were expected to come up all over the coutry linked to rural areas and were likely to attract nearly Rs. 150 crore in foreign investment. In this sector, several foreign companies already operating in the country were being permitted to raise their equity and thus may net another Rs. 150 crore.

a. *Bakery industry* : Produces bread, biscuits, cakes, cookies etc. using mainly wheat flour. Bread is now sometimes fortified with vitamins and minerals. Other ingredients used are sweet potato *(Ipomoea batatas)* flour, tapioca flour and starch as well as maize starch and oats *(Avena sativa)*.

b. *Breakfast food* : This includes rolled oats, cornflakes (from Maize), wheat flakes, shredded and puffed wheat, etc.

c. *Snack foods* : Such products include potato chips, chips made from bananas, jackfruit, tapioca etc. Others are roasted or salted groundnuts, cashewnuts, peanut candies, chocolate coated kernels, etc. 'Mixtures' or *chana chur* are mixtures in various proportions and combinations of pounded and flattened gram, and gram products groundnut, cashewnut, shredded and flaked coconut, curry *(Murraya koenigii)* leaves flavoured with spices.

d. *Beverages and instant foods* : These are products of cocoa, pre-cooked maize meal, soya *(Glycine max)* flour, maize endosperm, groundnut flour and oilcake, tapioca flour, wheat etc.

e. *Protein food formulations* : Various such formulations are now being manufactured. Government is encouraging a formulation of wheat flour 75 parts, tapioca flour 17 parts and groundnut flour 8 parts. Another formulation, *bal-ahar*, a children's nutritious food manufactured from *bulgar* wheat flour, groundnut flour and skim milk powder in the ratio 7: 2: 1 or whole wheat flour 65 parts, groundnut flour 18 parts, dehusked sesame *(Sesamum indicum)* flour 7 parts, bengal gram flour 10%, fortified with vitamins B_1, B_2, niacin, calcium and iron salts is also being actively encouraged. Production of baal-ahar was 40,000 tonnes, which was gradually to be raised to 1 lakh tonnes. Various other brands of formulations are also being produced.

f. *Infant and invalid food* : Tapioca yields sago which produces puddings, porridges and macaroni. Malted food and malted milk production in 1997-98 has touched 55,000 tonnes. "Malt extracts" from barely *(Hordeum vulgare)*, *ragi (Eleusine coracana)*, jowar, oats and wheat are also used in bakery industry to some extent, while the bulk is used in the distillery industry.

4. BREWERY INDUSTRY

I. Country liquors :

In India distilled liquor is produced almost throughout the country on a cottage-scale from fermented molasses, palmyra jaggery, *mahua (Madhuca indica)* flowers, rice and from the juice tapped from the following palms date, palmyra, coconut, and *nipa (Nypa fruticans)*. There is a considerable amount of trade in this country product, produced in the tribal belts as well as urban areas. The country liquors are sometimes spiced with various flavouring agents.

II. **'Foreign' liquors :**

Imitation foreign liquors like brandy, gin and rum are produced from molasses and spirit, while whisky is produced from molasses, spirit and malt.

Genuine whisky is produced from barley malt while genuine brandy is produced from grape juice. These are manufactured by several large units. Grapes, grown indigenously, is mostly consumed as fresh fruits, desert fruits, ***kishmish*** or rasins, while small quantities are used in the preparation of ayurvedic and unani medicines, and some for manufacture of grape-juice, grape syrup and selected seedless varieties are canned. The wine industry uses grapes which are mostly imported. A beginning has been made to produce wine from locally grown suitable types for production of rasins. Beer is produced by fermentation of malted barley. Hops (female inflorescence of *Humulus lupulus*) is added to give it a flavour and for preserving it. India, in 1975, imported 185.6 tonnes of hop valued at Rs. 40.6 lakh. Hops is now being cultivated indigenously to meet out increasing demands of beer.

During 1980-81, there were about 123 distilleries with an annual installed capacity of 6.64 lakh litres. The recent liberalisation of the Government's economic policies has turned out to be a boon for the beer and alcohol industry, which expects an investment of Rs. 390 crore by non-resident Indians with an equity participation of Rs. 90 crore.

5. PROCESSED FEEDS

Feeds fall into the categories of cattle feed, poultry feed, pig feed and to some extent feed for horses, sheep, goat and laboratory animals. By 1970 or so this industry had 28 units in the organised sector, which produced about 190,000 tonnes of processed feeds, of which poultry feed accounted for 58,000 tonnes. Besides these, in the unorganised sector there were many units engaged in hand-mixing of feeds, mainly for poultries.

The ingredients of these feeds include grains and seeds of bajra, barley, black gram *(Vigna mungo)*, chin *(Panicum miliaceum)*, horse gram *(Dolichos uniflorus)*, jowar, oats, *Cassia tora*, ragi, maize, etc. The other raw ingredients are generally the byproducts of the milling and other industries. Mention may be made of the byproducts of grains, 'chunis' of 'arhar' (*Cajanus cajan*), black gram,

gram, grain seivings, maize bran and gluten, defatted rice bran, rice polish, wheat bran, the oilcakes of copra and coconut cake, cotton seed, groundnut, maize, mustard *(Brassica campestris* ssp. *oleifera* and *B. juncea)*, safflower *(Carthamus tinctorius)* sesame and soyabean meal. Other ingredients are tubers of tapioca, brewers grain, molasses, dried yeast sludge, mango seed kernel, mahua flower and residue, etc.

6. SUGAR INDUSTRY

Sugar is obtained from complex interspecific hybrids between *Saccharum spontaneum, S. officinarum and S. sinense.* The sugar industry is a major plant-based industry. In 1983-84, it employed about 3.25 lakh workers and many million farmers and agriculturists were connected with it. Up to Sept. 1998, there were 465 sugar factories, of which over 275 were in the co-operative sector. The latter accounted for 57% of the total sugar produced. India is one of the leading sugar producing countries. In 1997-98 sugarcane production was 2763 lakh tonnes which yielded over 130 lakh tonnes of sugar. About 50 60% of the total cane produced is utilised for 'gur' production, 25 - 30% for production of white sugar, about 10% for planting purposes and about 5% for 'khandsari' production. 'Gur' is manufactured on cottage industry scale in the unorganised sector. In 1998-99 the sugar cane production in India reached 290.66 m tonnes.

The byproducts of sugar are :

a. *Bagasse* : This is used as a fuel in sugar factories. Recently it use has also as a raw material, along with certain long-fibred pulps, for manufacture of writing paper and particle and fibre boards.

b. *Cane filter cake* : It is used as a fertiliser and for manufacturing lime and several other products.

c. *Molasses* : It is used for manufacturing industrial alcohol, liquors, for flavouring 'hookah' tobacco, as a cattle feed, in foundries and as fuel. The alcohol producing industry has flourished primarily because it is able to utilise the molasses byproduct. This in turn has led to development of a number of alcohol based industries with a wide range of organic chemical products, like acetic acid, acetic anhydride, acetone, butanol, ethyle acetate, polyethene, stryene, PVC and synthetic rubber.

Beet sugar *(Beta vulgaris* var. *crassa)* :

Sugar is also obtained from beet root. In 1981-82 there was only one factory which produced 1810.6 tonnes of beet sugar.

Gur :

It is also obtained from *Phoenix sylvestris* and this 'gur' is more nutritious than the one obtained from sugar cane. Other sources of 'gur' are palmyra palm, coconut palm, and the toddy *(Caryota urens)*, palm. The fresh, unfermented sap or 'nira' of palmyra and date palms is a nutritious beverage which is bottled and marketed, though in a limited extent.

7. SPICES INDUSTRY

I. Spices :

India is the largest producer and exporter of spices in the world. Indian spices are of superior quality and are, therefore, much in demand. In 1996-97, the total production of spices was 27.8 lakh tonnes. Exports in 1996-97 were expected to exceed Rs. 1200 crore.

a. *Black pepper (Piper nigrum)* : It is one of the main spices and alone constitutes about 85% of the total spices exported. In 1990-91, its production was expected to be around 45,000 tonnes. In 1989-90, 42,000 tonnes black pepper worth Rs. 210 crore were exported. Limited quantities of green pepper in brine amounting to 338 tonnes and valued at Rs. 41.6 lakh, dehydrated green pepper amounting to 49 tonnes and valued at Rs. 21.3 lakh and white pepper amounting to 8 tonnes and valued at Rs. 2.8 lakh were also exported.

b. *Ginger (Zingiber officinale)* : Ginger is also an important spice. In 1990-91, the production of ginger was expected to be 1.7 lakh tonnes. In 1989-90, 5,200 tonnes of valued at Rs. 10.4 crore ginger was exported.

c. *Cardamom :*

(i) *Small cardamom (Elettaria cardamomum) :*

The small cardamom is in greater demand than the large cardamom. Its production in 1990-91 was 4250 tonnes. In 1989-90 export of small cardamom was worth Rs. 11.25 crore.

(ii) *Large cardamom (Amomum subulatum) :*

The large cardamom export in mid 1980's was about 200 tonnes which fetched Rs. 140 lakh.

d. The estimated production figures in 1990-91 of some of the other spices and their export figures and values for 1989-90 are given below.

(i) *Chillies (Capsicum* spp.) : 80,000 tonnes and 8,000 tonnes valued at Rs. 14.95 crore.

(ii) *Turmeric (Curcuma domestica) :* 2.7 lakh tonnes and 13.000 tonnes worth Rs. 13 crore. India is the largest producer and exporter of turmeric.

(iii) *Coriander (Coriandrum sativum) :* Production was 3 lakh tonnes.

(iv) *Garlic (Allium sativum) :* Production was 2.75 lakh tonnes.

(v) *Curry powder :* This is a mixture of several spices. Export of 3000 tonnes of this commodity was valued at Rs. 5 crore.

(vi) *Saffron (Crocus sativus) :* Production in 1981-82 was 10.13 tonnes.

e. Total exports in 1981-82 of the following spices was 17,635 tonnes valued at Rs. 14.85 lakhs : these are cumin *(Cuminum cyminum)*, fennel *(Foeniculum vulgare)*, fenugreek *(Trigonella foenum graecum)*, celery *(Apium graveolens)*, dill *(Anethum graveolens)*, ajowan *(Trachyspermum ammi)*.

Realising the vast export potential of spices, several schemes have been formulated for the development of traditional and non-traditional spices, such as pepper, clove *(Syzygium aromaticum)*, Nutmeg *(Myristica fragrans)*, cinnamom, etc., by maintenance of demonstration plots and by the distribution of seedlings and accessories, etc. to farmers. The Spices Board is promoting scientific methods of cultivation to boost production and by the introduction of improved high-yielding varieties. The application of tissue culture techniques for the supply of plantlets of spices of superior strains of uniform quality in large numbers, such as, cardamom, vanilla, clove nutmeg, ginger and trumeric has also been taken up by the Spices Board to ensure quality. Easy methods of vegetative propagation of pepper and nutmeg and high production technologies for pepper and cardamom have also been developed by the Indian Agricultural Research Institute.

II. Spice Oils and Oleoresins

Spices are almost exclusively used in food flavouring in the Indian house hold sector and also of several South-east Asian countries. However, in industrially advanced countries of the west, where processed foods are consumed in large quantities, except for pepper, most of the spices (80 90%) are used by the industrial sector and its household sector prefers to use spice extractives like oils and oleoresins. Till about ten years back, India traditionally exported only spices. If it had produced and exported these spice products the unit value in foreign exchange realised would have been considerably higher than by exporting an equivalent quantity of spice itself. Due to lack of know-how spice oil and oleoresins conforming to stringent specifications could not be manufactured to enable But conditions have now changed and India is fast emerging as a major producer and exporter of spice oils and oleoresins and the industry has a bright future.

Total spice oils exported in 1981-82 was 16.6 tonnes valued at Rs. 2.63 crore. The major spices, whose oils and oleoresins are exported, are pepper, ginger, turmeric, cardamon, cinnamom *(Cinnamomum zeylanicum)* leaf oil, caraway *(Carum carvi)* oil, chillies, fenugreek, clove, coriander, etc.

8. OILS AND OILSEEDS

India is a major oilseed growing country. It has a highly developed oil-based industry employing more than 1 crore people. Primarily it is a edible-oil industry which accounts for 83% of the total supply of vegetable oil. The nonfood uses are mainly in the soap, paint and varnish industries. India faces a chronic shortage of edible vegetable oil. During insufficient or delayed monsoons production is adversely affected and correspondingly imports are more. In 1989-90, 6.07 lakh tonnes of edible oils were imported. In 1998-99, the total oilseeds production stood at 25.68 tonnes and 22.53 lakh tonnes of edible oils worth Rs. 6,925 crore were imported.

The vegetable oil industry has been modernised and the age-old *ghani* has been replaced to a large extent by rotaries, hydraulic presses and expellers. The unorganised sector, represented mostly by the *ghani*, is small. In 1973, in the organised sector there were 235 registered large oil-milling units. Establishing modern solvent extraction plants is being encouraged to obtain maximum yield from oilseeds. Upto April 1991, 823 licenses had been issued for such units. The production from these units increased from 3.04 lakh tonnes in the oil year 1981-82 to 7.98 lakh tonnes in the oil year 1989-90.

There has been a worldwide increase in the demand for edible vegetable oils partly due to health concerns, which has resulted in a decline in consumption of animal fats. In order to increase utilization of untapped non-conventional sources of edible oil, the industry has been allowed to blend groundnut oil (a conventional edible oil) with refined soyabean oil (a non-conventional edible oil) in order to increase the utilisation of the untapped non-conventional sources of edible oil.

1. **Groundnut** ***(Arachis hypogaea)*** **:**

In earlier years, 85% of the total oil produced was used in the manufacture of *vanaspati*, but gradually its use was reduced and now its use is totally prohibited in manufacture of *vanaspati*. The groundnut oil is now replaced by cotton seed oil in vanaspati manufacture.

The demand for groundnut oil exceeds production within the country. In 1979-80 refined groundnut oil to the tune of 3,002 tonnes was imported. Now a days, however, to meet this shortage, the cheaper soyabean and palm oils are being imported. The cultivation and production of these two oilseed plants indigenously is being actively encouraged. About 80.9% of the total oil produced is used for oil extraction, 12% as seed for sowing, 5.1% for edible purposes and

2% in the form of 'hand picked selected' (HPS) kernels for export. The use of groundnut oil in the soap industry is now restricted to about 50,000 tonnes per year in the unorganised sector.

II. **Rapeseed/Mustard (varieties of *Brassica campestris* ssp. *oleifera* and *B. juncea*):**

The term 'rapeseed' is a generalised term applied to the seeds of the brassica cultivated in many parts of the world as an oil-seed crop. Although there are several distinct species, subspecies and varieties, but the oils obtained are similar in composition and contents and is known as rapeseed or colga oil. In India, the edible oil is termed as mustered oil.

The export of mustard seed and oil has been banned except under very special circumstances, primarily to encourage oil crushing within the country. Annual production of mustard oil in 1980-81 was 6.87 lakh tonnes and of oil cake was 13.96 lakh tonnes. In 1981-82 the production of mustard oil was 5.28 lakh tonnes. To meet the demand of edible oil, 7150 tonnes rape/colza seeds valued at Rs. 1.9 crore were imported during the same period. In 1990 production of mustard oil-seed was 41.23 lakh tonnes.

III. **Coconut *(Cocos nucifera)* :**

In 1982, this important oil-seed sector had 1439 crushing units. In 1990, production of coconut was 63 lakh tonnes. The oil is extracted from copra, which is the dried kernel of the coconut. During 1981-82, production of copra was 3.71 lakh tonnes, milling copra 3.31 lakh tonnes and edible copra 40,000 tonnes.

IV. **Cotton-seed (*Gossypium* spp.) :**

Cotton-seed is a byproduct of cotton ginning industry and the oil is mainly used for manufacture of *vanaspati*. The oil-cake is used for manufacture of cattle feed and soap. In 1981-82, cotton-seed oil production was 2.10 lakh tonnes. Decorticated cotton seed extractions/expellers, a byproduct of scientific processing has no internal market and is exported. In 1981-82, 2 lakh tonnes of the above, worth Rs. 28.4 crore, was exported. In 1990, 36.10 lakh tonnes of cotton seed was produced.

V. Soyabean *(Glycine max)* :

There has been a rapid increase in production of this oil-seed in the last decade or so. Production of soyabean rose from 2.5 lakh tonnes in 1978-79 to 22.5 lakh tonnes in 1990. Soyabean oil is also used in the paints, varnish and enamel industries, while the oil-cake is edible and is used in the processed feeds and food products industries.

VI. **Sesamum or til** *(Sesamum indicum)* :

Over 82% of the sesamum oil produced is utilised for edible purposes. In 1989-90 the oil-seed production was 6.2 lakh tonnes, while in 1990 it was 5.50 lakh tonnes. The oil is also used in the soap, cosmetics and pharmaceutical industries. The oil-cake is an esteemed livestock feed.

VII. **Sunflower** *(Helianthus annuus)* :

Since sunflower oil contains 60% polyunsaturated fatty acid which controls cholesterol levels in human beings, it is now being preferred to conventional oils by many and, therefore, the use of this edible oil is increasing. Production of oil-seed in 1989-90 was 5.5 lakh tonnes. The oil-cake is a livestock feed and the crop an useful fodder.

VIII. **Safflower** *(Carthamus tinctorius)* :

A non-conventional edible oil, it is gradually finding a market. Oil-seed production in 1990 was 4.91 lakh tonnes. It is also used in manufacture of soaps, paints, linoleum, enamels, while the oil-cake is a cattle feed and manure.

IX. **Castor** *(Ricinus communis)* :

India is a major castor oil producer. In 1989-90 oil-seed production was 4.75 lakh tonnes. Export of castor oil in 1979-80 amounted to Rs. 52.10 crore. With suitable processing it can be used in soap manufacture thereby relieving the pressure on other edible oils to the extent of 25%.

X. **Linseed** ***(Linum usitatissimum)*** **:**

Annual production in 1989-90 of this oil-seed was 4 lakh tonnes. The oil is used in various industries.

XI. **Oil palm** ***(Elaeis guineensis)*** **:**

The cultivation of this palm which is a native of west Africa is being vigorously taken up in India. The help of tissue culture.techniques have also been adopted to enable large-scale plantations. The reason is that the oil palm is the highest edible oil yielding plant. Compared to groundnut, sunflower and soyabean which produce 0.8, 0.7 and 0.6 tonnes oil per hectare, respectively, its production is 4-5 tonnes per hectare. It can, therefore, play an important role in bridging the gap between demand and supply. The oil-palm also yields palm kernel oil used in various industries. The expected yield from a 1976 plantation in 2500 hectares is: Palmoil 4446 tonnes, kernel oil 616 tonnes and oil-cakes 616 tonnes.

XII. **Niger seed** ***(Guizotia abyssinica)*** **:**

Production of this oil-eed in 1989-90 was 2.1 lakh tonnes. It is mainly used for edible purposes.

XIII. **Ricebran :**

Of late this by product is being used for extracting edible oil. The stalk is also used as cattle feed.

9. VANASPATI INDUSTRY

Vanaspati is a mixture of edible vegetable oils which is refined, hydrogenated, deodorised and vitaminised. It closely resembles 'ghee'. The vanaspati industry is the second largest plant-based industry next to the sugar industry. In 1982-83, about 15,000 persons were directly employed, while indirectly the Vanaspati Industry employed 60,000 persons. In 1989-90 there were 120 licensed vanaspati units and the production from these, between November 1989 and October 1990, was 8.8 lakh tonnes and touched 19.9 lakh tonnes during 1998-99. Its capacity is also partially utilised for manufacture of margarine, bakery shortening and refined oil for consumption and industrial hard oils for soap making.

At present, the edible vegetable oils used in the industry are mainly cotton seed oil, palm oil (mostly imported) and to a limited extent rice bran oil, mustard/rapeseed oil and sal seed oil. The byproducts are utilised in the soap industry.

10. PLANTATION INDUSTRIES

Most of the industries in this category are major industries, many of which are making rapid strides in the export market.

I. Tea *(Camellia sinensis)* :

Tea is one of the most important plantation crops. India is the largest producer, consumer and exporter of black tea. Tea production in 1991 was 741.7 m kg, while exports were 203 m kg valued at Rs. 1,100 crore. CTC tea production in 1991 was 578 m kg, most of which was being consumed within India. The estimated production of orthodox tea in 1991 was 163.7 m kg, most of which was being exported. In 1997 the production of Tea reached 810.6 m kg of which 196.4 m kg were exported.

Some of the products are packaged tea, tea bags, instant tea, etc. Instant tea is manufactured from green leaf and not from manufactured black tea. It is produced mainly for the export market by sevral units. In 1982, 7.66 m kg instant tea was produced. Export of 8.54 million kg worth Rs. 4.34 crore was made in 1981-82. In 1991 export of instant tea was up by 0.48 million kg over the previous year, packet tea was up by 7.5 m kg. while bulk tea declined by about 15 million kg.

Tea waste was used to produce caffeine, there being 2.5% content in it. In 1971, there were 4 units which manufactured 33,800 kg of caffeine.

II. Coffee *(Coffea arabica, C. canephora* and *C. liberica)* :

India produces about 3% of the total world production of coffee. In 1991, coffee production stood at 2 lakh tonnes. In 1989-90, export of 1.30 lakh tonnes fetched Rs. 359 crore. During the same period instant coffee export figure stood at 2,500 tonnes. During 1996-97 the export of coffee reached Rs. 1426 crores or US $ 402 m. The coffee plantations engaged about 16 lakh workers. Over 98% of the plantations are small holdings of less than 10 hactares. In 1981, there were 99,802 coffee estates of which 97,709 were small-holding estates. In 1997, the production of coffee in India reached 2.30 lakh tonnes of which 1.3 lakh tonnes, worth Rs. 1307 crores, was exported. Incidentally the export has been more or less stagnating over the last decade.

III. Rubber *(Hevea brasiliensis)* :

The cultivation of rubber is predominantly undertaken by small holders, numbering about 4.10 lakh. In 1990-91 production of rubber was 3.3 lakh tonnes, while consumption, which has always exceeded production, was 3.7 lakh tonnes. The shortage of rubber is a chronic one and in 1990-91 upto 31,700 tonnes of rubber had to be imported. In 1997, the production of rubbers reached 5.9 lakh tonnes, thus leaving a gap in demand and supply of just 5%.

Apart from the tyre industry, which is a bulk consumer of about 55-60% of rubber produced, and conveyor belts, most of the other products are made by small-scale sector units. The total number of rubber goods manufacturing units is about 5752, of which over 200 units are fairly well organised. About 52% of rubber consumed is used by automative tyres and tubes, cycle tyres and tubes account for about 11%, while belts and hoses account for about 6%. The rest is accounted for by other products. The rubber goods industry offers direc and indirect employment to over seven lakh people.

IV. Tobacco *(Nicotiana tabacum* and *N. rustica)* :

India is the fourth largest producer of unmanufactured tobacco and is the sixth largest exporter of tobacco. In 1985-86 over 3 lakh people were employed in the tobacco industry. Tobacco production during 1997-98 was provisionally estimated at 573.60 m kg of which 116.5 m kg was Virginia tobacco. In 1989-90, about Rs. 172 crore worth tobacco and tobacoo products were exported. About 75% of tobacco exports comprises Virginia flue-cured tobacco.

Tobacco products may be graded as smoking tobacco, chewing tobacco and inhaling tobacco, which are produced by diverse industries. In the first category are the cigars, cheroots, cigarettes, bidis, pipe and hookah mixtures. The second category of tobacco products include surti, zarda, kimam, dokta, sukha, pan-parag and *pan masalas*. In the last cagegory is the snuff.

In 1981-82, there were 19 cigarette factories in the private sector and one in the joint sector. Production of cigarettes in 1981 was 86,838 million pieces. In the same period there were about 10 zarda (Chewing tobacco) manufacturing factories and 3 snuff factories. In 1981-82, the export of cigarettes, bidis and hookah tobacco paste fetched Rs. 2.1 crore.

The bidi industry usually uses the leaf of tendu *(Diospyros melanoxylon)* as the wrapper for the tobacco. The sale of 'tendu patta' (leaf) is a source of revenue to the forest departments. Other leaves used as wrappers are *Diospyros exsculpta, Bauhinia racemosa, Castanopsis indica, Butea monosperma and Shorea robusta.* The *bidi* industry is a thriving one and in 1973 itself there were 2171 registered factories. About one fifth of the total tobacco produced is utilised by the bidi industry. In 1981, it was estimated that about 300 million pieces of bidis were manufactured.

The consumption of tobacco has marginally declined due to increased consciousness of the harmful effects of smoking. Therefore, some of the tobacco companies have gone in for diversification of their products to offset losses incurred due to decrease in sale of tobacco and tobacco products.

V. **Cashewnut** ***(Anacardium occidentale)*** **:**

This crop is an important foreign exchange earner since it holds a virtual monopoly in international cashew trade. It is now being turned into a plantation crop. Cashewnut is now becoming more and more popular in developed countries and cashew kernels and the oil are major export items. There are about 310 cashew processing factories where roasting, shelling, peeling, grading and packing of cashewnuts takes place. India produces about 40% of the world cashewnut. In 1996-97, cashewnut production was to the tune of 4.30 lakh tonnes. Export figures for 1979-80 are, as follows-29,786.5 tonnes of cashew kernels (whole) worth Rs. 96.39 crore, 8,209.2 tonnes cashew kernels (broken) worth Rs. 21.7 crore and 13,031.1 tonnes cashewnut shell liquid (CNSL) worth Rs. 14.6 crore. The export of cashewnut kernels during 1996-97 had been worth Rs. 1288 crores or US $ 363 m.

The juice of the cashew apple, which is the fleshy receptacle of the cashewnut, is used in making syrup, juice, candy and pickle after removal of its astringent compounds. The CNSL is a valuable raw material for the manufacture of various industrial products. New pesticides, insecticides, dyes and drugs have also been prepared from its phenolic constituents. It also has therapeutic uses.

VI. **Cocoa** ***(Theobroma cacao)*** **:**

Large scale plantations initiated from mid 1960's has given rise to a crop which produces enough for meeting internal demands. During 1992, however, one of the leading units manufactureing cocoa products incurred losses due to crop failure which forced it to make imports of raw materials thereby cutting down profit margins. Estimated production of cocoa beans in 1982-83 was 3000 tonnes. In 1982, there were about 6 major processing units. The cacao or cocoa/chocolate powder, obtained from cocoa beans, forms a highly nutritious beverage and a food. It is the basic raw material for production of drinking cocoa (chocolate), chocolates and other products. It is extensively used in the bakery and the confectionery industries. The production of cocoa products in 1989-90 was 40,000 tonnes.

Cocoa is exported as cocoa bean, powder, chocolates, cocoa butter, etc. and during 1980-81, 308 tonnes of cocoa, valued at Rs. 59 crore, and 23 tonnes of cocoa products, valued at Rs. 4 crore, were exported.

VII. **Betel** ***(Piper betel)*** **:**

Cultivation of betel vine involves highly specialised techniques and extreme care as the crop is a delicate one. It is, therefore, restricted to small holdings and the industry is in the unorganised sector. The mature or near mature leaves constitute the 'pan', taken as a masticatory. It is chewed with various ingredients depending on the individual taste. The production figures and other data could not be collected but besides production for internal combustion some amount of export of 'pan' leaf also takes place.

The following crops, though strictly not falling in the category of plantation crops, are treated here.

VIII. Coconut/coir *(Cocos nucifera)* :

The coir industry is more than a hundred years old. In 1982, there were 3932 units producing coir and coir products, of which 3704 units were in Kerala itself. The 1981-82 production figures are as follows : coir fibre 1,70,000 tonnes; coir yarn - 1,22,900 tonnes; coir products - 23,400 tonnes; coir ropes - 35,690 tonnes; curled coir - 2,500 tonnes; rubberised coir goods - 1,500 tonnes. Products include mats, mattings, rugs, carpets, etc. Various handicrafts and toys are also produced. Export of coir fibre and coir products in 1981-82 was 30,079 tonnes valued at Rs. 26.94 crore.

Besides the coir fibre and the coconut oil, the coconut shell is used for fuel, the leaves for thatching, fibre used as a broom and the coconut stem yields an inferior wood.

The Coconut Development Board recently placed bulk orders for supply of coconut shells. The coconut shells are being converted into containers for serving ice-cream and salaads. Gradually a global market is emerging in developed western nations for these coconut shells. Coconut shells were used for serving ice-cream during the Summer Olympiads held in Barcelona, Spain, in July-August, 1992.

IX. Arecanut *(Areca catechu)* :

India ranks first in both cultivated area and production of areca nuts in the world. In 1980-81, areca nut production was 1.91 lakh tonnes. Exports were to the extent of 370 tonnes worth Rs. 73.7 lakh.

11. PAPER INDUSTRY

The paper industry in India is more than a hundred years old. It is a vital core industry and employed more than 1.27 lakh people in 1985-86. At present there are 31 large, integrated pulp and paper mills, besides which 296 small and medium paper mills are operating. The country is self sufficient in respect of common varieties of paper, printing paper and paper board, and only certain varieties of paper, including newsprint, have to be imported. At present, the production of paper and paper board was 45.5 lakh tonnes. The industry is facing a shortage of raw material. Of late, many plants have been set up which depend on non-conventional raw materials, such as waste paper, rags and agro-residues. Till the 1960's, bamboo (70%) and sabai grass were the principal raw materials used for manufacture of pulp, papers and board. Nowadays, utilisation of bamboo has been reduced and have been partially replaced by wood and other non traditional raw materials, like rags, waste paper, and agricultural waste. India is one of the largest paper pulp producing country, principally from *Dendrocalamus strictus* and *Bambusa arundinacea*. At present, bamboo and hardwood constitute 30-51%, of raw materials used for paper making. Besides the above two named bamboo species, other bamboos used are a few other species of *Bambusa and Dendrocalamus, Schizostachyum pergracile, Gigantochloa auriculata* several species of *Ochlandra;* other species are are Salai *(Boswellia serrata)*, conifers, like *Abies pindrow* and *Picea smithiana*, Grasses used as raw materials, are Sabai, *Themeda arundinacea, T. cymbaria, Vetiveria zizanioides, Heteropogon contortus, Saccharum procerum, Erianthus ravennae, Phragmites karka*, etc. Other raw materials are bagasses (the fibrous stalks left after crushing sugar canes obtained from sugar mills), waste paper, straw from wheat and rice plants, rags, etc. In 1980-81, there were 7 paper mills which supplemented their raw materials with bagasse.

There are 39 mills manufacturing newsprint. The production of newsprint in 1998-99 was 5.00 lakh tonnnes. The demand for newsprint is partially met with imports, varying from 1.82 lakh tonnes in 1996-97 to 3.05 lakh tonnes in 97-98.

The Handmade paper industry with incentives from All India Khadi and Village Industries Board has been partially meeting the demands of blotting paper, filter paper, drawing paper and bond paper. The raw materials used are rags, waste paper, jute, grasses, straw, linseed stalks, cotton linters and wood barks.

12. TIMBER INDUSTRY

Timber extraction and sale of timber is almost wholly controlled by the Forest Departments of the State Governments and constitutes one of the chief sources of revenue for the forest departments. The total production of wood in 1981-82 was estimated to be 20.31 million cu.m, of which 8.2 cu.m constituted industrial wood. Fuel wood production was 12.019 million cu.m. including wood for charcoal. some of the important timbers in demand are teak *(Tectona grandis)*, Sal *(Shorea roubsta)*, gamar *(Gmelina arborea)*, hollock *(Terminalia myriocarpa)*, chuglam *(Terminalia bialata)*, shisham *(Dalbergia sissoo)*, rosewood *(D. latifolia)*, champ *(Michelia champaca)*, *Artocarpus hirsutus*, red sanders *(Pterocarpus santalinus)*, deodar *(Cedrus deodara)*, ebony *(Diospyros* spp.), chir *(Pinus roxburghii)*, Kail *(P. wallichiana)*, *Xylia xylocarpa*, Mahogany *(Swietenia mahogoni)*, willow *(Salix* spp.) garjan *(Dipterocarpus* spp.) Salai *(Boswellia serrata)*, etc.

I. Plywood and other boards :

Compressed boards in this category have several major advantages over solid wood. Plywoods are manufactured in different qualities depending upon the purposes for which they are used. Allied to plywoods are several products, such as fibre hard boards, particle boards, veneered particle boards, fibre-insulation boards, high density wood particle boards, medium density wood-based laminates, wooden flush door shutters, etc. Fibre boards, hard boards and insulation boards are made from thinnings from forests, plywood waste, saw-mill waste, etc. Particle boards are made from wood waste of all types, including lops and tops of trees, edgings from saw mills, shells of groundnut, fibres of leaf and leaf petioles of date palm and many unorthodox raw materials. Innovative techniques have been involved for products like improved or modified wood which are specially treated with synthetic resins or other material involving impregnation.

II. Sports goods :

In 1971-72, there were about 725 units in the country manufacturing sports goods, the majority of which were in the cottage-scale sector. Of late, due to increased attention to sports activities the industry has received a boost. Sport, products, with wood as a raw material include items like posts, presses, rackets, bats, sticks, wickets and items of indoor games, such as boards, parallel bars, etc.

The timbers used for making the above sports items, include mulberry *(Morus alba)*, ash *(Fraxinus* spp.) willow *(Salix babylonica)*, Beech *(Fagus sylvatica)*, canes and rattans, rosewood, safeda *(Populus alba)*, teak, deodar, chir, sal, tun *(Toona ciliata)*, jaman *(Prunus cornuta)*, etc.

III. Ships and boat building :

Traditional boats are still made out of wood, which are plank-built or dug out of logs. Marine crafts are also made from marine plywood, specially manufactured for this purpose.

The following timbers are used for boat construction ainee *(Artocarpus hirsutus)*, benteak *(Lagerstroemia lanceolata)*, Indian laurel *(Terminalia tomentosa)*, sal, *Calophyllum elatum*, *Acacia nilotica*, khair *(A. catechu)*, bijasal *(Pterocarpus marsupium)*, mango, padauk *(P. dalbergioides)*, *Artocarpus chaplasa*, *Melia composita*, bhendi *(Thespesia populnea)*, semal *(Bombax ceiba)*, baing *(Tetrameles nodiflora)*, etc.

IV. Toys :

During 1971-72, there were 336 units manufacturing toys, of which 24 were engaged in manufacture of wooden toys only, and a few were manufacturing toys made from papier mache (paper pulp), coconut pith, 'shola' *(Aeschynomene aspera)*, etc. Earlier, toys were almost wholly made from wood and tin. These are mostly replaced by plastic, vinyl and other synthetic materials now. However, traditional wooden toys are still manufactured in the cottage industry sector. The toys are usually lacquer painted. The woods more commonly used in this industry, are haldu *(Haldina cordifolia)*, jack-fruit *(Artocarpus heterophyllus)*, sandal-wood, *Gardenia latifolia*, *Givotia rottleriformis*, *Uncaria gambier*, *Pterocarpus santalinus*, shisham, walnut, *Diospyros* spp., etc.

V. Match Industry :

Both match boxes and match sticks are manufactured from specially suited timber. Match sticks are also made from paper and packed in cardboard folders. There were 1169 match factories in the country about 30 years back, many of them located in southern India. During the same period there were 20 factories which produced splints and boxes. Most of the factories were small and medium-scale manufacturing units in the cottage sector. Some of the timbers used in this industry include, *Ochlandra travancorica*, *Ailanthus* spp., *Alstonia* spp., *Anthocephalus chinensis*, semal, salai, *Canarium euphyllum*, *Endospermum* spp., *Evodia* spp., *Hymenodictyon excelsum*, *Pterocymbium tinctorium*, *Wrightia tinctoria*, *Zanthoxylum limonella*, *Trewia nodiflora*, *Swintonia floribunda*, etc.

VI. Pencil Industry :

The raw materials for manufacturing pencils were previously imported into India. Substitute Indian woods are now being used, such as *Cedrus deodara and Cupressus torulosa*. Other plant wood used in this industry are *Alstonia scholaris, Bombax ceiba, Canarium euphyllum, Holigarna arnottiana, Hymenodictyon excelsum, Larix griffithiana, Mastixia arborea*, etc.

VII. Canes and bamboos :

The cane industry : There are about 2000 small to medium cottage scale units, mostly in the unorganised sector which manufacture cane furniture and other products. In 1981-82, cane production was 2.91 lakh kg valued at Rs. 5.85 lakh. Over 18 species of *Calamus* and two species each of *Daemonorops* and *Plectocomia* are commercially important. The thick canes are used mostly for manufacturing walking sticks, furniture frames, and umbrella handles. The canes which are thin are generally used for making baskets, seats and backs of chairs, lamp shades and fancy items. Some of the more important species of canes are *Calamus gamblei, C. thwaitesii* var. *canaranus, C. nambariensis, C. pseudotenuis, C. tenuis, C. rotang* and *Daemonorops jenkinsiana*. The processed canes of *C. andamanicus* and *C. pseudorivalis* from Andaman Islands are in great demand. The bulk of *C. nambariensis* is exported to Sylhet in Bangladesh for their cottage industries.

Bamboo industry : Besides being used in the paper industry, bamboos are used for construction work, fencing, as scaffolding material, for manufacture of household items, ornamental vases, mats, hats, baskets and wicker works, furniture, sports articles, bows, arrows, walking sticks, ladders, tentpoles, etc. Out of the annual estimated production of 95 lakh tonnes of bamboo in 1986-87, nearly half was consumed by the paper industry. The more important species are *Bambusa arundinacea, B. balcooa, B. tulda, B. pallida, B. vulgaris* and *B. polymorpha, Dendrocalamus strictus, Melocanna baccifera, Gigantochloa* spp., *Schizostachyum* spp. and *Arundinaria racemosa*.

VIII. Saw mills :

The growth of the wood-based industries is directly linked to the development of the saw mill industry. Saw mills saw log of wood into planks, baulks and scantling. In 1982, there were 3430 saw mills in India, of which 1086 were small units.

13. HANDICRAFTS

The handicrafts industry is mostly village-based and is in the small-scale cottage sector. Its potential as a foreign exchange earner has been fully appreciated. The state governments have set up their Handicrafts Development Corporations, while in the central sector the Development Commissioners of Handicarafts have cèntres in the leading Indian cities which act as design centres. The industry provides employment to about 40 lakh artisans scattered all over India. In 1998-99, export of handicrafts fetched Rs. 7072.34 crore as compared to Rs. 5998.58 crore during 97-98, and included items like woollen carpets and druggets, art metal ware, hand printed textiles, wood wares, zari, ivory products, etc.

A wide range of articles from ornamental vases, lamps, decorative pieces, fancy articles, wall-hangings, decorative furniture, baskets, mats, toys, etc. are some of the products. The wood used for many of the articles comes from choice timbers, such as walnut, sandal wood, ebony, marblewood *(Diospyros marmorata)*, etc. Coconut and coir products, papier mache articles, cane products, shola, lacquered decorative articles, etc. are some of the specialities. Beads from *Elaeocarpus* spp., *Cucurbita pepo, Abrus precatorius, Putranjiva roxburghii, Coix* spp. are also prepared. Baskets and weaving materials are made from bamboos, canes, grasses and sedges. Some of the species involved are toddy palm, coconut palm, date palm, *Typha australis, Cyperus articulatus, C. Compactus, C. corymbosus, C. elatus, C. malaccensis, C. radiatus, Clinogyne dichotoma, Erianthus munja,* etc.

14. PHARMACEUTICAL INDUSTRY

More than 40% of the pharmaceutical preparations are derived from plants. If bacteria and fungi are also included then the figure comes to over 60%. In comparision to other developing countries India has a very advanced pharmaceutical industry. It has achieved international standards in sophistication of production technology. In 1989-90, drugs worth Rs. 4060 crore were manufactured, while for 1990-91 figures were expected to touch Rs. 4300 crore.

During 1997-98, the production of bulk drugs and formulations has been of the order of Rs. 2623 crore and Rs. 12,068 crore respectively. In 1989-90, drugs worth Rs. 842.70 crore were exported. There are about 250 units manufacturing drugs in the organised sector, six in the joint sector, five in the public sector and about 5000 units are present in the small-scale sector. India also occupies a leading position in the supply of medicinal plants and related products. In 1971, total export of these items to six of the most advanced nations was worth approximately U.S. $6.4 million. The main crude drugs which find a good market, include Aconite *(Aconitum napellus)*, Aloes *(Aloe barbadensis)*, belladonna *(Atropa belladonna)*, cinchona *(Cinchona* spp.), dioscorea *(Dioscorea prazeri*, etc.), digitalis *(Digitalis purpurea)*, ephedra *(Ephedra gerardiana)*, ergot *(Claviceps purpurea)*, hyoscyamus *(Hyoscyamus niger* and *H. muticus)*, ipecac *(Cephaelis ipecacuanha)*, isafgul *(Plantago ovata)*, opium *(Papaver somniferum)*, papain *(Carica papaya)*, podophyllum *(Podophyllum hexandrum)*, pyrethrum *(Chrysanthemum cinerariaefolium)*, rauvolfia *(Rauvolfia* spp.), rhubarb *(Rheum emodi)*, senna *(Cassia angustifolia)*, stramonium *(Datura stramonium)*, periwinkle vinca *(Catharanthus roseus), etc.* Export of medicinal plants and herbs in 1974-75 was worth Rs. 1391.9 lakh. Export of crude opium topped the list with an amount of 759.6 tonnes worth Rs. 17.5 crore during the same period, followed by psyllium *(Plantago ovata)* husk worth Rs. 7 crore, kuth *(Saussurea costus)* roots, zeodvary *(Curcuma zoedaria)* roots and senna leaves and pods. Export of derivatives and active principles amounted to Rs. 4.45 crore in 1974. Among others, export of ß-ionone in 1974-75 was worth Rs. 1.7 crore, menthol Rs. 29 lakh, alkaloids of nuxvomica Rs. 25 lakh, papain Rs. 15 lakh, berberine hydrochloride Rs. 10.4 lakh.

Some of the drugs are briefly enumerated here.

I. Cinchona *(Cinchona succirubra, C. officinalis, C. robusta, C. ledgeriana* and *C. ledgeriana "x" calisaya)* :

In 1976, production of dry bark was 5-6 lakh kg, which in turn yielded 18,000 to 20,000 kg. of quinine salts valued at Rs. 1.2-1.5 crore. The industry employs about 4000 labourers and earns Rs. 1 crore in foreign exchange. There are only two plantations, both in the public sector. The demand for quinine has come down due to virtual eradication of malaria and replacement of quinine by synthetic substitutes. Therefore, of late the manufacture of quinidine is picking up. Quinidine is used in treating coronary ailments and psychic ailments.

II. Opium *(Papaver somniferum)* :

The cultivation of poppy has been under Government control since the end of last century. The latex of poppy yields raw opium, the narcotic properties of which has encouraged illegal cultivation of poppy and production and trade in heroin, a major cause of drug abuse. The raw opium is processed in the two Government factories, one each in Madhya Pradesh and Uttar Pradesh, to produce (a) export opium, (b) medicinal opium powder and cake, and (c) excise opium. India exported 730 tonnes of opium in 1980. The medicinal opium and opium alkaloids of which major ones are morphine, codeine, papaverine and thebain are used in preparation of drugs and formulations. The excise opium is produced in small quantities for supply to registered addicts. India produces over 80% of the total world output of legal opium.

III. Rauvolfia *(Rauvolfia serpentina)* :

About 25-27 tonnes of dry roots are collected on a restricted scale from the wild every year (data of 1976). If demand increased this amount could be raised to about 70 tonnes. The actual present supply is 30 tonnes dry roots from all sources. The demand for the raw drug and the alkaloids is considerable within India as well as the international market. The supply could be increased if only large scale cultivation of *R. serpentina* is undertaken. Already this plant has become scarce in its natural habitat and falls in the category of threatened species verging on 'rare' status.

IV. Senna *(Cassia angustifolia)* :

In 1974-75, about 7000 tonnes of senna leaves and pods were marketed. During this period there were 12 large processing units to clean, grade and bald the produce. Of this, 6317 tonnes worth Rs. 2.71 crore were exported.

V. Belladonna *(Atropa belladonna* and *A. acuminata)* :

During 1976, the internal demand for belladonna was 70 tonnes dry leaf of the drug. The quantity collected from the wild became reduced due to dwindling natural resources. The figure stood at 4 quintals in 1974-75, whereas in 1966-67 this figure was 81 quintals, a clear indication of over-exploitation. The cultivation of belladonna has been taken up in the public sector and in 1975-76 the total production was 472 quintals.

VI. **Agar** *(Gelidiella acerosa, Gracilaria corticata, G. edulis*, etc.):

The annual production of agar-agar in 1976 was 100-200 tonnes, which was likely to double in the near future, while the annual requirements by the 1980's was put at about 500-600 tonnes. At that time, it was assessed that the natural supply of agar-agar from the marine alga *Gelidiella acerosa* was 10-15 tonnes (dry) per annum. It was assessed that there would be acute shortage due to indiscriminate and unscientific harvesting of this alga as well as, alternative sources, *Gracilaria* spp. and others.

VII. **Vinca** *(Catharanthus roseus)* :

This drug has come into prominence due to discovery of anticancer activities of some of its alkaloids (of which there are over 100 in this species), of which vinblastin and vincristine are the most important. The export of roots and leaves of this plant has started since the mid 1960's and has been increasing every year. Indiscriminate exploitation from the wild may lead to its virtual extinction.

IX. The indigenous systems of traditional medicine :

There have been efforts at reviving the indigenous systems of medicine, such as ayurveda, unani and siddha. This can be gauged from the tonnes of, formulations and drugs which are commonly found in the market now a days based on these systems of medicine. Ayurvedic herbs exported in 1974-75 amounted to 117.8 tonnes valued at Rs. 4.8 lakh. The demand for ayurvedic medicines is increasing. However, in the absence of uniform methods for preparing ayurvedic drugs standardisation has become difficult and there is no quality control.

X. Homoeopathic system of medicine :

Homeopathy is becoming increasingly popular due to its comparatively fewer side effects and relatively cheaper treatment. Homeopathic medicines in the form of tonics and formulations are now in demand and the industry is expanding. However, the bulk of raw materials and many drugs of high potencies or mother tinctures in the homeopathic system are all imported. Many of the vegetable drugs required for indigenously preparing mother tinctures are also imported.

We have to put a curb to the indiscriminate exploitation of the forests for medicinal plants extraction. Due to increased awareness the public and the private sectors are making efforts at "or" have already started large-scale cultivation of selected medicinal plants in order to stop the harmful practice of indiscrimate exploitation of our natural resources.

15. ESSENTIAL OILS AND PERFUMES

Essential oils are extracted and used in various indistries, chiefly in the soap and cosmetics industries, pharmaceutical industry, and in other industries, like confectioneries, aerated waters, 'attars', scented tobacco, 'agarbattis', incense, insect-repellants and in the paint and varnish industries. In 1974-75, export of essential oils fetched Rs. 9.3 crore. Important essential oils produced are sandal wood oil, lemongrass oil from *Cymbopogon flexuousus* and *C. citratus*, palmarosa oil form *C. martinii (motia* variety), eucalyptus oil from *Eucalyptus globulus* and *E. citridiora*, Khus oil from *Vetiveria zizanioides*, linaloe oil from *Bursera penicillata*, davana oil from *Artemisia pallens*, valerian oil from *Valeriana jatamansi*, Indian olibanum from *Boswellia serrata*, ajowan oil from *Trachyspermum ammi*, cinnamom oil from *Cinnamomum zeylanicum*, citronella oil from *Cymbopogon narduus*, ginger grass oil from *Pelargonium graveolens*, jasmine oil from *Jasminum auriculatum*, *J. officinale* forma *grandiflorum*, champak oil from *Michelia champaca*, turpentine oil from *Pinus roxburghii* and other spp., patchouli oil from *Pogostemon cablin*, citrus oil from *Citrus aurantifolia* and *C. reticulata*.

I. Perfumery Industry :

Natural perfumes are mostly obtained from essential oils of certain plants and their products. These are-attars or ottos, which are flower distillates; agarbattis or incense sticks; alcohol-free products; concentrated and dilute alcoholic solutions. The attars or ottos, used for perfuming tobacco, agarbattis, hair oils, soaps, etc., are obtained from rose, jasmine, kewda, champa, khus, henna/mehndi, bakula, harsingar, kadamba, keser, kuth, etc. Attars are essentially a cottage-industry product whose market fluctuates and has now declined primarily because their purity and quality are not standardised. In contrast to this the wide range of standard quality perfumery compounds are freely available in the market. Agarbattis, which emit fragrant fumes when burnt are a flourishing cottage as well as small-scale industry. The alcohol-free products are used in the cosmetics and soap industry. Floral and aromatic waters (rose water, kewda and khus waters) are used for diffusing perfumes in temples and on ceremonial occasions, and also used in ayurvedic and unani medicines. They are prepared by distilling floral and herbal (vegetative) parts in water.

II. **Flavouring essences :**

These are obtained from aromatic plants and are some times mixed with synthetic essences. They are used in soft drinks, confectionery items, chewing gums, desserts, icings, baked goods, drugs and pharmaceutical preparations. Some essential oils, like peppermint, anise, etc. are used in toothpaste and have anti bacterial property. Natural flavours are obtained from extract of *Vanilla fragrans*, lemon, spices, almond, etc.

III. **Turpentine oil :**

This oil is obtained from the oleo-resins tapped from *Pinus roxburghii* and from *Boswellia serrata*. It is used in varnishes, paints and lacquers, in pharmaceuticals, perfumes, synthetic pine oil, as disinfectants, insecticides, and as an important raw material for synthesis of terpene chemicals used in many industries. Resin also finds use in various industries. In 1980 or so the annual production of crude resin was about 48,000 tonnes.

16. SOAP INDUSTRY

In 1971, there were 44 units in the large-scale sector manufacturing different brands of soaps, while in the small-scale sector, there were approximately 3500 units. The raw materials for manufacturing soaps are fatty material, soap-stocks and resins. The fatty material consist of tallow or palm oil, edible oils of low quality, such as oils of linseed, castor, rice bran, mahua, etc. The hard fats include partly hydrogenated groundnut, linseed and castor oils. Soft and hard soapstocks are available from oil refining and vanaspati factories, using coconut, *mahua*, linseed, castor, groundnut oils and various minor and non-traditional oils and low grade fatty stock from neem *(Azadirachta indica)*, karanja *(Pongamia pinnata)*, kusum *(Schleichera oleosa)*, sal, kakhan *(Salvadora oleoides)*, etc. About 45% of total resin production, obtained from turpentine distilleries, is diverted for the soap industry. The soap industry has expanded over the past decade or more.

Essential oils and aromatic chemicals extracted from aromatic plants are also used for perfuming soaps.

17. PAINTS AND VARNISHES

This industry uses linseed oil, castor oil *(Ricinus communis)*, tung oil *(Aleurites fordii)*, tobacco seed oil, safflower oil, coconut oil, cotton seed oil, soyabean oil and several other oils as drying oils. It also uses resin and cashewnut shell liquid resin besides turpentine oil.

Paints are broadly classified into (a) building and structural paints, (b) coating for transport vehicles, railway coaches and ships, and (c) general industrial finishes. There are many large-scale and small-scale units in this thriving industry.

18. DYES AND TANS

I. Dyes :

Natural dyes to a large extent have been replaced by synthetic dyes. Limited amount of natural dyes are produced, such as cutch from *Acacia catechu*, kamala from *Mallotus philippensis*, annatto from *Bixa orellana*, turmeric from *Curcuma domestica*, Haematoxylin from *Haematoxylon campechianum*, saffron from *Crocus sativus*, chlorophyll from *Spinacia oleracea*, carotene from *Daucus carota*, litmus from lichen species, etc. They are mostly produced in the small to medium scale sector and are used in various ways.

II. **Tans :**

The tannin from *Acacia mearnsii* has almost replaced the bark tans obtained from *A. nilotica and Cassia auriculata.* Other important tannin yielding species in use by the tanning industry, are *Rhizophora mucronata,* and *Ceriops tagal, C. roxburghiana,* while the myrobalans are obtained from *Terminalia chebula* and *Phyllanthus emblica.* They are chiefly used in the leather industry and in the writing ink-industry.

III. **Inks :**

One of the constituents of printing ink is resins and natural resins are obtained from shellac and rosin. Writing inks have several ingredients of vegetable origin. An important source are the galls produced on *Quercus infectoria* and allied species imported for the tanning and ink industries. Other tannins used for making low grade inks are obtained from *Caesalpinia digyna, C. coriaria, Terminalia chebula, T. bellirica, Acacia catechu* and *Phyllanthus emblica.*

19. LAC AND SHELLAC INDUSTRY

Although lac is an insect exudation, this is produced only when this parasitic insect attaches itself to the twigs and branches of some host specific trees in the larval stage. The lac is the exudate which the insects excrust themselves with for protection. The host specific trees are kusum *(Schleichera oleosa)*, palas *(Butea monosperma)*, ber *(Ziziphus mauritiana)* and ghont *(Z. xylopyrus)*. The lac industry uses the crude lac or stick lac and refines it to produce seed lac, shellac, button lac, garnet lac, dewaxed lac and bleached lac in cottage scale and large-scale shellac factories. India is one of the major lac-producing countries. In 1982-83, there were 198 shellac factories with a production of 13,420 tonnes lac, out of which 7,000 tonnes were exported. In 1981-82, 10,700 tonnes lac worth Rs. 15.66 crore was exported.

Shellac is mainly used as surface-coating material and is used in other industries such as printing inks, handicrafts, pharmaceuticals, cosmetics, hair lacquers, electrical industry, etc. Lac is used in manufacture of French polish, gramophone records, electrical insulation materials, hats, grinding wheels, adhesives, metal enamelling, nail polish, dental plates, lac bangles, jewellery fittings, crayons, etc.

20. KATHA AND CUTCH INDUSTRY

An important forest based industry, there are 3 large-scale units in the organised sector which has a total annual production of about 1000-1600 tonnes cutch. The unorganised sector of the tribal communities produce about 3000 tonnes of katha. These products are derived from khair *(Acacia catechu)*. Katha is used as a masticatory with pan, the betel leaves, and in medicine. *Cutch* is rich in catechu-tannic acid and is used in dyeing cotton and Silk and in calico printing. It is also used to dye ship sails, mail bags and for making jute rot-proof, for dying pulp and paper and tanning fishing nets.

21. INSECTICIDES AND PESTICIDES

The natural organic insecticide used are pyrethrum extracts, nicotine sulphate and rotenoids. The plants, which possess insect-repellant properties include *Nicotiana* spp. with nicotine, *Chrysanthemum cinerariifolium* with pyrethrum, several leguminous plants such as *Derris* etc. with rotenoids, *Quassia amara, Ricinus communis*, etc. In 1982-83, production of pesticides, including chemical pesticides, was 65,000 tonnes.

22. CO-OPERATIVE INSTITUTIONS

The co-operative movement has made noteworthy progress in agricultural credits, marketing and processing of agricultural produce, supply of farm inputs, distribution of consumer goods. Co-operatives are mostly village-based. The total value of agricultural porduce marketed by the Co-operatives amounted to above Rs. 6274 crore in 1989-90. The total value of foodgrains handled by the marketing co-operatives was about Rs. 1128 crore in 1986-87.

Independent processing units in the co-operative sector include large units such as co-operative sugar factories, spinning mills and solvent extraction plants. Medium and small units such as rice mills, oil mills, cotton ginning and pressing units, jute-baling units are mostly adjuncts of co-operative marketing societies. In March, 1989, there were 2422 agro-processing units. During 1989-90 sugar season between October and September, 211 co-operative sugar factories produced 66 lakh tonnes sugar, which accounted for about 60% of total production of sugar in the country.

In 1990, total number of co-operative spinning mills were 10,948 in the growers sector and 61 in the weavers sector, having about 11% of total spindlage capacity in the country. In 1987-88 there were 300 oil mills and similar units in the co-operative sector.

23. MISCELLANEA/RECENT TRENDS

I. Sal :

Leaves are extensively used for manufactureing platters (Plates) and various other containers and receptacles. Dried leaves are inter-woven and compressed and cut to the desired shapes and sizes. These are manufactured on a cottage scale in the unorganised sector. The leaves of palas *(Butea monosperma)* are also used in a similar fashion.

II. Tissue culture techniques :

These techniques are now being employed to augment biomass production for use as fuel, fodder, timber and industrial/commercial wood in increasing amounts. Two pilot plants at several research laboratories are carrying out large-scale micropropagation/bulk multiplication of major forest tree species with the aim of producing several million plantlets a year for use as indicated already.

III. Biofertilisers and Organic Manures :

a. *Biofertilisers :* It has been demonstrated that biofertilisers are an effective, cheap and renewable supplement to chemical fertilisers. Emphasis has been laid on an integrated nutrient supply to the crops in question, through combined use of fertilisers, organic manures and bio-fertilisers. *Rhizobium* inoculants have been found effective in fixing nitrogen in pulses, legume fodders and oil-seeds, like soyabean, groundnuts, etc. Blue-green algae (BGA) have been found to be successful in nitrogen-fixation in low-land paddy. The BGA is also able to reduce salinity of the water. In order to fully utilise benefits of biofertilisers, the Government has started a nationwide project on development and use of biofertilisers and has set up a national centre at Ghaziabad (U.P.) with six regional centres. The anticipated production of the BGA, *Rhizobium* inoculants, from these centres in 1990-91 was 85 tonnes. During 1988-89, sixty BGA centres have produced 110 tonnes of the algae and in 1989-90 it was 200 tonnes. This level of production was expected to be maintained in 1990-91. Efforts are on to develop efficient algal strains which could grow and fix nitrogen under adverse conditions for wheat, because wheat cultivation does not require submerged water conditions as rice does.

b. *Organic manures* : It is estimated that about 100 crore tonnes of organic waste in the form of crop residues, besides cowdung, are available in the country. There is a potential of 6500 lakh tonnes of rural compost and 160 lakh tonnes of urban compost which has not been fully utilised. These materials contain approximately 65 lakh tonnes of nitrogen, 25 lakh tonnes of phosphate and 45 lakh tonnes of potassium. Even if a significant portion of this could be recycled, our agricultural economy would improve and the crop land would become better. The Government has taken steps to promote technology which would enable utilisation of these wastes to provide low-cost compost and to enrich these, if need be, with nutrients.

IV. Natural health foods :

Due to increase in the awarness about the harmful effects of chemical ingredients such as artificial and synthetic inputs for agricultural crops, the use of natural health foods is gaining popularity and has almost become a craze in affluent developed countries and societies. Crops grown without or with minimal use of chemical fertilisers, pesticides, insecticides; products without artificial colours and flavours as well as additives and foodstuffs with minimal processing and refining are, therefore, growing in demand. Global trade in natural health foods is a multi-million dollar business. There is a vast export potential for exotic foods, natural products, such as unsweetened food spreads, dehydrated fruits and vegetables, unprocessed honey and spices and natural herbs and herbal preparations. Indian food industry could take advantage of this newly emerging trend.

V. Cut flowers :

The world demand for cut flowers amounted to U.S. $2.2 million in 1987. Netherlands, the single largest exporter of cut flowers, handled 65% of world trade alone. Israel, Spain and Italy have also surged ahead. Thailand is a comparatively newcomer. India with its variety of soils and climatic conditions should take advantage of this. We should, therefore, first of all identify market opportunities and assess the extent of demand. Then efforts should be made to mobilise cultivation and supplies through a co-ordinated effort in both production and export marketing.

24. CONCLUSION

Agriculture is rapidly and increasingly becoming science-based and closely linked with industry. Recent advances in biotechnology, genetic engineering, photosynthesis, tissue-culture, etc. are coming closer to one another and are merging areas of collaborative research for promoting the growth of agricultural productivity. The conservation and planned exploitation of germplasm resources and the inventorisation of natural resources are among some of the priorities and thrust areas of agricultural research and education. The latter is one of the basic objectives of the Botanical Survey of India.

Today there is a crying necessity to initiate drastic measures for conserving our natural resources and prevent its further relentless and indiscriminate exploitation. It must be realised that this excessive exploitation has led to a rapid depletion and destruction of our forests. In the past two to three decades it is estimated that we have lost about 40% of our forests. We must try to inculcate a scientific approach in the extraction of natural resources and plan it in such a manner as to give it a reasonable change to renew and replenish itself again and again. The alarming depletion of the forests and natural resources with the total destruction of several elements is compelling us to make all out efforts at collecting and preserving genetic resources of cultivated and economic plants in germplasm banks.

Large scale cultivation of economically important species has to be encouraged to put a check to their exploitation from nature. Our aim should be to leave something for posterity.

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14. WASTELAND DEVELOPMENT AND SOCIAL FORESTRY

(N.P. Singh)

INTRODUCTION

With the advent of civilisation, the land has been meeting such basic needs, as food, fodder, fuel, clothing and shelter as well as other material needs of the mankind. Soil, therefore, constitutes the most precious resource for any nation. However, the increasing pressure of both human and livestock population, coupled with the resultant depletion of vegetation cover, has exposed the land surface to the vagaries of nature. This has lead to the erosion of top soil, thus converting large tracts of the country into wastelands. As it threatens to undermine the basic means of the life support systems, an all out concerted effort is needed not only to check the menacing expansion of the wastelands, but also to reverse the trend through environemntally viable and socially beneficial corrective measures. As the social forestry can effectively address the problem, it is inseparably linked to the wasteland development. Various issues involved in this regard are being discussed and summarised.

Wasteland Development :

The rural poor heavily depend on land in the absence of substantial growth in employment in the country. But because of heavy pressure of population, the degradation of land has diluted land's inherent capacity to support life systems, which results into wastelands.. Rapid expansion of wastelands is seriously undermining the productive resource base. The Table 1 below shows the state-wise land use according to the land use classification.

Table shows that out of a total estimated area of 304 million ha, agricultural land occupies about 142 million ha, while the forests occupy about 67 million ha. The forest cover of India is indicated state-wise in Table 2. According to an estimate, of the above said nearly 93 million ha of agricultural land and about 36 million ha of forests are suffering from various kinds of degradation respectively, which shows that more than half the area is degraded. These estimates of wastelands in India are furnished state-wise in Table 3, whereas some split details are provided in Table 4 (also 3 maps).

Table-1. State-wise land use according to the land use classification

(Thousand hectares)

State/Union Territory	Reporting area	Forests	Area put to non-agricultural use	Barren and unculturable land	Permanent pastures and other grazing lands	Land under misc. tree crops and groves not included in net area sown	Culturable waste land	Fallow lands other than current fallows	Current fallows	Net area sown	Total cropped area	Cropping intensity	Net irrigated area	Gross irrigated area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Andhra Pradesh	27,440	6,172	2,216	2,296	899	272	901	1,469	2,181	11,034	12,769	115.7	3,527	4,518
Assam	7,852	1,985	912	1,541	184	250	107	86	91	2,696	3,556	131.9	572	572
Bihar	17,330	2,736	1,659	964	136	214	415	937	1,991	8,278	9,641	116.5	2,319	3,358
Gujarat	18,826	1,965	1,078	2,502	845	4	1,969	302	491	9,670	10,189	105.4	2,155	2,522
Haryana	4,394	136	328	88	27	..	46	–	171	3,596	5,306	147.6	2,356	3,559
Himachal Pradesh	3,113	809	153	144	1,089	41	239	14	43	571	958	167.8	93	159

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
J. & K.	4,506	2,759	304	256	123	94	145	8	93	724	1,002	138.4	318	405
Karnataka	19,050	3,030	1,131	829	1,260	332	495	491	1,126	10,356	11,151	107.7	1,486	1,792
Kerala	3,885	1082	276	86	5	55	130	27	44	2,180	2,862	131.3	259	389
Madhya Pradesh	44,211	14,015	2,205	2,369	2,820	163	1,795	1,009	808	19,027	22,215	116.8	2,656	2,744
Maharashtra	30,758	5,312	998	1,722	1,584	183	987	804	866	18,302	19,957	109.0	1,927	2,686
Manipur	2,211	602	26	1,419	--	24	--	..	--	140	188	134.3	65	75
Meghalaya	2,249	812	85	231	17	145	454	261	51	193	208	107.8	50	51
Nagaland	1,099	286	28	--	—	200	63	262	95	165	178	107.9	66	76
Orissa	15,540	6,640	632	265	560	423	249	189	452	6,130	8,326	135.8	1,215	2,006
Punjab	5,033	216	440	90	4	4	37	1	39	4,202	6,915	164.6	5,550	6,148
Rajasthan	34,235	2,151	1,510	2,892	1,836	50	6,195	1,920	2,021	15,660	18,395	117.5	3,218	4,088
Sikkim	729	295	70	209	97	2	1	7	2	76	103	135.5	12	12
Tamil Nadu	13,001	2,030	1,781	590	155	201	330	568	2,087	5,259	6,030	114.7	2,255	2,732
Tripura	1,018	578	..	120	--	98	2	2	2	246	381	154.9	29	38
Uttar Pradesh	29,748	5,120	2,336	1,120	299	568	1,147	756	1,176	17,226	24,708	143.4	9,884	12,125
West Bengal	8,846	1,184	1,293	121	4	162	374	61	82	5,565	7,004	125.9	1,834	1,834
Union Territories	9,006	7,276	111	28	12	69	230	329	221	473	594	125.6	123	148
All India	**304,110**	**67,151**	**19,552**	**20,139**	**11,956**	**3,554**	**16,313**	**9,503**	**14,133**	**141,769**	**172,636**	**121.8**	**39,969**	**52,029**

*Excludes area under the illegal occupation of China and Pakistan. (Source: Indian Agriculture in Brief, 21st Edition).

Table-2. Forest cover of India

(Area in sq. km)

Sl. No.	State/UTs	Dense Forest (Crown density 40% and above)	Open Forest (Crown density 10 to 40%)	Mangrove	Total Forest cover
1.	Andhra Pradesh	23,048	19,859	383	43,290
2.	Arunachal Pradesh	54,155	14,447	--	68,602
3.	Assam	15,548	8,276	--	23,824
4.	Bihar	13,300	13,224	--	26,524
5.	Delhi	16	10	--	26
6.	Goa	995	252	5	1,252
7.	Gujarat	6,337	5,250	991	12,578
8.	Haryana	370	234	--	604
9.	Himachal Pradesh	9,560	2,961	—	12,521
10.	Jammu & Kashmir	11,020	9,420	--	20,440
11.	Karnataka	24,854	7,546	3	32,403
12.	Kerala	8,454	1,880	--	10,334
13.	Madhya Pradesh	82,745	48,450	--	131,195
14.	Maharashtra	23,622	22,397	124	46,143
15.	Manipur	4,937	12,481	--	17,418
16.	Meghalaya	4,044	11,613	--	15,657
17.	Mizoram	4,348	14,427	--	18,775
18.	Nagaland	3,487	10,734	—	14,221
19.	Orissa	26,101	20.629	211	46.941
20.	Punjab	511	876	—	1,387
21.	Rajasthan	3,690	9,663	--	13,353
22.	Sikkim	2,423	706	--	3,129
23.	Tamil Nadu	8,676	8,367	21	17,064
24.	Tripura	1,819	3,727	--	5,546
25.	Uttar Pradesh	22,958	11,036	--	33,994
26.	West Bengal	3,557	2,669	2,123	8,349
27.	A & N Islands	6,520	127	966	7,613
28.	Chandigarh	6	1	—	7
29.	Dadra & Nagar Haveli	159	45	--	204
30	Daman & Diu	--	3	--	3
31.	Lakshdweep*	--	--	--	--
32.	Pondicherry*	--	—	--	--

*No discernible forest cover. (Source : Forest Survey of India : State of Forest Report, 1997).

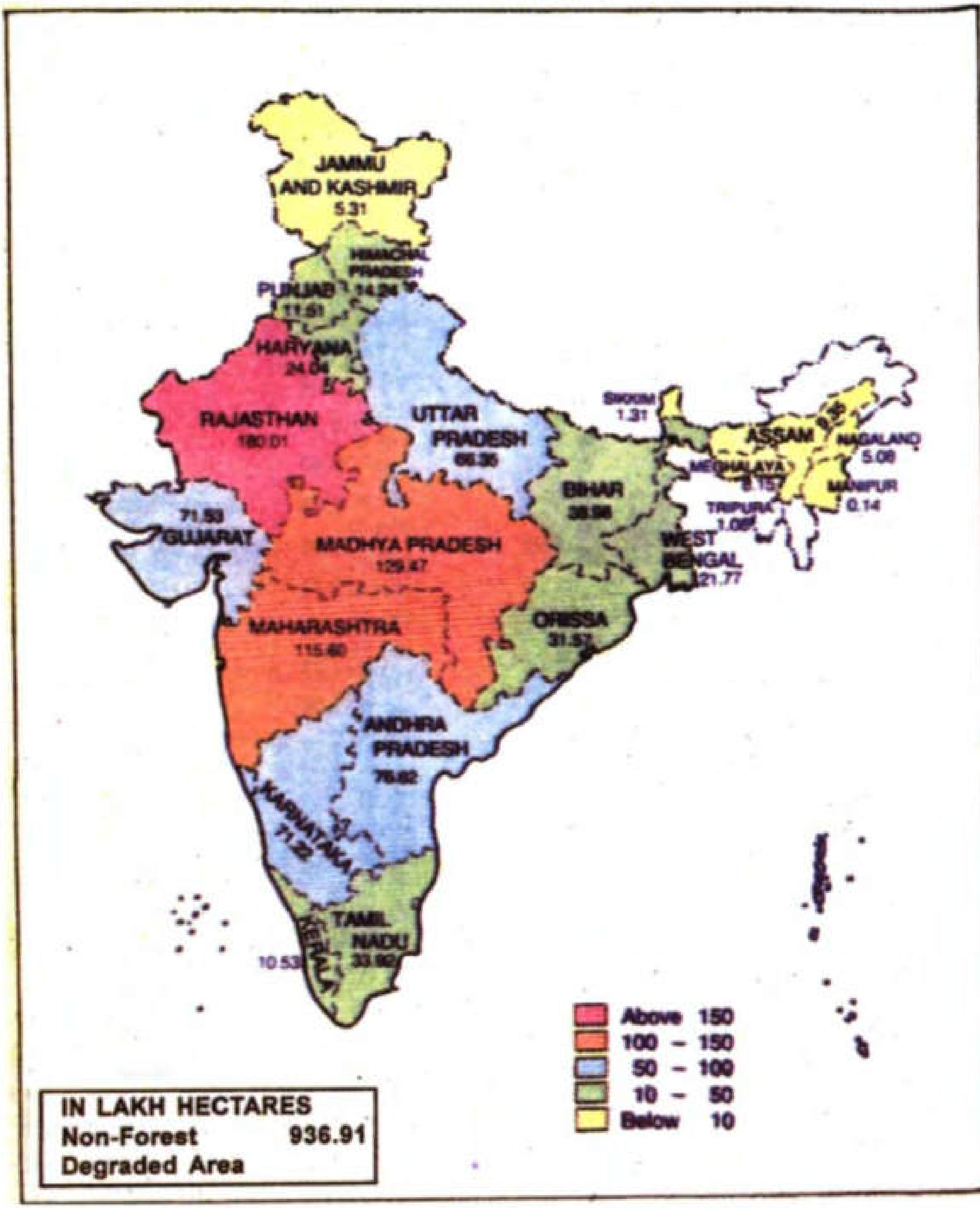
Table-3. Estimates of wastelands in India

(Lakh hectares)

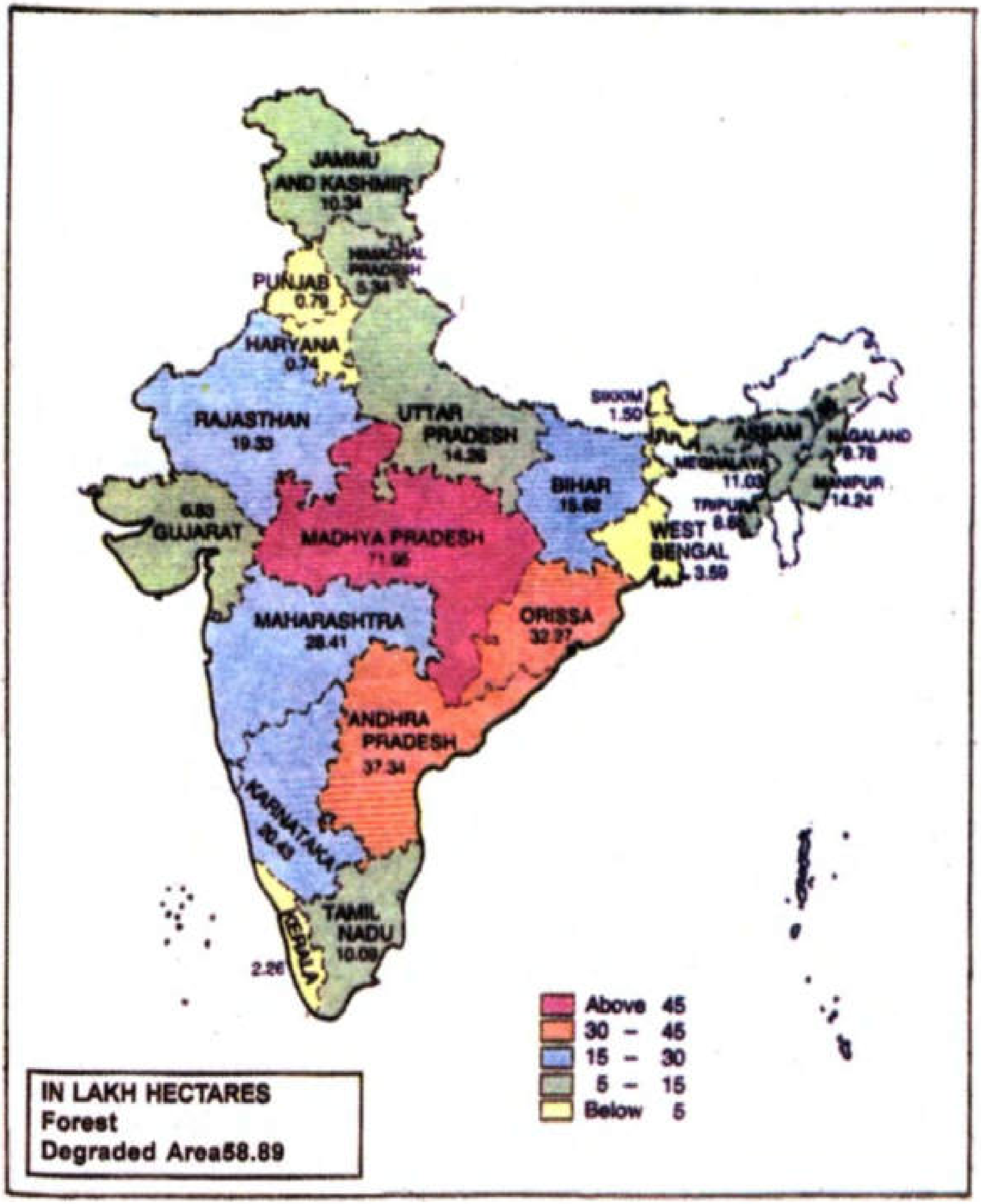
States/UT	Non-Forest Degraded Area*	Forest Degraded Area**	Total
Andhra Pradesh	76.82	37.34	114.16
Assam	9.35	7.95	17.30
Bihar	38.96	15.62	54.58
Gujarat	71.53	6.83	78.36
Haryana	24.04	0.74	24.78
Himachal Pradesh	14.24	5.34	19.58
Jammu & Kashmir	5.31	10.34	15.65
Karnataka	71.22	20.43	91.65
Kerala	10.53	2.26	12.79
Madhya Pradesh	129.47	71.95	201.42
Maharashtra	115.60	28.41	144.01
Manipur	0.14	14.24	14.38
Meghalaya	8.15	11.03	19.18
Nagaland	5.08	8.78	13.86
Orissa	31.57	32.27	63.84
Punjab	11.51	0.79	12.30
Rajasthan	180.01	19.33	199.34
Sikkim	1.31	1.50	2.81
Tamil Nadu	33.92	10.09	44.01
Tripura	1.08	8.65	9.73
Uttar Pradesh	66.35	14.26	80.61
West Bengal	21.77	3.59	25.36
UTs	8.89	27.15	36.04
Total	936.91	358.89	1295.80

* Source : Society for Promotion of Wasteland Development (SPWD), New Delhi. 1984

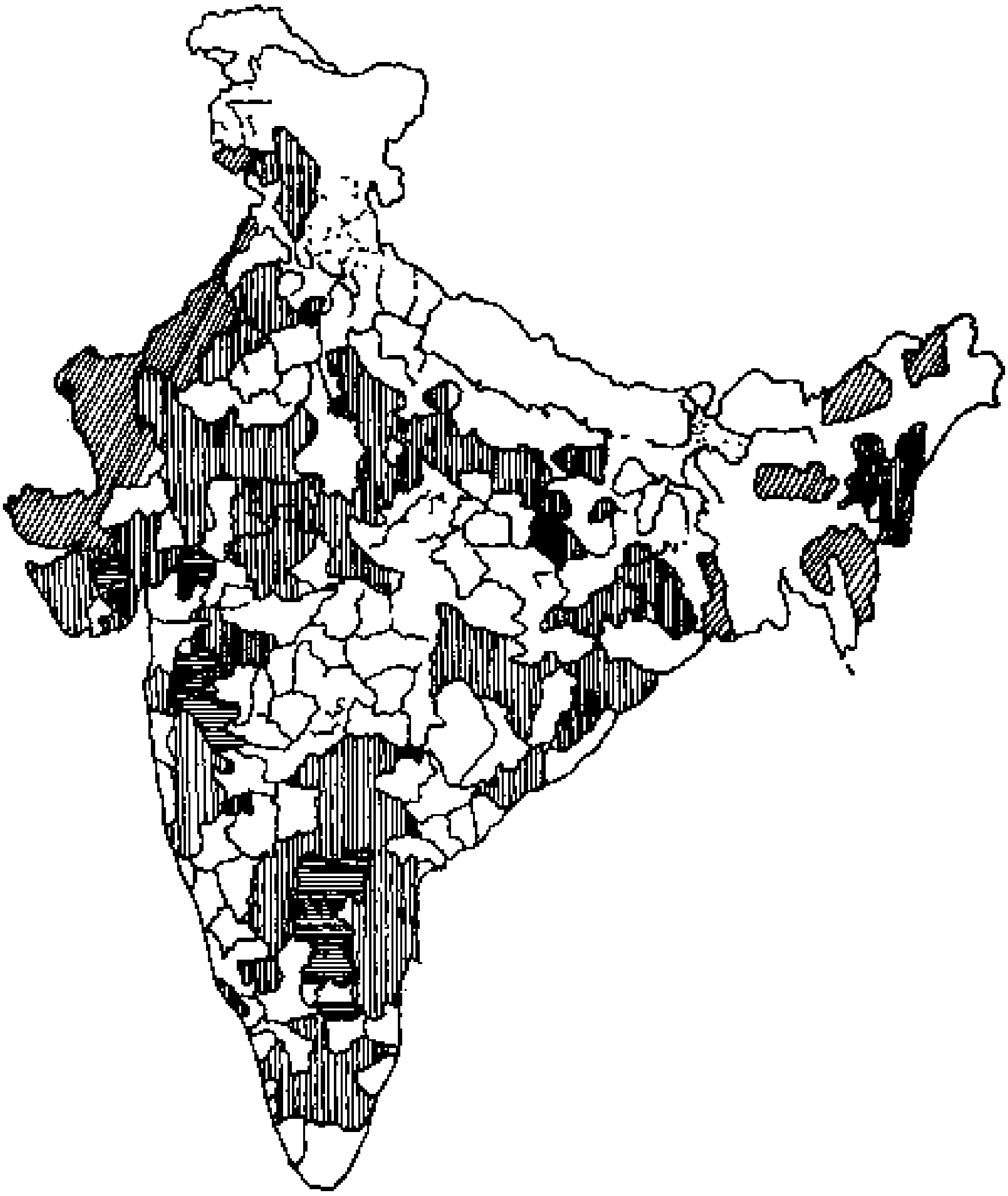
** Barren area notified as forest not included in the above figures.



Map 16. Estimated wastelands in India in non-forest degraded area (source : SPWD, New Delhi).



Map 17. Estimated wastelands in India in forest degraded area (source : SPWD, New Delhi).



Map 18. Map showing 146 districts with wastelands
(source : NWDB, New Delhi).

Table-4. Estimates of Wastelands in India (Non-Forest Area Only)
(Lakh hectares)

States/UTs	Saline & Alkaline Lands	Wind Eroded Area	Water Eroded Area	Total
Andhra Pradesh	2.40		74.42	76.82
Assam	--	--	9.35	9.35
Bihar	0.04	--	38.92	38.96
Gujarat	12.14	7.04	52.35	71.53
Haryana	5.26	15.99	2.76	24.04
Himachal Pradesh	--	--	14.24	14.24
Jammu & Kashmir	--	--	5.31	5.31
Karnataka	4.04	--	67.18	71.22
Kerala	0.16	--	10.37	10.53
Madhya Pradesh	2.42	--	127.05	129.47
Maharashtra	5.34	--	110.26	115.60
Manipur	--	--	0.14	0.14
Meghalaya	--	--	8.15	8.15
Nagaland	--	--	5.08	5.08
Orissa	4.04	--	27.53	31.57
Punjab	6.88	--	4.63	11.51
Rajasthan	7.28	106.23	66.59	180.01
Sikkim	--	--	1.31	1.31
Tamil Nadu	0.04	--	33.88	33.92
Tripura	--	--	1.08	1.08
Uttar Pradesh	12.95	--	53.40	66.35
West Bengal	8.50	--	13.27	21.77
UTs	0.16	--	8.73	8.89
Total	71.65	129.26	736.00	936.91

Source : Society for Promotion of Wasteland Development, New Delhi-1984.

As early as in 1928, the Royal Commission on Agriculture made a very strong recommendation that all wastelands, viz. village forests under the control of revenue department should be handed over to forest departments of respective states and be managed as fuel and fodder reserves for the people. But the problem of wastelands did not get its due recognition till very recently. A committee on Natural Resources, in 1963, seems to be the first one to present a study on wastelands including saline, alkaline and waterlogged lands and their reclamation measures. Suddenly these problems gained importance and got a big boost for over the last decade. The nineties saw a score of papers and books in this direction. To mention a few: Tweari and Mascarhenas (1983) selected Singhbhum district of Bihar for their studies on wastelands development and environmental management through community forestry. Singh (1985) presented the problems of wastelands in India. Yadav (1985, 1987) furnished diagnosis, treatment, genesis and utilisation of wastelands. Forest Research Institute, Dehra Dun (Anonymous, 1988) also came out with a compilation on wasteland development for fuelwood and fodder production. Ram Prasad (1988) provided the technology for wasteland development. Gupta and Maroo (1991) discussed the issues and challenges in the utilisation of wastelands.

Adiseshiah (1989) while providing the economics of wasteland development, defined the wastelands as a piece of land which has been damaged and has suffered degradation due to *inter alia:* its over use, wrong use or uncared for state which result in eroded soils, salinity and alkalinity, water logging, ravines and gully erosion and degraded forest land. The present concept, however, is that wastelands may be defined as lands where the production of biomass is less than its optimum productivity. It also refers to an available piece of land which is not being used to its optimum productivity, thus leading to national wastage. Abrol and Dhruva Narayana (1990) while editing the technologies for wasteland development, mapped the degraded soils, viz. soils of arid, semi-arid, sub-humid, humid and salt affected soils. Sastry *et al.* (1990) and Singh (1989) have dealt with plants that could be used for reclamation of wastelands along with detailed list of plants. Sastry *et al.*, (*l.c.*), in particular, suggested over a thousand species for various habitats.

As the problem of wastelands attained prominence and the need for their development was recognized, many seminars were conducted to guide its proper development. ICAR sponsored a seminar and a Summer Institute at the Central Arid Zone Research Institute, Jodhpur in 1986 on the wastelands and their utilization (Shankaranarayan, 1988) and on wastelands in arid and semi-arid zones and technologies for their improved utilization (Anonymous, 1986) respectively. A seminar was organised at New Delhi in 1986 on the dimensions of wasteland development (Anonymous, 1989). Another one was organised at Balrampur in 1987 on the utilization of wastelands for sustainable development (Sharma *et al.*

1990). An international workshop was also organised at New Delhi in 1990 on the land use systems research (Anonymous, 1992).

According to an estimate at least one-third of the total landmass of India is badly degraded and about half the forest area has poor or no forest cover. Rapid expansion of wastelands is endangering vital life support systems. Hence the Government of India felt an acute need for urgent action to tackle these problems. The first major decision was taken in 1985 with the launch of the Wastelands Development Programme to deal with issues, like ecological crisis caused by deforestation and degradation; socio-economic crisis caused by acute shortages of fuelwood and fodder and for making afforestation a people's movement. The National Wasteland Development Board was established in the same year and was given the mandate of undertaking wastelands development through a massive programme of afforestation and tree planting with people's participation. The programme was accorded high priority by inclusion in 20 Point Programme as point 16, which envisages that efforts will be made to grow more trees and raise more forests with the full involvement of people, protect the traditional rights of tribal population and local communities of access to firewood and forest produce, reclaim wastelands for productive use and plant appropriate vegetation in hill, desert and coastal areas. The Board realised that the afforestation effort on a country-wide basis could not succeed without the active participation of the public. The Government had neither the means, nor the money for such a massive programme.

A review of the work done by the Broad in the next four Years (1985-1989) revealed that though the afforestation targets under social forestry programmes had been achieved and some other initiatives taken, it was not satisfactory with regard to increasing the pace of afforestation, increasing the availability of fuelwood and fodder for the rural poor and in securing people's participation in the afforestation activities (Anonymous, 1989). Therefore, the programme of the Board was restructured and strengthened in 1989 and the Wastelands Development Programme was made a Technology Mission on 5.10.1989 (Anonymous 1990). Subsequently in April 1990, it was decided that this programme will be guided and overseen by the National Wastelands Development Board, which will adopt a mission approach for enlisting people's participation, harnessing the inputs of science and technology and achieving inter-disciplinary co-ordination in the programme planning and implementation. The programme would focus on checking land degradation and putting wastelands in the country to sustainable use, increasing biomass availability, especially fuel wood, fodder and forest produce and restoring the ecological balance. To implement this programme six 'mini-missions', viz. Planning and Policy, People's Participation, Technology Extension, Regeneration of Degraded Forests, Greening of Public Lands and Farm Forestry, were created.

Wasteland development cannot possibly be a single point programme. It requires a broader and more comprehensive approach, necessiating an inter-disciplinary and multi-pronged strategy. Therefore, the main elements of the Mission stragegy include: People's participation at all stages, specially through the panchayats; integrated land use planning on watershed basis; village level action plans; emphasis on conservation, ecological restoration and natural regeneration; fuelwood, fodder and timber production; Technology extension; Resolution of relevant policy issues like grazing and livestock management and reducing the pressure on the forests in the country, and the target areas, viz. degraded forest area, degraded pastures and public lands and private wastelands and dry farm lands. Some of the policy issues are land use mechanisms, grazing and livestock management, fuelwood conservation, wood substitution, benefit distribution under programmes on public lands, resource mobilization for Mission activities, institutional finance and other support for farm forestry and fiscal incentives to promote farmer-industry nexus.

The technology extension is aimed at treatment of problem lands, like saline/alkaline, arid/sandy and ravinous tracts and promotion of Agro/Farm Forestry on dry lands and especially to develop low cost technologies; evaluation of the available technologies; assess research gaps and to sponsor time-bound as well as result oriented programmes for treating/reclaiming different kinds of problem lands, fuel wood and fodder production, etc. The fastest developing field of biotechnology can help in choosing/improving the suitable species for various probelm areas.

Nearly half of the forest area of the country has become degraded with little or no vegetation. Its main causes are the biotic pressures, specially fires, grazing and removal of firewood and timber far in excess of the carrying capacity. Much of the degarded lands are on the forest fringes close to habitations. There are also siezable pockets of such degraded lands right inside the forest areas, including grasslands. (Fig. 3).

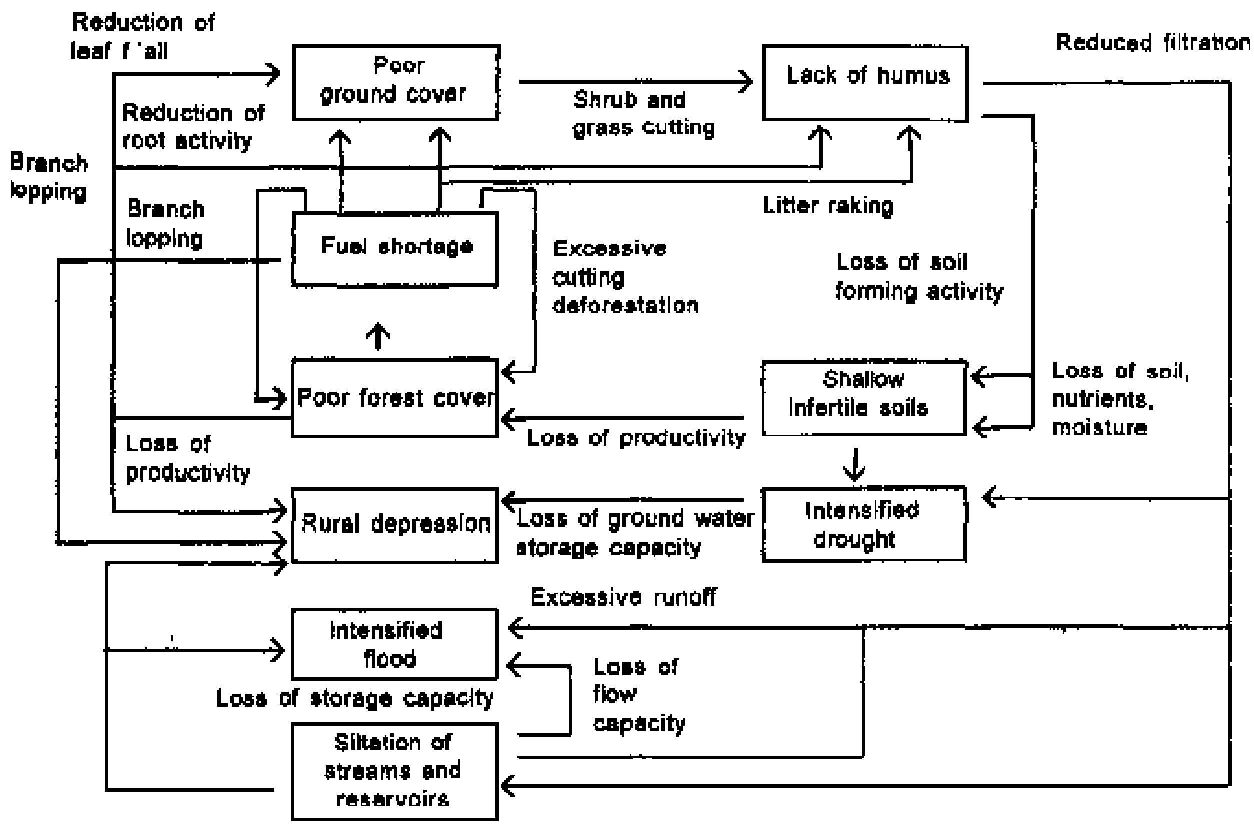


Fig. 3. Cycle of destruction in forest lands.

For ensuring environmental stability and restoring ecological balance, regeneration of such degraded forest lands is a national imperative. The earlier programme had over-played tree planting, which needs a change. Utmost priority should be given to aiding and fascilitating the process of natural regeneration and encouraging plantation of multi-tiered and diverse vegetation comprising indigenous species. Management intervention, including planting, should be restricted to degraded forest lands where natural regeneration is not possible. On such lands fuel wood, fodder, fruit and other useful species will have to be raised mainly for meeting the domestic requirements of the right-holders and the rural poor. Choice of species should be made in consultation with the local people. Grazing should be regulated and diverted to other areas with the co-operation of the local people. Cut-and-carry system of grass/fodder collection will have to be encouraged, besides stall feeding of cattle. Fuel-wood, fodder and small timber will have to be distributed to the right-holders on subsidised or free basis. Fuel-wood conservtion measures, like distribution of improved chullas, Kerosene, biogas, etc. will have to be taken up in a concerted manner in collaboration with the concerned line agencies. People's co-operation will have to be promoted in the protection of such areas through social fencing as far as possible.

The greening of public lands (other than forest lands) is needed to upgrade these lands mainly for biomass production. Most public lands many of which are grazing lands are common property resources. However, due to high grazing pressure and other factors, including non-involvement of local community, these lands have become degraded. The greening of these lands should be ensured for raising of fuelwood, fodder and timber for meeting the local needs. The livestock population has grown from 292 million in 1951 to 416 million in 1992, which has to be taken into account as these result increased grazing pressure.

The proposed aim of raising fuelwood, fodder and timber on and around farm lands and homesteads is to increase the productivity of unutilised or underutilised private lands. Keeping in view agro-edapho-climatic conditions, different modes of crops, legumes, grasses and trees will have to be developed and propagated. For rainfed lands agroforestry models involving multiple use species will have to be propagated so as to meet fodder, fuelwood and timber needs. The National Forest Policy lays down that for the sake of National Ecological Security and in the interest of forest conservation, wood for industrial needs should not be made available from the forest areas. Hence this requirement has to be raised on non-forest lands, specially on private dry lands. Efforts will, therefore, have to be made to develop appropriate models for raising industrial wood-based raw material through farm forestry. Special attention will have to be paid to the fostering of a farmer-industry nexus by providing all help and incentives to the farmers. Urban areas account for a substantial proportion of the fuelwood consumed, which is a priced and marketable commodity in urban areas. Therefore, raising of fuelwood to meet urban needs is often a bankable proposition. This has to be promoted both through distribution of seedlings and by incentives for block plantations. The National Bank of Agriculture and Rural Development (NABARD) has a number of schemes, some of which cater to certain aspects of Farm Forestry, under which individuals, private companies and corporations are eligible for bank finance.

It is estimated that the total coverage under the Afforestation Programme during the Seventh Plan Period (1985-90) was about 9 m ha. This is proposed to be almost doubled to make it 17 m ha during the Eight Plan Period (1990-95), viz. 9 m ha under regeneration of degraded forests, 2 m ha under greening of public lands and 6 m ha under farm forestry.

The major sources of finance within the country are State Plans, Ministry of Environment and Forests, Department of Agriculture and Co-operation and Department of Rural Development. The total allocation from all these sources for the Afforestation Programme during the Seventh Five Year Plan was about Rs. 2600 crores, which is now proposed to be raised to Rs. 4350 crores during the Eighth Five Year Plan. The foreign funding bodies include the World Bank, Swedish International Development Authority (SIDA), Canadian International Development Authority (CIDA), Danish International Development Authority (DANIDA) and the U.S. Agency for International Development (USAID). Many of the Wasteland Development and Social Forestry Projects are being funded by these bodies in various states.

There are several schemes being run by the National Wasteland Development Board under various heads, like Fuelwood and Fodder projects, Decentralised People's Nurseries, Margin Money Assistance, Integrated Wasteland Development Project, Aerial seeding, Conservation and Development of Minor Forest Produce including Medicinal Plants, Seed Development and Grants-in-Aid to voluntary Agencies. Some important projects include Delhi Campaign, Green Haryana Programme and Green Rajasthan Programme, etc.

In 1992, National Wasteland Development Board, with the mandate of developing wastelands in non-forest areas and regenerating degraded community and private lands was transferred to the newly created department of Wastelands Development in the Ministry of Rural Development. Consequently a National Afforestation and Eco-Development Board was created in the Ministry of Environment and Forests with the expanded mandate of eco-development along with regeneration of degraded forest areas and lands adjoining forest areas, national parks, sanctuaries and other protected areas, and ecologically fragile areas, like the Western Himalayas, Aravallis and Western Ghats. This is responsible for promoting afforestation, free planting, ecological restoration and eco-developmental activities in the country with its seven regional centres. Its major programmes also include integrated Afforestation and Eco-Development Projects scheme, Fuel-wood and Fodder Projects scheme, Raising of Minor Forest Produce including medicinal plants, Grants-in-aid to Non-Governmental Organisations and Voluntary agencies, Seed Development Schemes, Aerial seeding, Externally-aided Projects, etc. Besides, communication and general awareness its other major initiatives include description, classification and mapping of wastelands using Geographical Information System, technology extension and National Fund for Afforestation.

As already indicated earlier Wasteland Development and Social Forestry are inseparable. Therefore, many general points of Wasteland Development and the tree planting, i.e. Afforestation, in particular will be discussed under social forestry below.

Social Forestry :

The word 'forest' derived from the Latin word 'Foris', meaning outside, which probably refers to the village boundary or fencing. A large part of the earth was covered with vegetation before man appeared. The initial man, as is well known, was a hunter. Later he soon learnt the use of various forest products. Subsequently he started clearing forests for practicing agriculture a process which is ongoing till today. In the early part and till nearly the middle of this century there used to be patches of forests located in and around our villages from which the villagers used to derive their daily needs of fuel, fodder and small timber, etc., besides these serving as grazing grounds. But now with the manifold increase in the population of man and cattle, these have become either degraded or have just vanished, putting pressure on the far-flung forests. At present the total forest area seems to be about 19.7% of the total area of the country but it is getting depleted at an alarming rate and we are losing about 1.5 million hectares per year. All this has necessitated the need for reforestation or afforestation through social forestry.

The knowledge of medicinal and poisonous plants seems to have been much advanced during the time of 'Vedas' (*ca* 1500 BC). The epics 'Ramayana' and 'Mahabharata' speak a great deal about our forests. The 'puranas' had forewarned us about the deforestation. The forests were well-cared for during the Maurya and the Gupta periods but were mostly neglected during the Muslim period and early British period. But it started getting some attention during the nineteenth century, particularly in the later part.

The idea of today's so called social forestry seems to be deep seated in our culture as Lord Buddha wished every good Buddhist to plant a tree and to look after it for 5 years and likewise 5 trees should be planted in his life time. Even subsequently Emperor Ashoka got shade and fruit trees planted along the roadsides. The Forest Scientist Wastoby was perhaps the first person to use the word 'Social Forestry' in the Ninth Commonwealth Forestry Congress during 1968 at Delhi. He defined that "Social Forestry is a Forestry which aims at producing flow of protection and recreation benefits for the community" (Tewari, 1983). Subsequently it was included in our Fourth Five Year Plan (1969-74) as an idea to formulate and launch social forestry schemes. The idea was picked up and stressed in the subsequent Plans. Then what really is the Social Forestry? It is a programme recommended by the National Commission on Agriculture (NCA, 1976) (Khosla & Kohli, 1987). The main task assigned to it by the NCA is that it should meet the community requirements of fuelwood, fodder, timber and recreation. According to the NCA this task must be achieved by creating social forests, i.e. by raising trees on wastelands, village and panchayat lands and on the sides of roads, canal banks and railway lines.

Social Forestry has assumed great significance today. Several papers and books have been published about it. To mention a few; Rao (1979), Srivastava and Pant (1979), Jeff Romm (1980, 1981 a & b), Oka (1981), Claude Alvares (1982), Agarwala (1983), Tewari (1983), Tewari and Singh (1984), Anonymous (1984), Deshbandhu and Garg (1986), Khosla and Kohli (1987), Swarup and Chand (1987), Vyas (1981), Bhattacharyya (1990), Gordon *et al.* (1990), Jha and Sen (1991), Burch and Parker (1991) have discussed the measures and models for management of common, public, forest and community lands.

Bhattacharyya (1990) reasons that during the last 30 years, about 25 million hectares of land, which was recorded as culturable wastelands or barren uncultivated lands, etc. were cleared for the extension of agriculture. This wanton destruction of forests not only caused untold misery and hardship to the rural poor but also wrought havoc on the village economy. Apart from creating an ecological imbalance, sources of their living were destroyed. Keeping this in view, social forestry was started. A score of alternative terms are being used for Social Forestry, viz. community forestry, farm forestry, urban forestry, recreation forestry, environmental forestry, "Vanamahotsava", arboriculture, tree farming, forest farming, small scale forestry, village woodlots, bio-aesthetic plantations, energy plantations, three dimensional forestry, tree crops and livestock forestry for 4-F (fuel, forage, fodder, fertilizer) and agro-forestry, etc. Some people prefer community forestry over social forestry. But as community is a narrower term in comparision to society, community forestry at best can be treated as a superfluous name for social forestry and all the rest to be taken as narrow subdivisions under it. There are six basic needs of the society, viz. food, fodder, fuel, timber, healthy environment and income, which must be met by our social forestry. Hence there is a growing concern and consequently need for extending social forestry as much as possible. India has a total forest area of 19.27% (Table 1) as against the desirable area of 33.3%. Of this forest cover, good standard forests may be only 60% and the remaining 40% are marginal ones. This area also is getting depleted at an alarming rate year after year. Therefore, extension is need of the times and that is where social forestry fits into. Afforestration benefits us by way of increased employment, creation of an economic capital, increased food and fodder production, avenues for cottage industry, regulation of streams, rivers and underground water, increasing longevity of dams and reservoirs, control of floods, control of wind and dust storms and better climate, etc. The greed of the rich and necessity of the poor have played havoc with the forests in our country. Therefore, the afforestation under social forestry provides one of the best plans for raising the standard of the poorest class of our society, both during its execution and latter when it matures for its exploitation by way of unlimited benefits to the society. (Fig. 4).

The environment of any locality in nature is maintained by its vegetation. It is well known that the leaves absorb carbon di-oxide and release oxygen in the atmosphere. It is calculated that on an average 1 ha of woodland absorbs about 3 tons of carbon di-oxide and release about 2 tons of oxygen per annum. Therefore, any programme of afforestation is bound to improve the environment.

The status of our forests is well knwon today that they are degrading, both qualitatively as well as quantitatively. More afforestation is, therefore, imperative to check and reverse this process. The fuel wood will continue to remain the major source of energy and in India. As about 75-80% of population in India lives on agriculture, raising of fuel wood plantations and village forests is necessary for improvemnt of their living conditions. Brandis visualised the role of village forests over a century back, which was followed up by the then Government. Social forestry today is a multipurpose and multi product concept, for the people, of the people and by the people. So people should never be forgotten, whether it is the governmental agency or any voluntary one which is executing the programme.

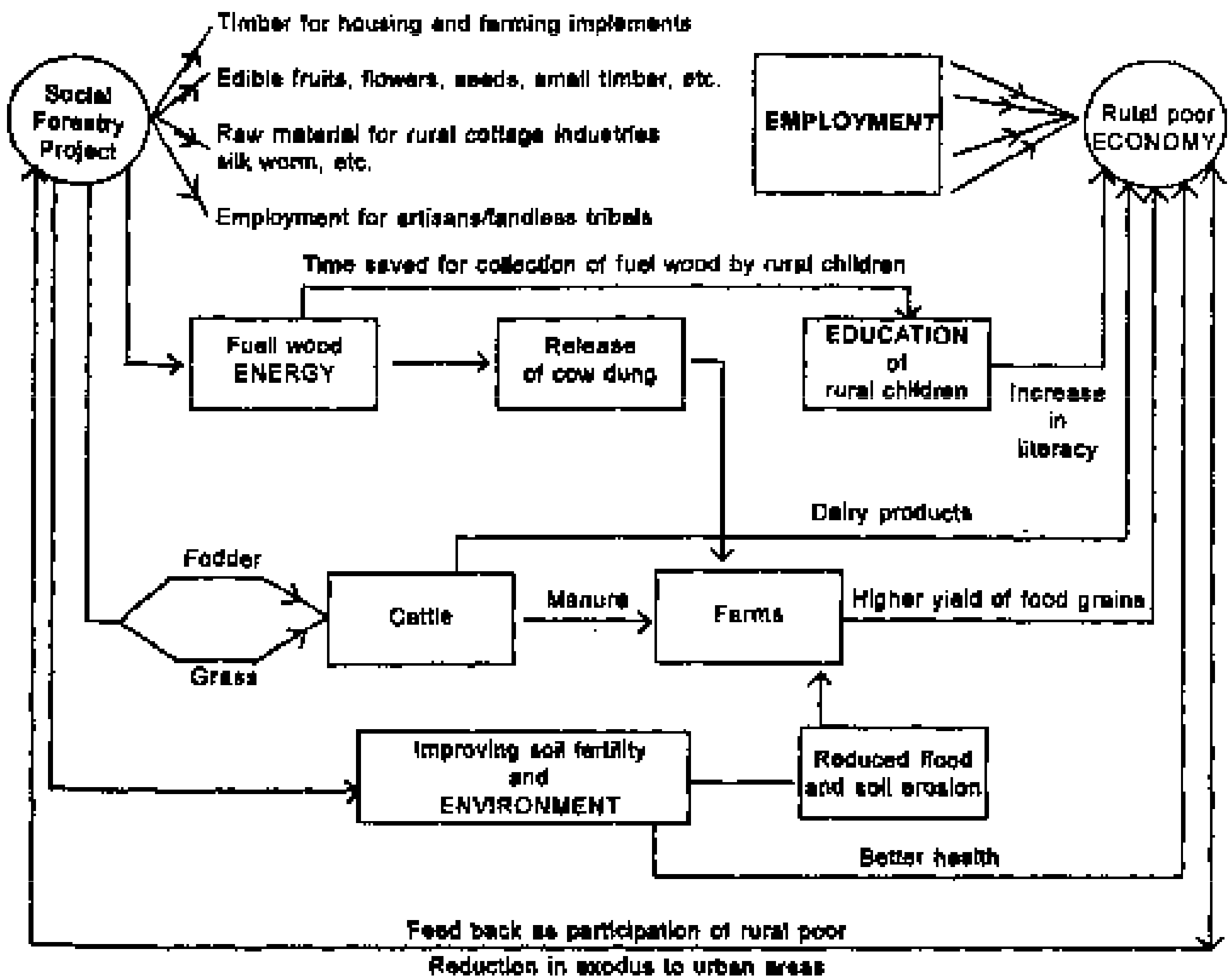


Fig. 4. Social forestry in the service of rural poor.

The planting techniques will have to be different as the area available for social forestry is in scattered blocks of various structures. Besides, the choice of species will also be limited to suit the local conditions from place to place. However, general principles according to Tewari (*l.c.*) are :

1. There should be some main, useful tree species of longer rotation, say 60 years or more, i.e. *Madhuca latifolia, Azadirachta indica, Tamarindus indica, Mangifera indica, Terminalia arjuna, Artocarpus heterophyllus, Albizia* sp., etc. These are to be planted at wider spacing of 10-12 m.

2. There should be a middle storey tree crop of medium rotation age, say of 30-40 years, i.e. *Derris indica, Dalbergia sissoo, Acacia nilotica, Albizia* sp.,

etc, that can be planted in between the lines of main tree species and which will yield fuelwood, seeds and fruits, etc.

3. There can be short rotation tree crop of 5-10 years or so, i.e. *Eucalyptus* sp., *Leucaena leucocephala, Moringa oleifera, Sesbania grandiflora, Acacia nilotica, Prosopis juliflora,* etc. These could be planted in some areas at rather closer spacing of say 2 x 2 m. They will be mainly fuel-wood and leaf fodder yielding trees

Such an intensive planting will ensure maximum utilisation of solar energy and soil nutrients from various depths. It should be seen that 2-3 leguminous tree species are definitely there. This will ensure self-manuring of the otherwise impoverished soil. Fencing of these plantations will be necessary in most cases. As far as possible live hedge fencing of *Acacia nilotica* and *Prosopis juliflora* is raised, the former in non-alkaline soils and the later in alkaline soils. These will also yield fuel-wood later. *Terminalia arjuna* is good in alkaline soils, which is used for rearing tassar cocoons. Technique of planting along the road-sides, canal sides and railway tracks is quite different. Along the roads where there is possibility of planting only one row, generally shade and fruit trees are planted with *Acacia nilotica* and *Prosopis juliflora* as fencing. Whenever wider strips are available, multiple row of planting of fire-wood species along with shade and fruit bearing species may be done at close spacing. In the case of railway line planting, the first row of plants should be raised at a distance of not less than 6 m from the centre of the track. The plants away from the track should be species whose height may be in ascending order. This will ensure that during wind storm no tree may fall on the tracks, affording safety to the traffic. Canal planting is almost like the road-sides. *Morus alba* may be raised here for rural cottage industry for silk production.

Under block planting, the blank mounds of village tanks, compounds of school buildings and other vacant lands in or near the village can be taken up for planting of tree species, like *Madhuca latifolia, Azadirachta indica, Pongamia pinnata, Mangifera indica*, etc. Other trees may include *Acacia nilotica, Leucaena leucocephala, Morus indica, Terminalia arjuna, Moringa oleifera, Sesbania grandiflora, Eucalyptus* sp., *Ziziphus mauritiana, Aegle marmelos* and *Emblica officinalis*, etc., with a fencing of *Acacia nilotica* and *Prosopis juliflora,* wherever possible. Many of these species provide necessary source of raw material for cottage industries, like hide tanning, 'pattal' making, basket making, oil crushing, paper making, etc. This will help the people below the poverty line in getting employment. Many of these species can also be used for planting on the field bunds, around households and compounds and other wastelands.

Choice of species, including exotics, suitable for various habitats regionwise, viz. temperate Himalayan, sub-tropical and tropical region, the last one including high rainfall aeas of western Ghats, W. Bengal and Assam, medium rainfall areas of Indo-Gangetic plains and the Peninsula and dry areas of Rajasthan and Peninsular India have been provided by Anonymous 1984, Tewari, 1983, Tewari and Singh 1984, Singh 1989, Khosla and Kohli 1987, Sastry et al. (1990), from whcih selections have to be made depending on the locality, situations and the actual need of the local people.

Chinese had built several dams and reservoirs on major rivers, for controlling the floods, besides afforestation over 100 million ha during 20 years from 1949-1970, which has almost controlled the problem. A similar approach is being planned for the containment of floods in the Ganges and other major rivers of India.

Employment potential is a very important component of social forestry. Employment is generated in the planting work, in the protection, irrigation and care of plantations, in collection of flowers, fruits and seeds, etc., in processing for extraction of oil from the seeds so collected, in marketing and subsequent processing of the oil and oil cakes produced, in the dairy industry to be developed from the fodder leaves available from the plantations, by rearing of silk worm on mulberry and tassar insects on arjun, from small scale paper pulp factories run on *Sesbania grandiflora* and *Moringa oleifera*, besides some indirect addition to income through minor forest products, etc. Some other benefits that are to be derived from social forestry programmes are prevention of environmental pollution, control of floods, increasing the productivity of the existing agricultural lands, habitat for bird and other wildlife, providing materials for low cost housing, increasing the yield of underground water resources and better inland navigation, etc. The local people must participate in all these programmes whole heartedly without any hesitation and must get the major share of benefits derived from these programmes. Then only the success of these schemes can be guaranteed.

According to Panda and Panda (in Ram Prakash *et al.* 1988) high density energy plantations result in income, employment, self-sufficiency, soil conservation, better land utilisation, insurance against failure of crops, development of multistoried agriculture and reducing evaporation losses, utility during drought years, thermal power generation based on fire-wood from HDEP, utilisation of industrial waste through HDEP and easing of the fuel-wood crisis.

The afforestation programme under social forestry in India was heavily loaded in favour of *Eucalyptus* species until a few years back. This over emphasis appeared right in view of its being extremely useful particularly for the production of paper and yarn. But now it is shrouded in mystery with so many points being raised against it. As it is now supposed to posses antiphytosocial properties, its indiscriminate cultivation at the cost of agricultural crops and other fast growing species should be looked into rationally till positive results on the contrary are not available. Instead our indigenous, fast growing species may be adopted in its place.

The social forestry programmes are currently going in most of the states of India with the help of governmental and other Indian agencies. However, some state projects are externally aided. The World Bank is aiding the states of West Bengal, Karnataka, Himachal Pradesh, Gujarat, Uttar Pradesh, Rajasthan, Kerala, Jammu & Kashmir and Haryana. The last two are partially aided by DANIDA also. The SIDA is aiding the projects in Tamil Nadu, Bihar, Orissa and Andhra Pradesh, while USAID is assisting the state of Maharashtra. This clearly shows that the deforestation and wastelands are global phenomenon and, therefore, afforestation through social forestry is the only answer.

In the end, a word of caution about the high expectations we have from the Social Forestry Programme in India. Mishra (in Trivedi *et al.* 1991) stated, "In 2000 A.D. when our population will be around 1 billion and the animal population about 700 million, there would be need for about 250 billion tons of food grains, 2000 million tons of dry and green fodder for animals along with 300 million tons of fuel wood".

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15. PROTECTED AREA NETWORK (PAN) : *IN SITU* CONSERVATION STRATEGIES

(H.J. Chowdhery & P.K. Hajra)

INTRODUCTION

"The universe is the creation of the supreme power ment for the benefit to all His creations. Individual species must therefore learn to enjoy benefits by forming a part of the system in close relation with other species. Let not anyone species encroach upon the others right."

Isho-Upanishad

Extinction is a well known biological phenomenon and infact the success of evolution is measured in terms of survival, failure by extinction. However, the recent extinctions are direcly or indirectly related to human activity. Many species have been recklessly destroyed because of their commercial exploitation on world wide scale as in the case of blue whale, fur-seal, musk-deer, the great one-horned rhino, elephant, tiger, etc. and even some of them have become extinct, like Dodo and India's hunting Cheetah, etc. which are the known examples of direct human activity. The same is true with many plant species as well. However, the majority of recent extinctions in plants and animals have occurred due to indirect human activity by way of environmental changes arising from the degradation and destruction of natural habitats, deforestation for agriculture and urbanisation. It is estimated that atleast 7.4 million hectares of forests are completely lost each year world-wide for road construction, human settlements, industry and land for farming and by over-grazing of grasslands, especially in dry regions.

The ability of the species to adapt themselves against the changing environmental conditions varies from species to species. Some of the endangered species biologically have a very low reproductive rate which can become disastrous if the normal low reproduction is foiled by changed environment.

The rapidly increasing population and increased human activity brought by the marvels of science and its application has produced astonishing results in terms of economic growth and prosperity. But at the same time it has badly damaged the ecological system, upon which the entire life support system is based. The situation becomes more critical in case of living resources because renewal is based on a judicious mix of conservation and sustainable utilisation, failing which they may be lost for ever. Unfortunately, the stress on the earth's environment and natural living resources is increasing day by day affecting the quality of life on this planet, and at the same eroding the carrying capacity of the earth in terms of its ability to meet basic human needs. According to an estimate every night atleast 700 million people, including children go to bed hungry, clean drinking water is a luxury and some 35 years from now this planet will have to support more than 8 billion humans in additions to billions of animals (Swaminathan, 1991). There has been a growing concern now about the survival and existence of human race on this planet because of the destruction of renewable and non-renewable natural resources as a result of human activity directly or indirectly. Although very late, but fortunately a sort of awareness has been generated all over about what could happen by the end of this century if the human activities damaging the earth's environment and resources are not stopped. The man has also started realizing that the earth, resources are limited and should be utilized in such a way that these assets are not damaged or destroyed and should be conserved for future generations. It has, therefore, become the need of the hour that all the developmental activities should be planned in such a way that the earth's environment and life support systems are conserved not only for the betterment of the human beings but also for every other living form which share this planet with us. The first United Nations Conference on Human Environment held at Stockholm in June, 1972 was a landmark step in this direction and is regarded one of the most important event in the field of environmental conservation, which has successfully focussed the world attention towards the dangers to human survival and quality of life posed by the continuous depletion and erosion of basic life support systems.

Concept of Protected Areas :

The concept of protected areas for the preservation of certain selected natural resources has existed in various ancient human societies. Well known classical writers, like Plato described the role of forests in the maintenance of water cycle, protection of soil erosion as back as 5th Century BC. Variety of motives led the past civilizations to take conservation measures which often were very different from the modern concept. Of these religious taboos have often been the prime objective of such protective measures. In many primitive societies trees, water and animals were worshipped which is evident by the existing sacred forests in many parts of the present day world. The excessive hunting of selected animals in the past also led to the introduction of protective areas. Alexander Von Humboldt (1767-1859), a German biologist and geographer, who is regarded as the pioneer of the present day ecology, for the first time propounded the theory of nature conservation and relationship between the human beings and their environment.

The first nature reserve of the present times was established by a group of French painters referred as Barbizon School, who officially protected the part of "Fontainebleau forest" for its natural beauty in 1853. In 1864, President Abraham Lincoln of the United States of America, on the recommendation of an American naturalist John Muir, voted unanimously through Congress a law declaring Yosmite Valley and adjoining *Sequoia* forest of Mariposa a nature reserve and the state of California was entrusted with the responsibility of preserving the forest of *Sequoia gigantea*. However, it was on Ist March, 1872 when the 1st ever National Park of the world "The Yellowstone National Park" was established by promulgating a federal Law by, the United States of America prohibiting any development which may alter its character as a "pleasure, ground or public park".

Till the end of the Nineteenth Century only Britain followed the suit and declared vast areas of its empire into national parks, like "The Glacier National Park" in Canada (1886), "Royal National Park" in Australia and the "Sabie National Reserve" in South Africa (1898) which later became the famous "Kruger National Park" in 1926. Subsequently, Sweden declared six National Parks in 1909, followed by Switzerland, which established a National Park in Engadine in 1915, based purely on scientific considerations. Subsequently, between the two world wars, the protected areas kept on multiplying all over the world and the nature protection became the global concern. By the middle of the 20th Century, the need for an International Organisation for nature conservation was felt necessary to help, advise and, assist countries their National Conservation Programmes and ultimately in 1948, many international official and on-official authorities/organisations founded the "International Union for the Conservation of Nature and Natural Resources" (IUCN).

The creation of National parks was further emphasized and popularized through various international conferences, like "The effect of man on the Biosphere", a United Nations Educational, Scientific and Cultural Organisation (UNESCO) sponsored conference in Paris in 1968 and "Man's Environment" in Stockholm in 1970. The international conference organised by UNESCO in 1968 prompted the International Biological Programme (IBP), IUCN and many other International and National Organisations to initiate studies for the protection and preservation of flora and fauna. Subsequently at the 10th General Meeting of the

IUCN, the Survival Service Commission reviewed the status of endangered plant species and their habitats. As a result, the enactment of United States Endangered Species Act (1973), the U.K. Wild Creatures and Wild Plant Act (1975), development of international conventions on conservation, such as Wetland Convention, World Heritage Convention, Endangered Species Convention and South Pacific Convention and the setting up of Biological Records Centre of the Nature Conservancy, U.K. and Threatened Plants Committee of the IUCN with regional and specialist groups on Palms, Orchids, Cycads, tree ferns and succulents, etc. have drawn world-wide attention and have helped create awareness for the conservation, preservation and protection of the flora.

Though it was very late but finally in 1980 the International Union for conservation of Nature and Natural Resources (IUCN) launched the "World Conservation Stragety" (WCS) which defined conservation as" the management of human use of the Biosphere so that it may yield the greatest sustainaable benefit to present generation while maintaining its potential to meet the needs and aspiration of the future generation as well". The WCS has three main objectives :

- Maintenance of essential ecological process and life support systems.
- Preservation of genetic diversity.
- Sustainable utilization of natural resources and ecosystems.

The 10 different kinds of protected Areas, included in the United Nation list compiled by the IUCN with the help of United Nations Environment Programme (UNEP), UNESCO and the World Wide Fund (WWF) for nature, for the purpose of conservation in 1982, are as follows :

1. Scientific Reserve/Strict Nature Reserves.
2. National Parks/Provincial Parks.
3. Natural Monuments/Natural Landmarks.
4. Nature Conservation Reserve/Managed Nature Reserves/Wildlife Sanctuaries.
5. Protected Areas.
6. Resource Reserves.
7. Anthropological Reserves/Natural Biotic Areas.

8. Multiple Use Management Areas/Managed Resource Areas.
9. Biosphere Reserves.
10. World Heritage Sites (Natural).

Of these, India has only four, viz. Biosphere Reserve, National Parks, Wild Sancturies and World Heritage Sites.

According to an estimate there were 3500 major protected areas established in 125 countries covering a total area of about 4.3 million square kilometers in the World by 1988. Today there are nearly 10,000 protected areas recognised across the globe, covering *ca* 6.3 per cent of the global landmass (IUCN, 1994). But unfortunately even this significant increase in the protected areas has not been able to stop the depletion of many plant and animal species nor it could check the degradation of ecosystems which are very often completely destroyed. Some of the most vulnerable and threatened ecosystems identified in the present day world are Tropical and Subtropical Islands; Tropical Rain Forests; Arid and Semi-Arid Regions; Mediterranian Ecosystems; Subtropical Mountain Valleys of southern Asia and South America and Fresh water Areas. Such ecosystems have exceptionally high diversities and may face complete extinction if their over exploitation continues at the present rate. During the past 10 years about 25000 plant species (Lucas & Synge, 1978) and over 1000 species of vertebrate animals (IUCN, 1975) are reported to be on the way of extinction.

The only answer to this problem is the total protection of plant and animal species through establishing the nature reserves. In view of the world's fast growing population, which is going to be around 8000 million in the near future, and in order to prodive enough food to such an enormous population, preservation of plant and animal genetic pool is very essential. The present resources will not be sufficient for this purpose as the survival of the present population is based only on a small number of plant (less than 300 species) and animal species. Whereas, *ca* 1.5 m species of plants and animals etc. recorded so far which may have enormous potential to feed the future world.

History of Protected Areas in India :

India, with its rich biological heritage, has also a long history and tradition of conserving the nature and natural resources. Worshipping trees, forests, rivers, ponds and mountains is a common feature in the social, cultural and religious ways of the Indian people from the time immemorial. The widely followed and practiced cult of non-violence and vegetarion food habit, restraints laid on the usage of wild animals, plants in particular season, sex, age of the concerned species were simple but very effective methods of conservation evolved by our ancestors. A large number of animals and trees have been associated with some good omen and are treated as sacred and protected by one or the other community. The Hindu sect widely practiced in our country prohibits its followers to cut a green tree or kill an animal. Hundreds of Bishnois, including children and women, laid their lives in order to prevent the cutting of green trees killing of animals by the rulers in Rajasthan, a tradition which is still followed. Apart from Hinduism other religions, like Buddhism, Jainism, etc. originated in this country have also preached, as philosophy of life, to love and protect the nature and all living beings.

The world's first recorded conservation measures were enforced and enacted by Emperor Ashoka as back as 3rd Century B.C., when he extended his benevolence to all living beings and established hospitals and protected places for animals and birds.

The well known manual of State affairs "Arthashastra", written in 4th Century B.C. by Kautilya, recommends strict protection and establishment of protected areas (Abhayaranyas). Great emphasis was laid by our sages on the conservation ethic in the natural surroundings of their Ashrams, the pride seats of learning in ancient times. Thus, the ethos conservation has been ingrained in our cultural heritage, manifested by India's with biological, ethnic and cultural diversity. In the subsequent period many hunting reserves were established by the rulers for their recreation and some of the existing ones have been converted into National Parks and Sanctuaries after Independence.

Phytogeography and Biodiversity :

The Indian region lies in the tropical belt streaching over an area of about 329 million hectares (2.46% of the total world's landmass). Geographically, it is situated between 68°51' and 97°25' E longitude and 6°45' and 37°6' N latitude. The diverse physiography and geology of the country has produced nearly all sorts of climatic conditions to support a large variety of ecosystems. This has resulted in all possible types of vegetation ranging from tropical to subtropical; temperate to alpine; humid evergreen rain forests to dry deciduous forests; hot dry deserts to cold deserts; mangroves to submerged; saline to fresh water; sand dunes to swamp vegetation, etc. As per the current estimate (Sharma, *et al*, 1997) estimate there are about 45,000 species of plants occur in India out of which *ca* 17,500 are angiosperms; 48 gymnosperms; 1200 pteridophytes; 2825 bryophytes; 6500 algae; 14,500 fungi and 2021 lichens with a very high percentage of endemism. Chatterjee, (1940) reported about 6700 species (*ca* 61%) as endemic out of the 11,000 species of flowering plants known from the erstwhile Indian region which included Pakistan, Nepal, Bhutan, Myanmar, Bangladesh and Sri Lanka. However, as per the current estimate, about 6100 species (*ca* 31%) of flowering plants are endemic out of the 17,500 species known from the present political boundaries of India. These endemic species are largely concentrated and confined to the Himalayan region, N.E. India and peninsular India. The endemism of such a high magnitude in the Indian flora, which is next only to Australia is mainly due to the presence of geographical barriers in the form of high Himalayan mountains in the North; Indian Ocean, Arabian Sea and Bay of Bengal in the southern region and the dry deserts in the western region which have virtually blocked the migration of species and at the same time tropical humid conditions prevailing in the Western Ghats and North-Eastern India are responsible for evolution and speciation of many endemic species.

The Indian flora shows affinities with the flora of Middle East, Central Asia, Russia, China and East Asia. Many Indo-Malayan and Sino-Japanese elements are of common occurrence in East Himalayan region, whereas European elements have found their way and naturalized in the temperate and alpine regions of North-Western and Western Himalaya. Western and peninsular regions of India have many African elements common in their flora.

Based on the habitat diversity the Indian region has been divided into the following 12 biogeographic provinces representing 3 Biomes and 2 natural Realms. The Himalayan region, including the trans-Himalayan cold desert areas of Ladakh and Himachal Pradesh, are part of the, Palaearctic Realm whereas the rest belong to the Indo-Malayan Realm (Udvardy, 1975):

Himalayan highlands
Tibetan
Thar desert
Malabar rain forest
Indus-Ganges Monsoon forest

Deccan thorn forest
Coromandel
Mahanadian
- Bengalian rain forest
Burma Monsoon forest
- Laccadives Islands
Andaman and Nicobar

Rodgers and Panwar (1988) have proposed 10 biogeographic zones of India based on the range of biological diversity for planning effective conservation strategy.

1. Trans Himalaya
2. Himalaya
3. North-East India
4. Gangetic Plains
5. Semi-Arid
6. Western Ghats
7. Deccan Peninsular
8. The Islands
9. The Coasts
10. Indian Deserts

Recently, Gadgil and Meher-Homji (1990) proposed 16 phytogeographical zones of India, whereas Balakrisnan (1996) divided Indian region into 11 phytogeographical zones as follows :

1. North-West Himalayas
2. Indo-Gangetic Plains
3. Eastern Himalayas (Arunachal Pradesh & Sikkim)
4. Assam (North-Eastern India)
5. Central India
6. Arid Zone
7. Northern Western Ghats and northern West Coast
8. Southern Western Ghats, southern West Coast and Lakshadweep
9. Deccan
10. Eastern Ghats and Coromandel Coast
11. Andaman & Nicobar Islands

Major threats to the Biodiversity :

The biodiversity throughout the world is being affected by the direct and indirect activities of man. In addition, such natural calamities as drought, floods, landslides, erosion, cyclone, gales, etc. are also responsible to some extent for the loss of biodiversity. It is felt that unless immediate and effective measures are not taken, we may loose some of our important natural living resources before knowing their potential economic use. The IUCN Threatened Plants Committee has listed following threat to plants :

1. Grazing
2. Regeneration of Scrub (& lack of grazing)
3. Changes in arable farming
4. Ploughing of old grassland
5. Forestry
6. Traditional rural practices
7. Flooding
8. Drainage
9. Water pollution
10. Air pollution
11. Industralization and urbanization
12. Road construction
13. Tourism and infrastructural facility development in Coastal/inland area
14. Dam construction
15. Mining and quarrying
16. Pressure from introduced plants
17. Collection for horticultural purposes/academic (Botany)
18. Critically low populaiton (say below 100 individuals)
19. Natural causes
20. Lack of pollinators

The major threats affecting the biodiversity are summarized below which are more or less the same for any region of India :

1. **Population pressure and encroachment of the forested area :**

   Rapid urbanisation and conversion of forest lands into human settlemtnts, agricultural fields, industrial areas causing pollution of various kinds which are harmful for all the living beings.

2. **Large scale removal of natural resources :**

   Quarrying and mining of coal, lime, marble, minerals, ores; fuelwood, medicinal plant, timber, and various minor forest products etc. from their natural habitat; fishing operations causing rapid depletion of marine resources and affecting the growth of marine flora and fauna. In addition, in the coastal area removal of coral reefs, sea weeds and coastal vegetation are some of the major causes threating the biodiversity.

3. **Habitat destruction :**

   Construction of roads, hydroelectric projects, urbanisation, tourism and industralisation, large scale felling of trees in catchment and coastal areas have far reaching ill effects on the biodiversity of a particular region. In addition to these, over grazing of meadows and forested areas entails heavy damage to the herbaceous and shrubby undergrowth, depletion of rare, endemic plants as well and at the same time it affects the germinating seedlings of trees.

4. **Exotic weeds :**

   Once the original vegetation is destroyed, various weedy elements such as, *Ageratum, Lantana, Polygonum, Mikania, Merremia*etc. invade such areas which causes natural regeneration of the vegetation extremely difficult.

Conservation Efforts :

As stated earlier nature conservation in India was given due importance since time immemorial however, it was further streamlined in the last quarter of the Nineteenth Century when several legislations were enacted for the protection of flora and fauna.

Out of the long list of various acts enacted from time to time, some of the important Central Acts meant for the conservation of Nature and Natural Resources are as follows :

1.	Fisheries Act	1897
2.	Live-stock Important Act	1898
3.	Destructive Insects & Pests Act	1914
4.	Forest Act (Reserved & Protected Forests)	1927
5.	Sugar Cane Act	1934
6.	Agricultural Produce Act (Grading & Marketting)	1937
7.	Drugs & Cosmetics Act	1940
8.	Coffee Act	1942
9.	Import & Export (Control) Act	1947
10.	Rubber (Production and Marketing) Act	1947
11.	Drugs (Control) Act	1950
12.	Tea Act	1953
13.	Prevention of Cruelty to Animals Act	1960
14.	Customs Act	1962
15.	Cardamom Act	1965
16.	Seeds Act	1966
17.	Wild Life (Protection) Act	1972
18.	Marine Products Export Development Authority	1972
19.	Water (Prevention & Control) Pollution Act	1974
20.	Tobacco Board Act	1975
21.	Coconut Development Board Act	1979
22.	Forest (Conservation) Act	1980
23.	Air (Prevention & Control) Pollution Act	1981
24.	National Oil seeds & Vegetable Oils Development Board Act	1983
25.	Inland Water ways Authority of India Act	1985
26.	Spices Board Act	1986
27.	Environment (Protection) Act	1986

In addition to these Central Acts, various state Governments have also brought-out a large number of acts for the conservation of nature and natural resources.

The most important step towards conservation was the enactment of the "Indian Wildlife Act, 1972" and the constitution of "Central Board of Wild Life" by the Government of India, which was later redesignated as "Indian Board for Wild Life" (IBWL), with following functions :

Conservation and control of wildlife through co-ordinated legislative and practical measures and declaration of certain animal species as "protected" and prevention of indiscriminate killing of wild animals.

Setting up of National Parks, Sanctuaries and Zoological Gardens.

To promote public interest in wildlife and its preservation.

To advice Government on policy for exporting living wild animals and wild-life products.

Prevention of cruelty to birds and animals.

To perform various other functions for which the Board has been constituted.

The IBWL also constituted specialized wings like Zoo Wing, Flora Wing and the Bird Wing for making appropriate recommendations for conservation to the Board after detailed studies in each case.

Apart from a large numbers of Wildlife and Forest Protection Acts, the Indian Constitution has also laid due emphasis on the need for protection of Environment and Ecology. The Constitution of India, adopted in 1950, in its Directive Principles of State Policy entrust the following responsibilities for the State and citizens through Article 48 A and Article 51A(g) which state that : "State shall endeavour to protect and improve the environment and safeguard the forests and wild life in the country". "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures."

The Biosphere Reserves :

The idea of Biosphere Reserve was initiated by UNESCO in 1973-74 under the Man and Biosphere (MAB) Programme. Conservation of natural areas and the genetic diversity they contain is the basic philosophy behind the concept of Biosphere Reserves, i.e. to provide *in-situ* conservation to plants, animals and microorganisms not in isolation but in their totality as part of wider ecosystem. As such, the Biosphere Reserves are established to address the needs of conservation of biodiversity and natural landscapes of pristine and representative ecosystems. A further objective of the programme is 'to predict the consequences of today's actions on tomorrow's world and thereby to increase Man's ability to manage efficiently the natural resources of the biosphere' (IUCN, 1979).

The concept of Biosphere Reserve was refined by a task force of UNESCO's MAB programme in 1974 and the first Biosphere Reserve was established in 1976. Since then the network of the international biosphere reserves has grown and by 1998 there were 356 reserves in 90 countries. The first International Biosphere Reserve Congress was convened by UNESCO and UNEP at Minsk (USSR) in 1983, and an action plan was drawn up with the cooperation of UNESCO, FAO, UNEP and IUCN.

The objectives of the International Network of Biosphere Reserves are :

(i) To conserve for the present and future human use the diversity and integrity of biotic communities of plants and animals within the natural ecosystem and to safeguard the genetic diversity of species on which their continuing evolution depends

(ii) To provide areas for ecological and environmental research including particularly baseline studies both within and adjacent to these reserves

(iii) To provide facilities for education and training

(iv) To maintain essential ecological process and life-support system

(v) To preserve genetic diversity, and

(vi) To ensure that the utilization of living resources and ecosystems in which they are found, are sustainable.

Concept of Biosphere Reserve :

The Biosphere Reserve concept envisages an approach for maintaining the integrity and biological support system for man and nature throughout the biosphere. As such, it involves conservation, restoration and acquisition of knowledge which can play the role of meeting scientific, economic, educational, cultural and recreational needs. They also represent means for maintaining the genepools of species of plants, animals and micro-organisms in totality, by setting aside representative areas of wide ranging natural ecosystem throughout the world, for conservation and research. It may, however, be noted that the Biosphere Reserves are not a substitute for, but a reinforcement to the existing protected areas.

(i) Structure and design of Biosphere Reserve : In order to achieve conservation and management objectives, a biosphere reserve is usually demarcated into (i) a natural or "Core Zone", which is the *Sanctum sanctorum* of the reserve and (ii) Buffer Zone for manipulative research and other human activities. Ideally the two zones should belong to same biome. Each reserve includes one or more of the following categories : (a) natural biomes (b) unusal or unique communities of biodiversity or areas with unusual natural features of exceptional interest, (c) harmonious landscapes resulting from traditional land use practices and (d) modified or degraded ecosystems which still have some capacity to revert to more or less natural conditions.

(ii) Selection Criteria : While selecting the representative natural areas it is suggested that the following criteria must be regarded as mandatory (UNESCO-MAB, Final Report No. 22, 1974).

(a) *Representativeness :* The site should represent all the characteristic features of a particular biome, so that information relating to the nature and dynamics of a reserve can be extrapolated to similar areas throughout a biogeographical region.

There may be critical areas within the biome, such as the centres of distribution of particular floristic elements or rare, endangered or threatened species. Such areas will have special significance for the conservation of genetic diversity and should be considered within the context of unique areas.

(b) *Natural genetic diversities :* Presence of genetic diversity and the potential for conservation of ecosystem in its totality.

(c) *Naturalness* : Priority being placed on the least modified areas and the modification should be interpreted broadly to include a range of conditions from total destruction of natural habitats.

(d) *Effectiveness as a conservation unit* : It involves a number of factors such as size, shape and location with respect to natural protective barriers. The area should be self regulating and free from human interference with legal protection which is of utmost necessity.

(e) *Importance* : The site should have unique richness in genetic resources; areas which need immediate attention due to continuing threat to species contained therein and have potential for preservation of accumulated knowledge by specific ethnic groups.

The Government of India has constituted a Indian National Man and Biosphere (MAB) committee to advise on policy and programme formulation for Biosphere Reserves in the country. This committee, in 1979, has identified a network of 14 representative ecosystems to be designated as Biosphere Reserves. So far, 12 Biosphere Reserves have been designated, till February 2000, in different biogeographic zones of the country (Table 1). Table 2 provides the list of Biosphere Reserves proposed by the Indian MAB Committee, which are yet to be designated.

Table-1. Details of Biospheres Reserve established so far in India.

Sl. No.	Biogeographic Retion	State	Name of the Biosphere Reserve	Area (in sq. km.)	Date of notification
(1)	(2)	(3)	(4)	(5)	(6)
1.	Western Himalaya	Uttar Pradesh	Nandadevi	2236.74 sq. km	18.1.1988
2.	North-East India	Meghalaya	Nokrek	820.99 sq. km	01.9.1988
3.	North-East India	Assam	Manas	2837.00 sq. km	14.3.1989
4.	Gangetic Plain	West Bengal	Sunderban	9630.00 sq. km	29.3.1989
5.	Coastal	Tamil Nadu	Gulf of Mannar	10500.00 sq. km	18.2.1989
6.	Western Ghat	Karnataka, Kerala & Tamil Nadu	Nilgiri	5520.00 sq. km	01.8.1986

(1)	(2)	(3)	(4)	(5)	(6)
7.	Islands	Andaman & Nicobar Islands	Great Nicobar	885.00 sq. km	06.1.1989
8.	Deccan Peninsular	Orissa	Simlipal	4374.00 sq. km	22.6.1994
9.	North-East India	Assam	Dibru Saikhowa	765.00 sq. km	28.7.1997
10.	Eastern Himalaya	Arunachal Pradesh	Dehang Debang	5111.50 sq. km	02.9.1998
11.	Central India	Madhya Pradesh	Pachmarhi	4926.28 sq. km	03.3.1999
12.	Eastern Himalaya	Sikkim	Khanchangdzonga	2619.92 sq. km	07.2.2000

Table-2. Biosphere Reserves proposed by Indian MAB committee, Ministry of Environment and Forests yet to be notified.

Sl. No.	Name of the Biosphere Reserve	State/U.T.
1.	Namdapha	Arunachal Pradesh
2.	Valley of Flowers	Uttar Pradesh
3.	Little Rann of Kutch	Gujrat
4.	Kanha	Madhya Pradesh
5.	Thar desert	Rajasthan
6.	Kaziranga	Assam
7.	North Islands of Andaman	Andaman & Nicobar

Table-3. Biosphere Reserves suggested by State government/expert groups/experts, yet to be notified.

Sl. No.	Name of the Biosphere Reserve	State/U.T.
1.	Abujmarh	Madhya Pradesh
2.	Amarkantak	Madhya Pradesh
3.	Cold desert	Jammu & Kashmir Himachal Pradesh
4.	Seshachalam	Andhra Pradesh
5.	Chintapalli	Andhra Pradesh
6.	Lakshdweep Islands	Lakshdweep

Comprehensive project documents for the above mentioned Biosphere Reserves, based mainly on the guidelines given by the International MAB Committee have already been prepared by experts and are being published by the Ministry of Environment and Forests from time to time.

National Parks and Sanctuaries :

The year 1972 proved to be a turning point in the history of wildlife conservation in India when the Union Government enacted the "Wildlife (Protection) Act" which provided a legal frame work to impose strict regulations on the hunting and trade in wildlife. Following this act, large areas in different parts of the country were declared as National Parks and Sanctuaries. In 1973 "Project Tiger", launched with nine reserves, has now a chain of 23 Tiger reserves covering an area of over 33,000 sq. km (Table 4). Similarly "Crocodile Breeding and Management Project" was undertaken with Food and Agriculture Organisation (FAO) and UNDP assistance in 1976 to protect three highly endangered species of Indian Crocodiles and now a number of Breeding centres and Sanctuaries have been set up in different parts of the country.

Likewise to save individual species many other projects were launched such as :

- Asiatic Lion in Gir (Gujarat).
- Barasingha in Kanha (Madhya Pradesh).
- Hangul in Dachigam (Jammu & Kashmir).
- Brow-antler deer in Keibul Lamjao (Manipur).
- Great Indian Rhinoceros in Kaziranga (Assam).
- Asiatic Elephants in different states where they are found.
- Himalayan Musk deer in Himalayan region (Himachal Pradesh, Jammu & Kashmir and Uttar Pradesh).
- Orchids in Arunachal Pradesh and Sikkim.
- *Rhododendron* in Sikkim.
- *Nepenthes* in Meghalaya.
- *Citrus* in Meghalaya.

Table-4. Tiger Reserves in India

Sl. No.	Name	State/Union Territory	Area (sq. Km)
1.	Bandhawgarh	Rajasthan	1162.00
2.	Bandipur	Karnataka	866.00
3.	Buxa	West Bengal	759.00
4.	Corbett	Uttar Pradesh	1316
5.	Dampa	Mizoram	500.00
6.	Dudhwa	Uttar Pradesh	811.00
7.	Indiravati	Madhya Pradesh	2799.00
8.	Kalakad-Mundanthurai	Tamil Nadu	800.00
9.	Kanha	Madhya Pradesh	1945.00
10.	Manas	Assam	2840.00
11.	Melghat	Maharashtra	1597.00
12.	Nagarjunsagar	Andhra Pradesh	3568.00
13.	Namdapha	Arunachal Pradesh	1985.00
14.	Palamau	Bihar	1026.00
15.	Panna	Madhya Pradesh	542.00
16.	Pench	Maharashtra	758.00
17.	Ranthambhore	Rajasthan	1334.00
18.	Simplipal	Orissa	2750.00
19.	Sundarban	West Bengal	2585.00
20.	Periyar	Kerala	777.00
21.	Sariska	Rajasthan	866.00
22.	Taroba	Maharashtra	620.00
23.	Valmiki	Bihar	840.00
	Total		33046.00

Despite all such policies and rules framed to protect the wildlife by Government of India, the destruction of forests and natural habitats continued unabated for want of more and more land for agriculture and other developmental activities as a result of rapidly growing population. Though the protected areas did exist in this country time back, long since it was only in the late nineteen sixties that the concept of conserving the fast depleting natural resources and degrading environment gained momentum resulting into many areas being brought under protected category in different parts of the country. This network has grown significantly in the following years and today India has about 85 National Parks and 448 Wildlife Sanctuaries (Table 5, 6) covering an area of about 1,48,000.00 sq. km or about 4.5 per cent of the total geographical area of the country or *ca* 20 per cent of the forested land of the country.

Table-5. National Parks and Wildlife Sanctuaries in India

Sl. No.	State/Union Territory	Total N.P./ W.L.S.	Total area (sq. km)
1.	Andaman & Nicobar Islands	8/94	1273.13
2.	Andhra Pradesh	4/21	12204.50
3.	Arunachal Pradesh	2/9	9245.98
4.	Assam	2/8	1920.58
5.	Bihar	2/19	4449.83
6.	Chandigarh	0/1	25.42
7.	Delhi	0/1	13.20
8.	Daman & Diu	0/1	2.18
9.	Goa	1/4	462.78
10.	Gujarat	4/21	17386.83
11.	Haryana	1/10	344.08
12.	Himachal Pradesh	2/30	5997.87
13.	Jammu & Kashmir	4/15	14057.74
14.	Karnataka	5/20	6710.19
15.	Kerala	3/12	2679.88
16.	Madhya Pradesh	11/32	17052.76
17.	Maharashtra	5/25	14953.94
18.	Manipur	2/1	266.65
19.	Meghalaya	2/3	301.69
20.	Mizoram	2/3	810.00
21.	Nagaland	1/3	226.43
22.	Orissa	2/18	7427.66
23.	Punjab	0/6	294.82
24.	Rajasthan	4/22	9520.20
25.	Sikkim	1/4	942.10
26.	Tamil Nadu	5/17	3072.66
27.	Tripura	0/4	603.62
28.	Uttar Pradesh	7/29	13537.95
29.	West Bengal	5/15	2748.21

N.P. = National Park / W.L.S. = Wildlife Sanctuary

Table-6. Statewise List of National Parks and Wildlife Sanctuaries in India

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Andaman & Nicobar	
Campbell NP	429.23
Galathea NP	110.00
Marine (wandoor) NP	281.50
Middle button island NP	0.64
Mount harriett NP	46.62
North button island NP	0.44
Saddle peak NP	32.54
South button island NP	0.03
Arial islands WS	0.05
Bamboo island WS	0.05
Barren island WS	8.10
Battimalv Island WS	2.23
Belle island WS	0.08
Bennett island WS	3.46
Bingham island WS	0.08
Blister island WS	0.26
Bluff island WS	1.14
Bondoville island WS	2.55
Brush island WS	0.23
Buchanan island WS	9.33
Chanel island WS	0.13
Cinque islands WS	9.51
Clyde island WS	0.54
Cone island WS	0.65
Curlew (B.P.) island WS	0.16
Curlew island WS	0.03
Defence island WS	10.49
Dot island WS	0.13
Dottrell island WS	0.13
Duncan island WS	0.73
East island WS	6.11
East of inglis island WS	3.55
Egg island WS	0.05
Elat island WS	9.36
Entrance island WS	0.96
Gander island WS	0.05

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Girjan island WS	0.16
Goose island WS	0.01
Hump island WS	0.47
Interview island WS	133.87
James island WS	2.10
Jungle island WS	0.52
Kwangtung island WS	0.57
Kyd island WS	8.00
Landfall island WS	29.48
Latouche island WS	0.96
Lohabarrack (saltwater crocodile)	22.21
Mangrove island WS	0.39
Mas k island WS	0.78
Mayo island WS	0.10
Megapode island WS	0.12
Montogemery island WS	0.21
Narcondam island WS	6.81
North brother island WS	0.75
North island WS	0.49
North reef island WS	3.48
Oliver island WS	0.16
Orchid island WS	0.10
Ox island WS	0.13
Oyster island -I WS	0.08
Oyster island -II WS	0.21
Paget island WS	1.36
Parkinson island WS	0.34
Passage island WS	0.62
Patric island WS	0.13
Peacock island WS	0.62
Pitman island WS	1.37
Point island WS	3.07
Potanma islands WS	0.16
Ranjger island WS	4.26
Reef island WS	1.74
Roper island WS	1.46
Ross island WS	1.01
Rowe island WS	0.01
Sandy island WS	1.58
Sea serpent island WS	0.78
Shark island WS	0.60

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Shearme island WS	7.85
Sir Hugh Rose island WS	1.06
Sisters island WS	0.36
Snake island -I WS	0.73
Snake island -II WS	0.03
South brother island WS	1.24
South reef island WS	1.17
South sentinel island WS	1.61
Spike island -I WS	0.42
Spike island -II WS	11.70
Stoat island WS	0.44
Surat island WS	0.31
Swamp island WS	4.09
Table (delgarno) island WS	2.29
Table (excelsior) island WS	1.69
Talabaicha island WS	3.21
Temple island WS	1.04
Tillongchang island WS	16.83
Tree island WS	0.03
Trilby island WS	0.96
Tuft island WS	0.29
Turtle islands WS	0.39
West island WS	6.40
Wharf island WS	0.11
White cliff island WS	0.47
	1273.13
Andhra pradesh	
Kasu Brahmananda Reddy NP	1.42
Mahaveer Harina Vanasthali NP	14.59
Mrugavani NP	3.60
Sri Venkateswara NP	352.62
Coringa WS	235.70
Eturnangaram WS	806.15
Gundla Brahmeswaram WS	1194.00
Kaundinya WS	357.60
Kawal WS	893.00
Kinnerasani WS	635.41
Kolleru WS	673.00

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Krishana WS	194.81
Lanja Madugu Sivaram WS	36.29
Manjira WS	20.00
Nellapattu WS	4.40
Pakhal WS	879.30
Papikonda WS	591.00
Pocharam WS	130.00
Pranahita WS	136.02
Pulicat lake WS	.500.00
Rajiv Gandhi (N) (Nagarjunsagar-Srisailam) WS	2221.09
Rajiv Gandhi (S) (Nagarjunsagar-Srisailam) WS	1347.00
Rollapadu WS	6.14
Sri Lankamalleswaram WS	464.42
Sri Vankateswara WS	506.94
	12204.50
Arunachal pradesh	
Moluling NP	483.00
Namdapha NP	1985.23
D'ering memorial (lali) WS	190.00
Debang WS	4149.00
Eagle nest WS	217.00
Itanagar WS	140.30
Kamlang WS	783.00
Kane WS	55.00
Mehao WS	281.50
Pakhui WS	861.95
Sessa orchid WS	100.00
	9245.98
Assam	
Kaziranga NP*	430.00
Manas NP*	500.00
Barnadi WS	26.00
Deepan beel WS	4.14
Dibru-saikhowa WS	640.00
Garampani WS	6.00
Laokhowa WS	70.00
Nameri WS	130.00

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Pobitara WS	38.84
Rajiv gandhi (orang) WS	75.60
	1920.58
Bihar	
Betla NP	231.67
Valmiki NP	335.65
Bhimbandh WS	681.99
Dalma WS	193.22
Gautam budha WS	259.50
Hazaribagh WS	186.25
Kabar lake WS	63.11
Kaimur WS	500.75
Koderma WS	177.95
Lawalong WS	207.00
Mahauaduar WS	63.25
Nagi dam WS	1.91
Nakti dam WS	3.32
Palamau (Betla) WS	747.60
Palkot WS	183.00
Parasnath WS	49.33
Rajgir WS	35.84
Topchanchi WS	8.75
Udaipur WS	8.74
Valmiki WS	461.00
Vikramshila (gangetic dolphin) WS	50.00
	4449.83
Chandigarh	
Sukhna lake WS	25.42
	25.42
Delhi	
Indira Priyadarshini (Asola) WS	13.20
	13.20
Diu	
Fudam WS	2.18
	2.18

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Goa	
Bhagwan Mahavir (mollem) NP	107.00
Bhagwan Mahavir (mollem) WS	240.00
Bondla WS	8.00
Chorao island (Dr. Salim Ali)WS	2.78
Cotigao WS	105.00
	462.78
Gujarat	
Bansda NP	23.99
Gir NP	258.71
Marine (gulf of Kachchh) NP	162.89
Velavadar NP	34.08
Balaram Ambaji WS	542.08
Barda WS	192.31
Dhumkhal (Shoolpaneswar) WS	607.70
Gaga vidi WS	3.33
Gir WS	1153.42
Hingolgarh WS	6.54
Jessore WS	180.66
Jambogodha WS	130.38
Kachchh bustard WS	2.03
Kachchh desert WS	7506.22
Khijadia WS	6.05
Marine (gulf of Kachchh) WS	457.92
Nal sarovar WS	120.82
Narayan sarovar WS	765.79
Paniya WS	39.63
Porbandar lake WS	0.09
Purna WS	160.84
Rampura vidi WS	15.01
Ratanmahal WS	55.65
Thol lake WS	6.99
Wild ass WS	4953.70
	17386.83
Haryana	
SultaNPur NP	1.43
Abubshehar WS	115.36

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Bhindawas WS	4.06
Bir bara ban WS	4.14
Bir shikargarh WS	7.58
Chautala WS	106.00
Chhilchhila WS	0.28
Kalesar WS	46.28
Khaparwas WS	12.31
Nahar WS	2.09
Saraswati plantation WS	44.55
	344.08
Himachal pradesh	
Great himalayan NP	620.00
Pin vallwy NP	675.00
Bandli WS	41.32
Chail WS	108.54
Churdhar WS	56.15
Daranghati WS	42.00
Darlaghat WS	140.00
Gamgul siahbehi WS	108.85
Gobindsagar WS	100.34
Kalatop-khajjair WS	69.00
Kanawar WS	54.00
Khokhan WS	14.05
Kias WS	14.19
Kibber WS	1400.50
Kugti WS	378.86
Lippa asrang WS	30.89
Majathal WS	92.00
Manali WS	31.80
Naina devi WS	156.00
Nargu WS	278.37
Pong dam lake WS	307.29
Renuka WS	4.02
Rupi bhaba WS	125.00
Sangla (raksham chitkul) WS	650.00
Sechu tuan nala WS	102.95
Shikari devi WS	214.00
Shilli WS	2.13
Shimla catchment WS	10.25

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Simbalbara WS	19.03
Talra WS	26.00
Tirthan WS	61.12
Tundah WS	64.22
	5997.87
Jammu & kashmir	
City forest NP	9.07
Dachigam NP	141.00
Hemis NP	3350.00
Kistwar NP	400.00
Baltal-thajwas WS	203.00
Changthang WS	4000.00
Gulmarg WS	180.00
Hirapora WS	110.00
Hokersar WS	10.00
Jasrota WS	4.00
Karakoram WS	5000.00
Lachipora WS	80.00
Limber WS	26.00
Nandini WS	33.34
Overa WS	32.00
Overa-aru WS	425.00
Ramnagar rakha WS	12.20
Surinsar mansar WS	39.13
Trikuta WS	3.00
	14057.74
Karnataka	
Anshi NP	250.00
Bandipur NP	874.00
Bannerghatta NP	104.00
Kudremukh NP	600.32
Nagarahole NP	643.39
Adichunchunagiri WS	0.84
Arabithittu WS	13.50
Bhadra WS	492.46
Biligiri rangaswamy temple WS	539.52
Brahmagiri WS	181.29

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Cauvery WS	510.51
Dandeli WS	843.16
Doraji bear WS	55.87
Ghataprabha WS	29.78
Gudavi WS	0.73
Melkote temple WS	49.82
Mookambika WS	247.00
Nugu WS	30.32
Pushpagiri WS	102.92
Ranebennur WS	119.00
Ranganathittu WS	0.67
Sharavathi valley WS	431.23
Shettihalli WS	395.60
Someshwara WS	88.40
Talakaveri WS	105.59
	6710.19
Kerala	
Eravikulam NP	97.00
Periyar NP	350.00
Silent valley NP	89.52
Aralam WS	55.00
Chendurung WS	100.32
Chimmony WS	90.00
Chinnar WS	90.44
Idukki WS	70.00
Neyyar WS	128.00
Parambikulam WS	285.00
Peechi-vazhani WS	125.00
Peppara WS	53.00
Periyar WS	777.00
Thattekadu WS	25.16
Wayanad WS	344.44
	2679.88
Madhya pradesh	
Bandhavagarh NP	448.00
Fossil NP	0.27
Indravati NP	1258.00

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Kanger valley NP	200.00
Kanha NP	940.00
Madhav-shivpuri NP	337.00
Panna NP	543.00
Pench (priyadarshini) NP	293.00
Sanjay NP	1938.00
Satpura NP	524.00
Van vihar NP	4.45
Achanakmar WS	551.55
Badalkhol WS	104.55
Bagdara WS	478.90
Barnawapara WS	244.66
Bhahramgarh WS	139.00
Bori WS	480.00
Gandhi sagar WS	368.62
Ghatigaon WS	512.00
Gomardha WS	277.82
Karera WS	202.21
Ken gharial WS	45.00
Kheoni WS	123.00
Narsingarh WS	59.19
National chambal WS	320.00
Neoradehi WS	1034.52
Pachmarhi WS	461.85
Palpur (kuno) WS	345.00
Pamed WS	262.00
Panpatha WS	245.84
Pench WS	449.39
Phena WS	110.74
Ralamandal WS	2.00
Ratapani WS	686.79
Sailana WS	12.96
Sanjay (dubri) WS	364.59
Sardarpur WS	348.12
Semarsot WS	430.36
Singhori WS	287.91
Sitandi WS	553.36
Son gharial WS	209.00
Tamor pingla WS	608.52
Udanti (wild buffalo) WS	247.59
	17052.76

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Maharashtra	
Gugamal NP	362.80
Nawegaon NP	134.88
Pench NP	257.26
Sanjay Ganghi (borivilli) NP	86.96
Tadoba NP	116.55
Andhari WS	509.27
Aner dam WS	82.94
Bhimashankar WS	130.78
Bor WS	61.10
Chandoli WS	308.97
Chaprala WS	134.78
Deolgaon-rehkuri WS	2.17
Gautala WS	260.61
Great indian bustard WS	8496.44
Jaikwadi WS	341.05
Kalsubai WS	361.81
Karnala	4.48
Katepurna WS	74.00
Koyana WS	423.55
Marine (malvan) WS	29.12
Melghat WS	1262.00
Nagzira WS	152.81
Nandur WS	100.12
Painganga WS	324.62
Phansad WS (part 1)	49.79
Phansad WS (part 2)	20.00
Radhanagari WS	371.88
Sagareshwar WS	10.87
Tansa WS	304.81
Yawal WS	177.52
	14953.94
Manipur	
Keibul-lamjao NP	40.00
Sirohi NP	41.80
Yangoupokpi-lokchao WS	184.85
	266.65
Meghalaya	
Balphakram NP	220.00
Nokrek NP	47.48

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Baghmara (pitcher plant) WS	0.03
Nongkhyllem WS	29.00
Siju WS	5.18

	301.69
Mizoram	
Blue mountain NP	50.00
Murlen NP	200.00
Dampa WS	340.00
Knwanglung WS	50.00
Ngengpui WS	170.00

	810.00
Nagaland	
Intanki NP	202.02
Fakim WS	6.41
Puliebadze WS	9.00
Rangapahar	9.00

	226.43
Orissa	
Bhitarkanika NP	367.00
Simlipal NP	845.70
Baisipalli WS	168.35
Balukhand WS	71.72
Bhitarkanika WS	170.00
Chandaka WS	175.79
Chilka WS[t]	900.00
Debrigarh WS	346.91
Hadgarh WS	191.60
Karlapat WS	147.66
Khalasunt WS	116.00
Kotagarh WS	399.50
Kuldiha WS	272.79
Lakhari valley WS	185.87
Nandankanan WS	14.26
Satkosia (north) WS	318.00
Satkosia (south) WS	478.52

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Simlipal WS	1354.00
Sunabeda WS	600.00
Ushakothi (badrama) WS	304.03
	7427.66
Punjab	
Abohar WS	186.00
Bir bunerheri WS	6.50
Bir gurdialpura WS	6.10
Bir motibagh WS	6.40
Harike lake WS[+]	86.00
Takhani rehampur WS	3.82
	294.82
Rajasthan	
Desert NP	3162.00
Keoladeo ghana NP*[1]	28.73
Ranthambore NP	392.00
Sariska NP	273.80
Bandh baratha WS	192.76
Bassi WS	152.90
Bhensrodgarh WS	229.14
Darrah WS	265.80
Jaisamand WS	52.00
Jamwa ramgarh WS	300.00
Jawahar sagar WS	100.00
Kela devi WS	676.38
Kumbhalgarh WS	578.25
Mount abu WS	288.84
Nargarh WS	50.00
National chambal WS	280.00
Phulwari ki nal WS	511.41
Ramgarh vishdhari WS	301.00
Sajjangarh WS	5.19
Sariska WS	492.00
Sawai man singh WS	103.25
Shergarh WS	98.71
Sitamata WS	422.94
Tal chhapper WS	7.90
Todgarh rawali WS	495.27
Van vihar WS	59.93
	9520.20

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Sikkim	
Khangchendzonga NP	850.00
Fambong lho WS	51.76
Kyongnosla alpine WS	4.00
Maenam WS	35.34
Singba (rhododendron) WS	1.00
	942.10
Tamil nadu	
Dr. J. Jayalalitha (Mudumalai) NP	103.24
Guindy NP	2.82
Indira gandhi (Annamalai) NP	117.11
Marine (gulf of mannar) NP	100.00
Mukurthi NP	78.46
Chitrangudi WS	0.47
Dr. J. Jayalalitha (Mudumalai) WS	217.76
Indira Gandhi (Annamalai) WS	919.95
Kalakad WS	223.58
Kanjirankulam WS	1.04
Karikili WS	0.61
Kuthankulam-Kadankulam WS	1.29
Mundanthurai WS	567.38
Point calimere WS (e)	17.26
Pulicat lake WS	153.67
Srivilliputhur (giant squirrel) WS	485.20
Udayamarthandapuram lake WS	0.45
Upper kothaiyar WS	64.00
Vaduvoor WS	1.28
Vedanthangal WS	0.30
Vellanadu WS	16.41
Vettangudi WS	0.38
	3072.66
Tripura	
Gumti WS	389.54
Roa WS	0.85
Sepahijala WS	18.53
Trishna WS	194.70
	603.63

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
Uttar pradesh	
Corbett NP	520.82
Dudhwa NP	490.00
Gangotri NP	2390.00
Govind pashu vihar NP	472.08
Nanda Devi NP*	650.00
Rajaji NP	820.03
Valley of flowers NP	87.50
Askot musk deer WS	600.00
Bakhira WS	28.94
Binsar WS	45.59
Chandraprabha WS	78.00
Govind pashu vihar WS	953.12
Hastinapur WS	2073.00
Kaimur WS	500.75
Katerniaghat WS	400.00
Kedarnath WS	975.00
KishaNPur WS	227.12
Lake bahosi WS	80.23
Mahavir swami WS	5.00
Mussoori WS	11.00
National chambal WS	635.00
Nawabgang WS	2.24
Okhla WS	4.00
Parvati aranga WS	11.00
Patna WS	1.00
Ranipur WS	230.00
Saman WS	5.00
Samaspur WS	7.99
Sandi WS	3.00
Sohagibarwa WS	428.21
Suhelwa WS	452.57
Sonanadi WS	301.76
Sur sarovar WS	4.00
Surha tal WS	34.00
Turtle WS	7.00
Vijai sagar WS	3.00
	13537.95

Name of National Parks and Wildlife Sanctuaries	Area (sq. kms.)
West bengal	
Buxa NP	117.10
Gorumara NP	79.45
Neora valley NP	88.00
Singalila NP	78.00
Sunderban NP*	1330.10
Ballavpur WS	2.00
Bethuadahari WS	1.21
Bibhutibhusan (parmadan) WS	0.60
Buxa WS	251.89
Chapramari WS	9.60
Haliday islands WS	5.95
Jaldapara WS	216.51
Jorepokhri WS	0.04
Lothian island WS	38.00
Mahananda WS	127.22
Narendrapur WS	0.10
Raiganj WS	1.30
Ramnabagan WS	0.14
Sajnakhali WS	362.40
Senchal WS	38.60
	2748.21

(Source : Wildlife Institute of India, Dehra Dun).

NP = National Park; WS = Wildlife Sanctuary.

* Declared as World Heritage Site

§ Declared as Ramsar Site

Prior to 1976 the subject of Wildlife was the concern of the State only as included in the List-II (State list) of the Constitution. However, in view of the importance of the subject and amount of attention it required, it was later transferred to the Concurrent List (List-III), through the 42nd Amendment in 1976, empowering the Government of India (Central Government) to legislate on these issues.

The most significant achievement in the field of conservation of wildlife and natural resources was the launching of the "World Conservation Strategy" in India by the then Prime Minister (late) Mrs. Indira Gandhi in 1980. Simultaneously, the formulation of the "National Conservation Strategy" was initiated and a few months later, the Forest (Conservation) Act was promulgated. The Forest (Conservation) Act, 1980 came as a major relief to check all such operations which may damage the forest and wildlife. According to this Act, no forest area can be de-reserved or diverted to any other purpose without the prior approval of the Central Government. The international trade in wildlife and wildlife products has been strictly regulated under the "Convention on International Trade in Endangered Species of Wild Fauna and Flora" (CITES) after India became one of the signatories to the convention.

The 15th meeting of the Indian Board of Wildlife held on 1st October, 1982 at New Delhi with late Prime Minister Mrs. Indira Gandhi as Chairperson framed a long term strategy and action programme for Wildlife conservation in India laying emphasis on :

- Establishment of Protected areas covering all major ecosystems with adequate geographical distribution.
- Restoration of degraded habitats to their original state.
- Rehabilitation of endangered and threatened species.
- Captive breeding programmes for threatened plant and animal species in Botanic Gardens and Zoological Parks.
- Effective management of the Protected Areas by fully trained personnel in Wildlife.
- Development of Research and Monitoring facilities for a better Scientific understanding of the habitat and population biology of the Wildlife.
- Wildlife education for popularising its importance and contribution for human betterment by way of keeping the environmental balance intact.

Under the Wildlife Protection Act and the Indian Forest Act, the following types of Protected Areas are recognised :

- National Park	(NP)
Wildlife Sanctuary	(WLS)
Game Reserve	(GR)
Closed Area	(CA)

Reserved Forest	(RF)
Protected Forest	(PF)

According to Wildlife Protection Act-1972, a NATIONAL PARK is defined as where, *"No person shall destroy, exploit or remove any wildlife or destroy or damage the habitat of any wild animal or deprive any wild animal of its habitat except under and in accordance with a permit granted by the Chief Wild Life Warden and no such permit shall be granted unless the State Government, being satisfied that such destruction, exploitation or removal of wildlife from the National Park is necessary for the improvement and better management of wildlife therein, authorises the issue of such permit"*. [Section 35(6) of the Act]. Apart from this grazing, private land holding or right is not permitted in a National Park {37(7) of the Act.}. *Similarly a SANCTUARY is defined as where, "No person shall hunt any wild animal or remove therefrom any wild animal, alive or dead, or any trophy, uncured trophy and meat derived from such animal provided that the Chief Wild Life Warden is satisfied that it is necessary that any wild animal in a sanctuary should be hunted or removed [a] for the better protection of wildlife or, [b] for any other good and sufficient reason, he may, with the previous approval of the State Government, grant a permit authorising any person to hunt or remove such wild animals under the direction of an officer authorised by him or cause it to be hunted or removed* [Section29(1) of the Act]. *The Chief Wild Life Warden shall be the authority who shall control, manage and maintain the sanctuaries* [Section 18-34) Chapter IV of the wildlife Protection Act 1972]".

In India, the maximum threat to the flora or plant life lies in such areas which are subjected to various developmental activities. Forests and areas near the villages or human settlements are also vulnerable due to impact of increased human activity in the form of grazing by cattle, "Slash and burn" or "Jhum" cultivation, fuel and fodder extraction, over exploitation of economic plants such as medicinal, edible, etc. The whole of Himalayan region, Western and Eastern Ghats, hilly tracts of Vindhya and Satpura, densely forested regions of Eastern India are such areas which are reeling under the pressure of many fold increased human population. These areas are incidently also rich in endemic species. According to Chatterjee (1940) Indian subcontinent has about 61% endemic flora with about 6,700 endemic species and 134 endemic genera of which Himalayas and Khasi hills alone harbour about 3000 species. The Indian region which has enormous floristic diversity is also very rich in cultivar diversity for which it is also termed as "Hindusthan Centre of Origin of cultivated plants" (Vavilov, 1951) as about 167 species of crops and 320 species of wild relatives of crops are known to have originated here. The rapid depletion of the flora means the loss in genetic diversity as well as the loss of wild relatives of crop plants. The conservation of crop genetic resources and their wild relatives is the most important and prime necessity of the hour as it is essential to make them available for future breeding programme to produce new and improved crops to feed the vast population. Although, the *ex-situ* conservation through seeds, plant parts, tissues, cells or whole plant in the artificial environment of seed-banks, Farm, Gene-banks, Cryo-banks, Tissue Culture Repositories or Botanic Gardens can preserve them for a longer period but this process has certain limitations too as the *ex-situ* conservation can neither provide the opportunity to the preserved species to continue its evolutionary process which it would have undergone in natural environment nor to compete with other species and to adapt itself to the changing natural conditions. But it can keep the germplasm safe when the plants are destroyed in their natural habitat. *In-situ* conservation means conserving the concerned species in its natural habitat where they continue to evolve and interact with other species and changing environment.

In India, the protected areas are located in almost all the major habitat types. This chain of protected areas ranging from deserts (cold and hot) to hilly regions, evergreen to deciduous forest although appears very impressive but it has failed to protect the floral components as the emphasis has been laid on the protection of certain animal species only for which these National Parks and Wild-life Sanctuaries were constituted. The word "Wildlife" has so far been considered synonymous with the wild animals and birds only, whereas the flora has invariably failed to receive adequate attention of the conservationists and naturalists.

Most of the protected areas in India, like other parts of the world, were set for wildlife conservation for protecting a rare mammal, bird, etc. but rarely if ever to conserve a plant species. However, during the past decade steps have been undertaken to establish reserves for protecting wild relatives of crop plants and other endangered plant species such as a "Gene sanctuary" in the Garo Hills for wild relatives of *Citrus*; the habitat of *"Nepenthes khasiana"* (Pitcher Plant) in Meghalaya and an "Orchid" Sanctuary in Arunachal Pradesh as protected areas to conserve the plants *in-situ*.

Future Strategies :

If the conservation of its biodiversity is not given adequate and immediate attention in India, one of the twelve world's megadiversity nations, this may have far reaching implications as, out of the 2503 cultivated plant species 320 (12.8%) come from Sino-Indian-Malayan Indonesian region. The Indian region alone contributes about 167 species (6.7%) that include some major important crops such as rice, sugarcane, millets, brassicas, pulses, citrus, mango, bannana, cardamon, Jute, cucurbits, bamboos, umbellifers, turmeric, pepper, ginger, betel vines, betel nuts, various kinds of herbal drugs, a variety of vegetables, fruits and many other important economic plants (Khoshoo, 1991).

Therefore, there is an urgent need to conserve those ecosystems where such species are concentrated. Such a conservation strategy should also involve the active participation of the local settlers who are dependent for their domestic needs on a particular ecosystem. Priority should be given to more fragile ecosystems and areas of endemism. A comprehensive inventory of the plant/animal species which occur in the protected area should be prepared so that the exact number of wild crop relatives, wild relatives of other economic plants, endemic rare and threatened species existing in a particular protected area is available as a ready reference and also for their poper management and monitoring.

Role of Botanical Survey of India in the study of the Protected Areas :

It is essential to know the status of individual species found in the protected areas for suggesting and adopting suitable conservation methods both *in vivo* and *in vitro* as the case may be.

Botanical Survey of India, which is responsible for the survey of the plant resources of the country; taxonomic studies on the flora and publishing district, state and National (Flora of India) floras; enlisting rare, endangered, endemic species and to undertake effective conservation measure; studies on the critical and fragile ecosystems; identification collection and preservation of such plants which are economically or otherwise useful for mankind, and numerous other aspects related to the country's flora, is playing a very significant role, both direct and indirect in the conservation of country's plant resources. As a result of extensive florsitic surveys conducted in different regions of India through various regional Circles of Botanical Survey of India, a sizeable amount of information has been generated on a variety of floral aspects, ecosystems, etc. including a number of fragile ecosystems, like Mangroves, Cold deserts, etc. and of protected areas, like National Parks, Wildlife Sanctuaries and Biosphere Reserves.

Besides, in its programme for the next millenium, the department has proposed to carryout survey and documentation of floristic diversity in fragile ecosystems and protected areas on priority basis.

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16. BOTANIC GARDENS : *EX SITU* CONSERVATION STRATEGIES

(R.K. Chakraverty & D.P. Mukhopadhyay)

Since the last quarter of the twentieth century there have been alarming reports on the loss of habitats leading to rapid extinction of biological species. With the acceleration of enormous developmental programmes including urbanisation and industrialisation, hydro-electric power stations and extension of mining, installation of the network of communication systems and lastly surveillance of defence mechanism, there is a sharp rise in soil erosion, loss of fertility status of the soil and shrinkage of the green coverage with appreciable depletion of biological diversity as a consequence of such habitat destruction. With the increase of these human activities and threats to natural populations conservation of floral components of the biological diversity of the countries has been emphasised seriously and has been the common concern across the globe. Botanic Gardens, thus have a major role by acting as refugia or safe abode of such threatened plant species and are making long term efforts for conserving the genetic resources and diversities with the help of modern tools and techniques of plant culture and cultivation. They are earmarked as the important centres of multiplication and conservation of plant species either threatened with extinction or restricted in specific areas as endemics.

Efforts have already been made in identifying the Botanic Gardens of the country situated in differnt regions and at the same time an inventorisation of the live collections, is in the process of completion, so that the coming generations may easily spot out the existence of threatened species required for multiplication and rehabilitation if situations arise as in the case of *Sophora toromiro* (Philippi) Skott. at the Easter Island or other species being reported at sporadic intervals. India is a country exhibiting unique assemblage of plant species with its diverse climatic and edaphic conditions. It is also pertinent to mention that India has a vast history of gardening and cultivation of garden and ornamental plants. Through centuries of practice and culture of gardening, many unique and outstanding centres of plant reserves or gardens have been developed, a number of which have been transformed into typical Botanic Gardens after the establishment of the Indian Botanic Garden, the erstwhile "Company Bagan" in 1787 by the Colonial administrators. It will be worthwhile to trace the history of gardens and Botanic Gardens in India, their role in the present environmental set up, distribution in various states and union territories and the most important collection of species having various degrees of threat.

History of development of Botanic Gardens in India :

In the 16th and 17th centuries Botanic Gardens in Europe, viz. Padua, Bologna, Salerno, etc. were founded as herbal medicinal gardens. From 17th century onwards with the rise of colonial era, some of the famous gardens of the world were useful centres of plant introduction and with the rise of commercial agriculture and forestry some such gardens became horticultural and fruit gardens. Thus Botanic Gardens all over the world seem to have been set up initially as utility gardens and with the passage of time they have been assigned other functions.

In India, however, since ancient times starting as early as from pre-Vedic, Vedic and post-Vedic periods upto pre-independence stage covering 'Gupta', 'Rajput', Mughal and British periods and finally during post-independence stage, the gardens had specific and distinct phases of development. These were intimately associated with the people, their culture, heritage and various other academic, literary, scientific, social and cultural thoughts and expressions. In order to understand the genesis, origin and development of Botanic Gardens in India, a knowledge on the aspect of development of gardens in general, is essential, as in most of the countries, the parks and gardens, established by various sections of the people at different stages were the primary source of the Botanic Gardens (Chakraverty & Mukhopadhyay, 1995).

In ancient India, important advancement towards civilisation took place in the Neolithic age, the pertinent culture began about 7500 B.C. in Western Asia (Randhawa, 1976). Probably during this period, agriculture and horticulture developed unknowingly when efforts were made to meet the necessities of day to day living by way of collecting fruits and cereals. It is believed that a race whose descendants are Sumerians of Mesopotamia and Dravidians of the Deccan, probably came to this country in about 4000 B.C. through the western passes and settled in the Indus valley. Thus it is considered that Mesopotamia was the birth place of agriculture and the ancient Sumerians were the first to develop of gardens (Randhawa, 1976).

The Indus Valley Civilisation (3000 to 2500 B.C.) represents Dravidian culture which flourished before the advent of the Aryans. Bhandarkar (1919) refers to cultivation of rice, date-palm and other fruits and vegetables during this period. About 2000 B.C. or later the Aryans advanced from North West across the Hindukush mountains and entered India through Afghanistan. The Dravidians tried to resist but failed.

A new era in the history and culture of India developed during the time of the Aryans. From the Vedas (2000 to 600 B.C.) which depict the history of the Aryans, it is revealed that they were great lovers of nature and natural beauties and were mainly involved in forest culture. The Vedas and the Upanishads, their religious books, give an account of the religious, moral and intellectual ideals surcharged by the beauty and majesty of the forests in India, the abode of the *Rishis*. "The epics of the Aryans the Ramayana and the Mahabharata, were probably compiled about 500 B.C." (Randhawa, 1976). Banerjee (1980) has however, mentioned the time of the Ramayana from about 2nd and 3rd Century A.D. and that of the Mahabharata about 4th Century A.D. the 'Panchvati forest' and 'Ashoka-Kanan' as mentioned in the Ramayana and the 'Kamyak forest' in the Mahabharata indicate clearly the early conception of gardens. A number of garden plants in cultivation during the period include Ashoka (*Saraca asoca* (Roxb.) de Wilde), Arjuna (*Terminalia arjuna* Roxb. ex DC.) Wight. & Arn., Champaca (*Michelia champaca* L.), Palasa (*Butea monosperma* (Lamk.) Taub., Kadamba (*Anthocephalus chinensis* (Lamk.) A. Rich ex Walp.), Banyan (*Ficus benghalensis* L.), Peepal (*Ficus religiosa* L.) and Kamal (*Nelumbo nucifera* Gaertn.).

Ancient Indian civilisation during the Vedic period was, therefore, mainly based on forests. In course of time forest flowers delighted the people and were used during pujas and presentation to near and dear ones on happy occasions. Other forest products served as food and medicine. These forests led to the origin of gardens of modern conception. During the time of Vatsyayana, author of 'Kamasutra', small residential gardens could be found in some urban areas.

Gardens During Post-Vedic periods :

After the epic period development of gardens from 600 B.C. to 300 A.D. during the period of *Buddhism* and *Jainism* on one side and *Vaisnavism* and *Saibism* on the other has to be considered. It is known that Siddhartha Gautama, the founder of Buddhism was born in 566 B.C. in the Lumbini Garden in Kapilabastu in southern parts of Nepal and his entire life span was associated with trees and gardens. "He was born in Lumbini park under a pipal tree, attained Nirvana under a Bodhi tree (*Ficus religiosa* L.) and died in a garden flanked by two trees. During Buddhist period gardens were laid out around monasteries and stupas. There were beautiful gardens in Nalanda and Taxsila which were renowned seats of learning" (Ghosh, 1984). Buddhism spread rapidly under the reign of emperor Ashoka who encouraged arboriculture and planting of trees along avenues and gardens. "The Mauryan emperors built beautiful palaces at their capital *Pataliputra*. Megasthenes said that the Royal Palace was provided with beautiful parks, artificial lakes and other means of enjoyments (Kundra, 1982).

The Gupta period (300-600 A.D.) was remarkable for the intellectual and cultural renaissance and all round developments of Indian traditions. Kalidasa's 'Abhijnana Sakuntalam', 'Meghadutam' and 'Ritusambara', composed during this period, give a vivid description of a number of flowers, flowering plants, flower gardens and forest trees.

"Vatsyayana described four kinds of gardens : (i) Promododyan for enjoyments of kings and queens, (ii) Udyan where kings passed time in playing chess with their courtyards, (iii) Brikshavatika where ministers and courtyards made merry with courtesans and (iv) Nandanvan dedicated to Lord Indra" (Randhawa, 1976)

In order to trace the history of gardens in ancient India, it is relevant to refer "Sarangadhara Paddhati", a book by Sarangadhara (1283-1301 A.D.) dealing with a chapter Upavana Vinoda, treating of arbori-horticulture which contains the following topics: (1) glory of the trees, (2) good and evil omen relating to residence near trees, (3) selection of soil (for planting) (4) classification of plants, (5) sowing of seeds, (6) the process of planting, (7) watering of plants, (8) plant protection rules, (9) construction of garden house, (10) soil study for digging wells, (11) rules for nourishment of plants, (12) recipe for nutrient solution, (13) treatment of disease and plant health, (14) ornamental marvels, (15) price fixation (Majumder, 1935).

Before the Mughals, the gardening history of India was nearly blank. Only Firoz Tughalak (1351- 1388 A.D.) greatly improved the city of Delhi and its surroundings by planting trees in gardens. He developed 1200 gardens around Delhi and restored 30 initiated by Alauddin; developed 80 gardens near Salaura and 44 in Chitor (Randhawa, 1976). The Rajput heritage and art in garden making has been exhibited at Ambar near Jaipur. In short, the gardens across the country exhibit different cultures represented in India Indo-Islamic, Rajput, Gujrati and Kashmiri. The Mughal gardens evolved with the Persian connections linking together (Heywood, 1973).

Mughal emperors in India are to a great extent responsible for the renaissance of gardening and introduction of roses, carnations, irises, narcissus, daffodils, lilies, tulips, etc. The beautiful Chinar tree *(Platanus orientalis* L.) and the exotic flowers were first introduced in Kashmir during this period as it has a more favourable climate than Persia and Central Asia.

Almost all the Mughal emperors had a passion for nature and they laid out beautiful gardens in cities of the north which were orderly and formal. Initially these gardens resembled Persian style but later remodelled in the background of new environment. The years between 1520 to 1658 (Babur to Shahjahan) were the best period for expansion of Mughal gardens which coincided with garden making in other parts of the world. There might be some resemblance between Mughal garden and Italian gardens, the country that pioneered the establishment of the Botanic Gardens in Pisa (1544) and Padua (1545), but the landscaping pattern around the houses and the attitude towards use of water in the garden along with some other differences exist between the two (Crowe, 1973).

With the decline of the Mughal rule, Indian gardens are known to have developed under patronage of local rulers. Asaf-ud-daulah (1775-1797), the fourth Nawab of Oudh was a patron of gardens after he shifted his capital to Lucknow. The Sikandar Bagh of Lucknow was laid out by Nawab Sadat Ali Khan (1789-1814) which was later improved by Nawab Wazed Ali Shah, the last King of Oudh (1847- 1856). This garden was later transformed into a modern Botanic Garden in 1953.

The Mughal gardens with some alterations were transformed into Rajput gardens. In gardens, the Rajput heritage is perhaps, most clearly seen at Ambar near Jaipur, built on barren rocks by Raja Man Singh (1590 - 1615). Gardens at Jodhpur, Mandor, Udaipur and some other places of Rajasthan were built in their own styles and fashions.

The gardens in South India were mostly developed during the rule of Hyder Ali and Tippu Sultan from 1760 to 1799. With their initiative some gardens were developed at Srirangapatna, Bangalore and Malavalli. Lalbagh garden at Bangalore was initiated during this period. After the death of Hyder Ali, Lalbagh continued to be a pleasure garden of his son Tippu which developed into a typical Botanic Garden during the British period under the stewardship of Nathaniel Wallich.

By the middle of 19th century English gardens and Botanic Gardens appeared in India in place of Charbagh type of gardens. The Botanic gardens a new conception of garden making which combine science with art in perfect harmony, was thus developed in India.

Greatest contribution of English poeple in India was the setting up of Botanic Gardens and also informal and mixed gardens. Various Agri-Horticultural Societies were also formed in different parts of India under active initiative of Rev. William Carey. These societies helped immensely in popularising gardens and garden plants (Randhawa, 1976). Some important gardens established during the British rule are (1) The Royal Botanic Garden (Indian Botanic Garden 1787); (2) Botanic Garden at Saharanpur (1817), (3) Lloyd Botanic Garden, Darjeeling (1878), (4) Government Gardens, Ootty (1947), (5) Sim's Park, Coonoor (1974), (6) Botanic Garden, Coimbatore (1908), (7) Bryant Park, Kodaikanal (1900), (8) Forest Research Institute and Colleges, Dehra Dun (1934), TBRI and a large number of parks and gardens comparable to organised Botanic Garden (Chakraverty & Mukhopadhyay, 1990). Based on ideas and concepts of English gardens, a good number of gardens of eminence were laid out during post independence period with informal designs. Buddha Jayanti Park (1956), parks around Lodhi tomb and the Rose garden of Chandigarh (1966) are some of the outcome of such conception. Japanese gardens also found place in India during post -independence period. The Roshanara Garden and the Quderia garden at Delhi were laid out based on ideas of Japanese gardens (Randhawa *et al.*, 1971).

In recent years, the Universities and some private enterprises in industrial concerns in cities and towns have been developing gardens with various objectives. A number of experimental Botanic Gardens under initiative of Botanical Survey of India have already been established in different agroclimatic zones of the country during this period. Proposal for establishing a network of Botanic Gardens are under active consideration or coming up at intervals, the latest of which is the Ficus Garden at Karnal in Haryana in 1991. The Ministry of Environment and forests proposes to set up a "National Botanic Gardens" at

NOIDA-Delhi; blending both, the modern concepts and the traditional heritage, to meet the requirement of conservation, education and recreation.

Role of Botanic Gardens :

Due to natural degeneration, reckless exploitation, destruction of natural habitats for developmental programmes and the use of harmful chemicals in agriculture innumerable plant species have been lost. About 60,000 plant species of the world's total estimate of 2,50,000 are under various degrees of threat. In India about 10 per cent of the estimated 17,000 flowering plants are enlisted as rare or threatened. Conservation of plant species has become a major concern throughout the world realising their importance and utility. Increase in human population, rapid urbanisation, industrial development and mobilisation of defence forces have seriously disturbed the natural ecosystem.

Botanic Gardens serve as living repository or refugia of plants of the country and also of selected exotic flora. They serve as excellent *ex situ* conservation and multiplication centres of threatened, rare and endemic plant species and may house germplasm collections of selected economic, ornamental and medicinal plants and their wild progenitors for future genetic source materials in crop improvements. Besides, they promote educational programmes and researches in experimental botany, ornamental, horticulture, propagation of rare and threatened species, species for afforestation and for alternative sources of food, fodder and fuel. Introduction of economic and commercially exploitable less known plant species, generating awareness regarding values of trees, exchanging viable propagation materials, organising exhibitions and flower shows are some other significant roles played by the Botanic Gardens at present. The changing roles of Botanic Gardens to meet the demands and requirements of the time have been discussed at length by various authors (Holttum, 1970; Purseglove, 1959; Raven, 1981; Khoshoo, 1987; Heywood, 1983, 1987; Larsen *et al.*, 1987; Brockway, 1979).

Environmental pollution, ecological imbalance and conservation of plant species especially those which are rare, threatened and endemic with acute possibility of extinction are matters of global concern and a need is emphasised all over the world to locate the network of such centres which can serve as fields for collection, conservation and multiplication of plants of academic utility and aesthetic values, besides protecting ecological balance, preventing environmental degradation and maintaining a pure, pollution free atmosphere in the locality. For example, the Indian Botanic Garden introduced and cultivated several rare and endangered species like *Bentinckia condapanna* Berry ex Roxb. (Basu, 1988), *Bentinckia nicobarica* (Kurz) Becc. (Basu, 1988) and *Platycerium wallichii* Hook.f. (Jain & Sastry, 1980). Multiplication of these species greatly increased the population and enabled to distribute to other centres, thus protecting these species from possible extinction. Similarly, Botanic Gardens have been found to play a pivotal role in either giving a safe abode in the Botanical Garden of the University of Bonn, Germany, e.g. *Sophora toromiro* (Philippi) Skott., an endemic species of Eastern Island (Lobin & Barthlott, 1988; Lobin, 1990; Weimarck, 1984) or multiplication and reintroduction of species of *Cupressus dupreziana* A. Camus and *Jubaea chilensis* (Molina) Baill. in Botanic Garden 'Villa Thuret', France (Auge & Ducatillion, 1991). The rescue of the endemic species *Ruizia cordata* Cav. (Sterculiaceae) from the Reunion Island which was in great danger of extinction and its cultivation, multiplication at the Conservatoire Botanique National de Brest, France and its eventual re-introduction to the wild (Lesouef, 1991) is another promising example of the role played by Botanic Gardens towards conservation and protection of endangered species.

Present and future role of Botanic Gardens :

1. Botanic Gardens should serve as 'refugia' for plants which are on the verge of extinction due to habitat loss. This can be achieved by undertaking mass culture of species, through tissue culture, seed propagation, etc. to increase plant population which have already been listed in 'Red Data Books', thus conserving the genetic diversity and resources of the country (Böcher & Hjerling, 1964; Heywood, 1964, 1976; Thompson, 1979; Gomez-Campo, 1979, 1987; Hawkes, 1987; Wilkins & Dodds, 1983; Withner, 1943; Mitchell, 1991; Steward, 1991).

2. The Gardens should act as centres of nature conservation activities and to propagate through mass education and demonstration of the environmental awareness and sanity to children and the future generations, in particular. It should act as a vehicle for environmental education, as is being gradually adopted in several countries of the world (Simmons, 1981; Taylor, 1971; Eloff, 1985a, 1985b, 1987; Bermejo, 1987; Boden & Boden, 1987; Nayar & Chakraverty, 1987).

3. In the world conservation strategy, Botanic Gardens can successfully play a role in conserving endangered species as *ex-situ* centres of conservation (Given, 1983, 1987; Mohan Ram, 1983; Abeywickrama, 1983; Ashton, 1987; Thibodeau & Falk, 1987). "The Botanical Survey of India with its main Botanic Garden and the regional experimental gardens established in different phytogeographical zones to suit the needs of plants occurring in different ecological conditions of the country" are maintaining rare, endangered and threatened plants of Indian flora (Khoshoo, 1986; Chakraverty & Mukhopadhyay, 1990).

4. A special role of Botanic Gardens as centres of research and training and action oriented plans for conservation can be thought of. Such Botanic Gardens can work on pollen storage, tissue culture, genetic engineering and other projects on crop improvements (Khoshoo, 1987; Meilleur, 1991; Walter, 1991).

5. *In-situ* conservation should also be done in the natural habitat of the species and there should be arrangement of periodical mapping of the population for purposes of protection of plants of scientific and commercial value.

6. Botanic Gardens should take interest in the preservation of plants growing in the nearest endemic centres and exchange freely all rare and endangered species (Nayar, 1987).

In India, out of *ca* 17,000 species of flowering plants, about 10 per cent are estimated to be under degrees of threat. About 17 per cent of these flowering plant species are represented by trees which constitute an important element in any tropical or temperate woodland ecosystem and depletion or loss of such trees in the ecosystem may ultimately cause loss of hundreds of dependent animal or plant species (Nayar, 1987). It has been worked out that in India about 2000 species will become rare or threatened by 2000 A.D. A disappearing plant species can take with it 10 to 30 dependent species viz, insects, higher animals and other plants (Nayar, 1987). In order to save this plant wealth from total extinction, conservation centres in various phytogeographical regions of the country require to be documented along with their existing live collections.

Studies were undertaken by the authors (Chakraverty & Mukhopadhyay, 1990) to enlist the network of Botanic Gardens and important parks and greeneries in India, including those located in the Universities and institutional campuses. Notable live collections of over 150 such refugia, considered to be *ex-situ* centres of conservation and cultivation, among others, rare and endangered plants and exchanging information of plant materials have been listed.

A large number of Botanic Gardens set up in early periods of Indian history and also during English period are attached to the Horticultural or Forestry Departments of the State Governments excepting, however, the Indian Botanic Garden and a few experimental gardens under the control of Botanical Survey of India. "There are new schemes mooted for the establishment of the National Botanic Garden at Delhi and funded gardens for conservation purposes through 'Model Botanic Gardens'. Though resource constraints are coming in the way, the the necessity to establish chain of Botanic Gardens is largely felt among people, scientists and administrators" (Nayar, 1987). Attempts should be made in the coming decades to establish Botanic Gardens in the states/union territories of India which are not at present gifted with this treasure and to increase the network gradually through exchange of plant materials. Botanical Survey of India can play a major role in this direction. Words of Kenton Miller (1985), Director General, IUCN remind us that "The Botanic Gardens of the world could and should develop into a major new global force for conservation".

Distribution of Botanic Gardens in India with reference to botanical regions of the country :

Chakraverty and Mukhopadhyay (1990) have listed 150 organised Botanic Gardens or large parks which are in some way comparable to Botanic Gardens in India. The list included 33 gardens under Government control, 77 gardens and parks of public and academic interest and 40 gardens run by the Universities. During the course of the present study an inventory has been made on statewise distribution of Botanic Gardens maintained by Government institutions, autonomous bodies and private sectors on the one hand (Table 1; Map 19) and those maintained by the Universities, etc. on the other (Table 2; Map 20) shown in tabular forms giving location, altitude, area, year of establishment and remarks. The object is to assess distribution of Botanic Gardens in eleven phytogeographical divisions of India, viz. North-west Himalaya, Indo-Gangetic plains, E. Himalaya, Assam, Central India, Arid Zone, northern Western Ghats and northern West Coast, southern Western Ghats southern West Coast and Lakshadweep, Deccan, Eastern Ghats and Coromandel Coast and Andaman & Nicobar Islands.

Table-1. *Statewise* (including Union Territories) distribution of Botanic Gardens

Sl. No.	State/Union Territory (U.T.)	Name of Botanic Garden	Location	Altitude (m)	Area (Hectare)	Year of establishment	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	**Andhra Pradesh**	–	–	–	–	–	P-(preferably in the vicinity of Hyderabad with emphasis on conservation of species endangered or endemic to Eastern Ghats)
2.	**Andaman & Nicobar Islands**	Experimental Botanic Garden of the Botanical Survey of India (BSI)	Nayashahr	40	30	1980	D
3.	**Arunachal Pradesh**	1. Experimental Botanic Garden of BSI, Sankie-View	Itanagar	250	124	–	D
		2. Botanic Garden, Orchid Research & Development Centre	Tippi, Bhalukpong	190	102	1972	
4.	Assam	--	Diphu, Haflong, Guwahati	--	–	--	D

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5.	Bihar	–	–	–	–	–	P (Preferably in the vicinity of Ranchi and Netarhat both for *in situ* and *ex situ* conservation of dry deciduous or evergreen forest elements)
6.	Chandigarh	–	–	–	–	–	P
7.	Delhi	Buddha Jayanti Park	New Delhi	218	29	1956	P
8.	Gujarat	1. Botanical Garden, Waghai-Dangs	Waghai	280	24	1964	–
		2. [illegible] Botanical Garden, Shahibag	Ahmeda-bad	70	26	1979	–
9.	Goa, Daman & Diu	–	–	–	–	–	P
10.	Haryana	–	–	–	–	–	One *Ficus* garden established at Karnal in 1991.
11.	Himachal Pradesh	–	–	–	–	–	P (Preferably in the vicinity of Kulu & Manali)

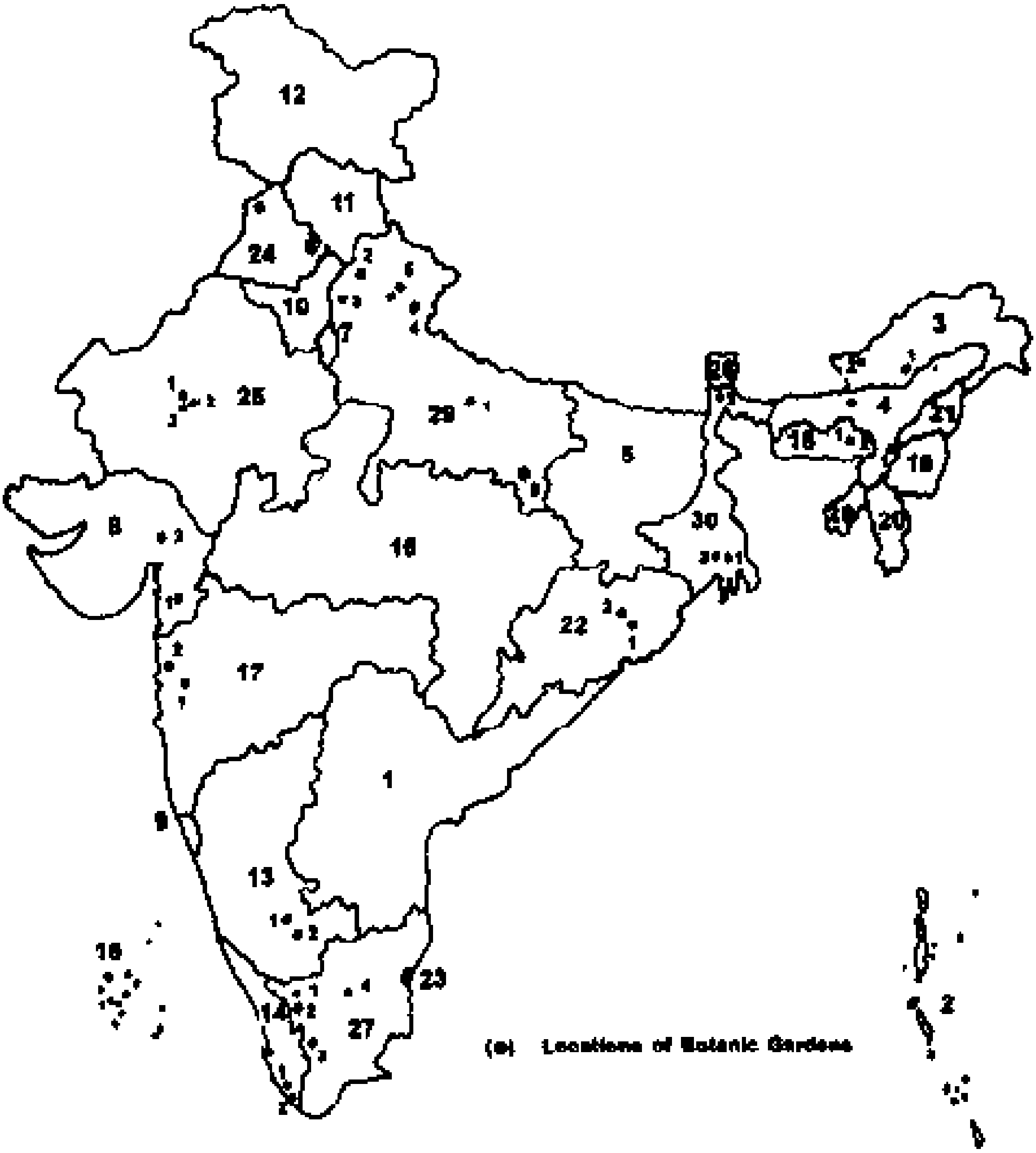
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
12.	Jammu & Kashmir	–	–	–	–	–	P (Preferably in the vicinity of Gulmarg with emphasis on *in-situ* conservation)
13.	Karnataka	1. Lalbagh Gardens	Bangalore	915	100	1760	–
		2. Sri Chamarajendra Park (Gubban Park)	Bangalore	915	124	–	–
14.	Kerala	1. Government Botanic Garden	Thiruvananthapuram	50	27	1858	–
		2. Tropical Botanic Garden	– " –	200	121	1979	–
15.	Lakshadwip	–	–	–	–	–	P
16.	Madhya Pradesh	–	–	–	–	–	P (preferably either in the region of Panchmari, Bori or Bastar).
17.	Maharashtra	1. Experimental Botanic Garden and Arboretum, BSI	Pune	650	18.3	1960	–
		2. Veeramata Jijabai Bhosle Udyanva Prani Sangrahalaya	Mumbai	6	19.5	1862	–

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
18.	Meghalaya	1. National Orchidarium and Botanic Garden, Woodlands, BSI	Shillong	1500	1.5	1959	–
		2. Experimental Barapani Botanic Garden, BSI	Shillong	1000	10.4	1966	–
19.	Manipur	–	–	–	–	–	P
20.	Mizoram	–	–	–	–	–	P
21.	Nagaland	–	–	–	–	–	P
22.	Orissa	1. State Botanical Garden	Barang	40	72	1963	P
		2. Regional Plant Resource Centre	Bhubaneswar	5	160	1985	–
23.	Pondicherry	Botanical Garden	Pondicherry	2	11	1826	–
24.	Punjab	Ram Bagh	Amritsar	232	44	1919	–
25.	Rajasthan	1. Botanic Garden, Central Arid Zone Research Institute	Jodhpur	210	22.4	1963	–
		2. Mandore Garden	Jodhpur	219	12.5	1928-29	–
		3. Umaid Garden	Jodhpur	220	15.0	1936	–

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
26.	Sikkim	1. Experimental Botanic Garden, BSI	–	–	–	–	P (as an Experimental garden under BSI with specific collection of Orchids and Rhododendrons)
		2. Jawaharlal Nehru Botanic Garden	Rumtek	2000	76.0	–	–
27.	Tamil Nadu	1. Government Botanic Garden	Odhakma-ndalam	2500	22.0	1847	–
		2. Sim's Park	Coonoor	1750	12.1	1874	–
		3. The Bryant Park	Kodaikanal	2000	8.8	1908	–
		4. National Orchidarium and Experimental Botanic Garden, BSI	Yercaud	1511	18.4	1963-64	–
28.	Tripura	–	–	–	–	–	P
29.	Uttar Pradesh	1. The National Botanical Research Institute	Lucknow	113	25.0	1800	Initially known as Sikandar Bagh
		2. Botanic Garden, Forest Research Institute and College	Dehra Dun	663	50.0	1934	–
		3. Horticultural Experiment and Training Centre	Saharanpur	275	68.0	1750	Known to be established before 1750
		4. Government Garden	Chaubatia (Almora)	1983	110.0	–	–

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		5. Experimental Botanic Garden, BSI	i. Pauri	1800	14.0	1975	–
			ii. Khirsu	1900	8.0	1975	–
			iii. Dehra Dun	650	1.0	1995	
		6. Experimental Botanic Garden, BSI	Allahabad	92	3.0	1960	With special preference to Rose, Crotons and Acacias.
30.	West Bengal	1. Indian Botanic Garden	Howrah	4.6	112.0	1787	Initially known as Royal Botanic Garden.
		2. Lloyd Botanic Garden	Darjee-ling	2134	16.7	1878	–
		3. Eden Gardens	Calcutta	6	6.0	1836-42	–

P = Proposals are being made for establishment of Botanic Gardens/Experimental Gardens; D = Botanic Gardens in early stage of development.



Map 19. Botanic Gardens in India, maintained by Government and Autonomous Institutions.

Table-2. Statewise (including Union Territories) distribution of Botanic Gardens maintained by Universities, Colleges, Research Institute and Agri-Horticultural Societies for teaching and research purposes.

Sl. No.	State/Union Territory (U.T.)	Name of Botanic Garden	Location	Altitude (m)	Area (Hectare)	Year of establishment	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Andhra Pradesh	1. Osmania University	Hyderabad	28	1.0	–	–
		2. Andhra University	Waltair	30	0.8	–	D.
2.	Andaman & Nicobar Islands	–	–	–	–	–	–
3.	Arunachal Pradesh	–	–	–	–	–	–
4.	Assam	–	–	–	–	–	–
5.	Bihar	1. Ranchi University	Ranchi	–	–	–	D
		2. Bhagalpur University	Bhagalpur	110	–	–	–
		3. Magadh University	Bodhgaya	131	6.5	1975	–

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		4. Bihar Agricultural College	Sabour	112	2.5	1923	–
6.	Chandigarh	Panjab University	Chandi-garh	340	6.5	1961	..
7.	Delhi	1. Delhi University	Delhi	220	1.0	1947	–
		2. School of life Science, Jawaharlal Nehru University	N. Delhi	..	–	..	D
		3. Horticultural Section, National Bureau of Plant Genetic Resources (NBPGR)	Delhi	218	2.1	1976	
8.	Gujarat	1. South Gujarat University	Surat	2	1.6	1978	–
		2. Saurashtra University	Rajkot	138	20.0	1978	–
		3. Gujarat Agricultural University	Junagadh	10	31.0	–	–
		4. Gujarat University School of Sciences (USSC)	Ahmeda-bad	10	2.5	1964	–
		5. Maharaja Sayaji Rao University	Baroda	34	10.0	1885	–
9.	Goa, Daman & Diu	–	–	–	–	..	
10.	Haryana	–	–	–	–		

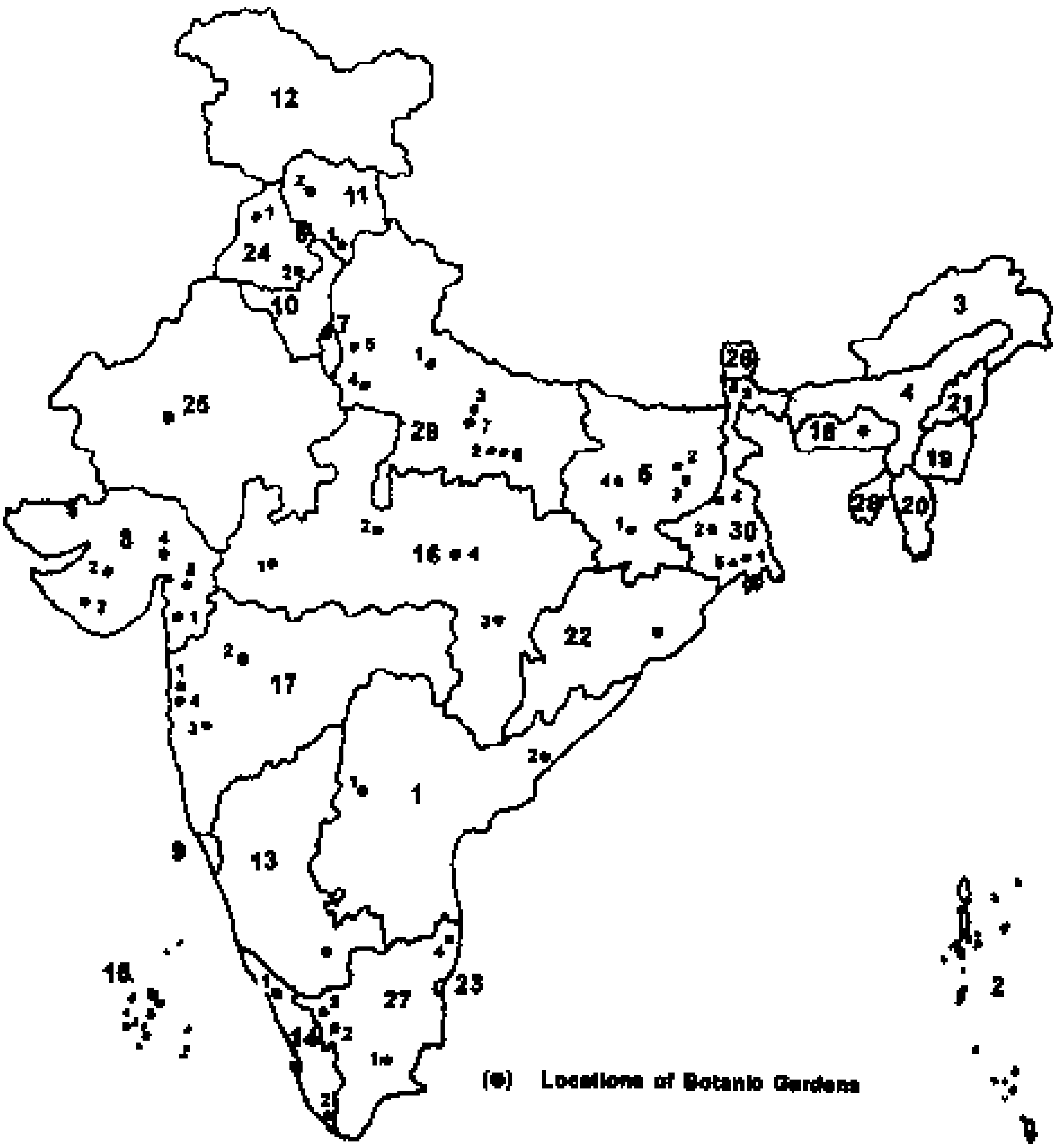
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
11.	Himachal Pradesh	1. Himachal Pradesh Krishi Viswavidyalaya (HPKVV)	SMS Nagar, Solan	1300	2.5	1979	..
		2. Dhauladhar Botanical Garden (HPKVV) campus	Palampur	1350	1.0	1981	—
12.	Jammu & Kashmir	—	—	..	..	—	..
13.	Karnataka	Gandhi Krishi Vigyana Kendra	Bangalore	930	26.5	1976	—
14.	Kerala	1. Calicut University	Calicut	100	19.0	1971	..
		2. Kerala University	Trivandrum	50	12.0	1968	..
15.	Lakshadwip	—	..	..	—	..	—
16.	Madhya Pradesh	1. Vikram University	Ujjain	492	0.8	..	—
		2. Saugar University	Saugar	550	3.5	1962	..
		3. Ravi Sankar University	Raipur	268	5.0	1979	..
		4. Jabalpore University	Pachpedi, Jabalpore	—	—	—	D

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
17.	Maharashtra	1. Indian Institute of Technology	Powai Bombay	4	21.9	1960	–
		2. Marathwada University	Aurangabad	310	15.0	1964	–
		3. University of Poona	Pune	379	0.3	1961	–
		4. Institute of Sciences	Bombay	2	0.2	1930	–
18.	Meghalaya	North Eastern Hill University	Shillong	..	..	..	D
19.	Manipur	–	–	–	..	..	–
20.	Mizoram	–	..	..	–	–	–
21.	Nagaland	–	–	..	..	..	–
22.	Orissa	Utkal University	Bhubaneswar	46	5.0	1971	–
23.	Pondicherry	–	–	–	–	–	–
24.	Punjab	1. Guru Nanak Dev University	Amritsar	232	9.5	1975	..
		2. Punjabi University	Patiala	251	11.5	–	..

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
25.	**Rajasthan**	–	–	–	–	–	–
26.	**Sikkim**	–	–	–	–	..	–
27.	Tamil Nadu	1. Madurai Kamaraj University	Madurai	600	1.60	1973	–
		2. Tamil Nadu Agricultural University	Coimbatore	427	17.5	1906	–
		3. Bharathiar University	Coimbatore	–	–	..	D
		4. Agri-Horticultural Society	Madras	2	7.5	1835	–
28.	**Tripura**	–	–	–	–	–	–
29.	Uttar Pradesh	1. Aligarh Muslim University	Aligarh	562	38.0	1962	–
		2. Roxburgh Botanic Garden, Allahabad University	Allahabad	9	1.2	1923	..
		3. Lucknow University	Lucknow	120	–	..	..
		4. Agra College	Agra	160	2.5	1930	–
		5. Meerut University	Meerut	300	8.3	1970	–
		6. Kulbhaskar Ashram Post Graduate College	Allahabad	9	2.0	1960	–
		7. Central Drug Research Institute	Lucknow	123	2.0	1951	..

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
30.	West Bengal	1. Calcutta University	Calcutta	4	2.0	1918	–
		2. Burdwan University	Burdwan	24	21.0	1964	–
		3. Darjeeling Govt. College	Darjee-ling	2050	3.0	1948	–
		4. Visva Bharati University (Uttarayan)	Santi-niketan	20	4.8	1939	–
		5. The Agri-Horticultural Society of India	Calcutta	6	9.0	1820	–

D = Botanic Gardens in early stages of development.



Map 20. Botanic Gardens in India, maintained by Universities, other Academic Organisations and Societies.

Table-3. List of rare, endangered, endemic and interesting species in different Botanic Gardens in India.

Name of the species	Family	Growing in Botanic Gardens
**Acanthophippium bicolor* Lindl.	Orchidaceae	BSI (SC)
Acanthophippium sylhetense Lindl.	Orchidaceae	BSI (EC), BG-ORD
Aerides emericii Reichb.f.	Orchidaceae	BSI (ANC)
**Aerides maculosum* Lindl.	Orchidaceae	BSI (SC)
Aerides odoratum Lour.	Orchidaceae	BSI (EC, NC) LB
Aesculus assamica Griff.	Hippocastanaceae	BSI(EC, NC), FRI
Agrostophyllum brevipes King & Pantl.	Orchidaceae	JNBG
Alnus nepalensis D. Don	Betulaceae	GBG
**Alsophila latebrosa* Hook.	Cyatheaceae	BSI (SC)
Alstonia kurzii Hook.f.	Apocynaceae	BSI (ANC)
**Anemia tomentosa* Sw.	Schizaeaceae	BSI (SC)
Arachnis cathcartii (Lindl.) J.J. Sm.	Orchidaceae	BSI (EC, SC), BG-ORD
**Arachnis clarkei* (Reichb.f.) J.J. Sm.	Orchidaceae	BSI (EC, SC), BG-ORD
Araucaria bidwillii Hook.	Araucariaceae	BSI (IBG, NC), FRI, LB
Araucaria columnaris Hook.	Araucariaceae	FRI
Arenga wightii Griff.	Arecaceae	BSI (IBG)
Arisaema attenuatum Barnes & Fischer	Araceae	BSI (SHC)
**Arisaema caudatum* Engl.	Araceae	BSI (WC)
**Arundina graminifolia* (D. Don) Hochr.	Orchidaceae	BSI (EC, SC)
**Ascocentrum ampullaceum* (Roxb.) Schltr.	Orchidaceae	BSI (NC, WC)
Asplenium nidus L.	Polypodiaceae	BSI (IBG, NC), FRI
Bambusa arundinacea Retz. var. *gigantea* Bahadur	Poaceae	FRI
Bambusa atra Lindl.	Poaceae	FRI
Bauhinia vahlii Wight & Arn.	Caesalpiniaceae	BSI (IBG, NC)
**Belosynapsis vivipara* (Dalz.) Sprague & Fischer	Commelinaceae	BSI (WC)
**Bentinckia condapanna* Berry ex Roxb.	Arecaceae	BSI (IBG, SC)
**Bentinckia nicobarica* (Kurz) Beccari	Arecaceae	BSI (IBG, SC)
Betula cylindrostachya Wallich	Betulaceae	FRI
Biermannia jainiana Hegde et Rao	Orchidaceae	BG-ORD
Bombax insigne Wallich var. *andamanica* Prain	Bombacaceae	BSI (ANC)
**Brainea insignis* (Hook.) J.J. Sm.	Blechnaceae	BSI (EC)
**Bulbophyllum careyanum* (Hook.f.) Spreng.	Orchidaceae	BSI (NC)

Name of the species	Family	Growing in Botanic Gardens
Bulbophyllum guttulatum (Hook.f.) Balak.	Orchidaceae	BSI (NC), LBG
**Bulbophyllum mysorense* (Rolfe) J.J. Sm.	Orchidaceae	BSI (SC)
**Bulbophyllum rauli* Arora	Orchidaceae	BSI (NC)
**Bulbophyllum triste* Reichb.f.	Orchidaceae	BSI (NC)
Butea buteiformis (Voigt) Grierson & Long	Fabaceae	FRI
Calamus andamanicus Kurz	Arecaceae	BSI (ANC)
**Calanthe densiflora* Lindl.	Orchidaceae	BSI (SHC), LBG
Calanthe herbacea Lindl.	Orchidaceae	BG-ORD (Tippi)
Calanthe masuca Lindl.	Orchidaceae	BSI (NC)
Canarium strictum Roxb.	Burseraceae	BSI (IBG)
Cardiocarpus andamanica (Kurz) Howard	Icacinaceae	BSI (ANC)
Casuarina cunninghamiana Miq.	Casuarinaceae	BSI (IBG) FRI
**Catamixis baccharoides* Thoms.	Asteraceae	BSI (NC)
**Ceropegia attenuata* Hook.	Asclepiadaceae	BSI (WC)
**Ceropegia vincaefolia* Hook. Ansari	Asclepiadaceae	BSI (WC)
Chrysoglossum robinsonii Ridl.	Orchidaceae	BG-ORD
Cleisostoma tricallosum Hegde et Rao	Orchidaceae	BG-ORD
**Coelogyne cristata* Lindl.	Orchidaceae	BSI (IBG, EC, NC) WC), LBG
**Coelogyne ovalis* Lindl.	Orchidaceae	BSI (EC, NC, WC)
Coelogyne stricta (D. Don) Schltr.	Orchidaceae	BSI (NC)
Coelogyne viscosa Reichb.	Orchidaceae	BSI (NC)
Commiphora wightii (Arn.) Bhandari	Burseraceae	NBRI
Coptis teeta Wallich	Ranunculaceae	BSI (APS, EC)
Corypha taliera Roxb.	Arecaceae	BSI (IBG)
Cyanotis burmanniana Wight	Commelinaceae	BSI (WC)
Cyanotis cerifolia Rolla Rao et Kammathy	Commelinaceae	BSI (WC)
Cyathea gigantea (Wallich ex Hook.) Holtt.	Cyatheaceae	FRI
**Cyathea spinulosa* Wallich ex Hook.f.	Cyatheaceae	BSI (NC, SHC), LBG
**Cycas beddomei* Dyer	Cycadaceae	BSI (IBG, SC), NBRI
**Cycas pectinata* Griff.	Cycadaceae	BSI (EC, IBG)
Cymbidium ensifolium (L.) Swartz.	Orchidaceae	BG-ORD
**Cymbidium iridioides* D. Don	Orchidaceae	BSI (EC, NC, SC), LBG
Cymbidium hookerianum Reichb.	Orchidaceae	BSI (EC), LBG
Cymbidium macrorhizon Lindl.	Orchidaceae	BSI, (NC) BG-ORD

Name of the species	Family	Growing in Botanic Gardens
**Dendrobium aphyllum* (Roxb.) Fisch.	Orchidaceae	BSI (EC, IBG, SC, SHC), LBG
Dendrobium aurantiacum Reichb.f	Orchidaceae	BSI (EC)
Dendrobium bensoniae Reichb.f.	Orchidaceae	BSI (EC), BG-ORD
**Dendrobium bicameratum* Lindl.	Orchidaceae	BSI (NC, SC)
**Dendrobium densiflorum* Lindl.	Orchidaceae	BSI (EC, IBG, NC, SHC), FRI, LBG
**Dendrobium haemoglossum* Thw.	Orchidaceae	BSI (SC)
**Dendrobium lawianum* Lindl.	Orchidaceae	BSI (SC)
**Dendrobium nobile* Lindl.	Orchidaceae	BSI (EC, IBG, NC, SC, SHC), LBG
Dendrobium normale Falc.	Orchidaceae	BSI (NC)
**Dendrobium secundum* (Blume) Lindl.	Orchidaceae	BSI (ANC)
Dendrobium seidenfadenii Sengh. & Bocken.	Orchidaceae	BSI (EC)
**Dendrobium subulatum* Lindl.	Orchidaceae	BG-ORD
**Dendrobium wardianum* Warn.	Orchidaceae	BSI (EC, SC), LBG
Derris andamanica Prain	Fabaceae	BSI (ANC)
Dinochloa maclellandii (Munro) Kurz	Poaceae	BSI (IBG)
**Dioscorea deltoidea* Wallich	Dioscoreaceae	BSI (NC)
Diospyros marmorata Parker	Ebenaceae	BSI (ANC)
Diplomeris hirsuta Lindl.	Orchidaceae	BG-ORD (Tippi)
**Dipteris wallichii* (R. Br.) Moore	Polypodiaceae	BSI (EC, IBG)
Drimia razii Ansari	Liliaceae	BSI (WC)
Drosera burmanni Vahl	Droseraceae	BSI (SC)
**Drosera peltata* Sm.	Droseraceae	BSI (SC)
Elaeocarpus sphaericus (Gaertn.) K. Schum.	Elaeocarpaceae	BSI (IBG), FRI
Ephedra foliata Boiss. & Kotschy ex Boiss.	Ephedraceae	BSI (IBG)
Epipogium roseum (D. Don) Lindl.	Orchidaceae	BG-ORD
Epipogium sessanum Hegde et Rao	Orchidaceae	BG-ORD
Epipogium tuberosum Duthie	Orchidaceae	BG-ORD (Tippi)
**Eremostachys superba* Royle	Lamiaceae	BSI (NC)
Eria alba Lindl.	Orchidaceae	BSI (NC)
Eria pubescens (Hook.) Lindl.	Orchidaceae	BSI (NC)
Eria spicata (D. Don) Hand.-Mazz.	Orchidaceae	BSI (NC)
**Eria andamanica* Hook.f.	Orchidaceae	BSI (NC)
Erythrina resupinata Roxb.	Fabaceae	NBRI

Name of the species	Family	Growing in Botanic Gardens
Evodia roxburghiana Benth.	Rutaceae	BSI (EC)
Ficus krishnae C. DC.	Moraceae	BSI (IBG, NC), FRI
**Flickingeria hesperis* Seidenf.	Orchidaceae	BSI (NC)
**Frerea indica* Dalz.	Asclepiadaceae	BSI (IBG, WC), NBRI
**Ginkgo biloba* L.	Ginkgoaceae	BSI (EC, NC), FRI, GBG, LBG
Glyphochloa mysorensis (Jain & Hem.) Clayton	Poaceae	BSI (WC)
**Gnetum gnemon* L.	Gnetaceae	BSI (EC)
Gnetum latifolium Blume	Gnetaceae	BSI (ANC)
**Gnetum ula* Brongn.	Gnetaceae	BSI (EC)
Gouania andamanica King	Rhamnaceae	BSI (ANC)
Grewia calophylla Kurz	Tiliaceae	BSI (ANC)
Herminium longilobatum Hedge et Rao	Orchidaceae	BG-ORD
**Hoya ovalifolia* Wight & Arn	Asclepiadaceae	BSI (WC)
**Hyphaene dichotoma* (Baker) Furtado	Arecaceae	BSI (IBG)
**Hyphaene thebaica* (L.) Mart.	Arecaceae	BSI (CC, IBG)
**Iphigenia sahyadrica* Ansari et Rolla Rao	Liliaceae	BSI (WC)
**Iphigenia magnifica* Ansari et Rolla Rao	Liliaceae	BSI (WC)
Iphigenia stellata Blatt.	Liliaceae	BSI (WC)
**Ischaemum raizadae* Hem. et Bill.	Poaceae	BSI (WC)
**Itea nutans* Royle	Iteaceae	BSI (NC)
Ixora barbata Roxb.	Rubiaceae	BSI (ANC)
Ixora finlaysoniana Wallich ex G. Don	Rubiaceae	BSI (ANC)
Lasianthus andamanicus Hook.f.	Rubiaceae	BSI (ANC)
**Leucas deodikarii* Bill. & Hem.	Lamiaceae	BSI (WC)
Licuala peltata Roxb.	Arecaceae	BSI (EC, IBG)
Lilium mackliniae Sealy	Liliaceae	BSI (EC)
**Lilium neilgherrense* Wight	Liliaceae	BSI (SC)
**Liparis biloba* Wight	Orchidaceae	BSI (SC)
Liparis viridiflora Lindl.	Orchidaceae	BSI (NC)
Listera divaricata Panigrahi & Taylor	Orchidaceae	BG-ORD
Livistona jenkinsiana Griff.	Arecaceae	BSI (AFS, EC)
Lodoicea maldivica (Gmel.) Pers.	Arecaceae	BSI (IBG)
Luisia zeylanica Lindl.	Orchidaceae	BSI (NC)
Lycopodium clavatum L.	Lycopodiaceae	BSI (SC)

Name of the species	Family	Growing in Botanic Gardens
**Lycopodium phlegmaria* L.	Lycopodiaceae	BSI (SHC)
Macaranga denticulata (Blume) Muell.-Arg.	Euphorbiaceae	BSI (SHC)
Magnolia insignis Blume	Magnoliaceae	BSI (SC)
Magnolia pterocarpa Roxb.	Magnoliaceae	BSI (IBG)
Malaxis andamanica (K. & P.) Balak. & Vasud.	Orchidaceae	BSI (ANC)
Malaxis acuminata D. Don	Orchidaceae	BSI (NC)
**Mangifera andamanica* King	Anacardiaceae	BSI (ANC)
**Mangifera sylvatica* Roxb.	Anacardiaceae	BSI (EC)
**Nepenthes khasiana* Hook.f.	Nepenthaceae	BSI (EC, NC, SC), TBG
Nypa fruticans Wurmb.	Arecaceae	BSI (IBG)
Nervilia aragoana Gaud.	Orchidaceae	BSI (NC)
Nervilia gammieana Schltr.	Orchidaceae	BSI (NC)
Olax nana Wallich ex Benth.	Olacaceae	BSI (IBG)
Olea gamblei C.B. Clarke	Oleaceae	BSI (IBG)
Orophaea catschallica Kurz	Annonaceae	BSI (ANC)
**Osmunda claytoniana* (L.) Mart.	Osmundaceae	BSI (EC)
**Osmunda regalis* L.	Osmundaceae	BSI (NC, SC)
Pandanus andamanicus Kurz	Pandanaceae	BSI (ANC)
**Paphiopedilum druryi* (Bedd.) Stein	Orchidaceae	BSI (SC)
**Paphiopedilum fairieanum* (Lindl.) Pfitz.	Orchidaceae	BSI (EC, NC, SC), FRI, LBG
**Paphiopedilum hirsutissimum* (Lindl.) Pfitz.	Orchidaceae	BSI (EC, SC)
**Paphiopedilum insigne* (Wallich ex Lindl.) Stein.	Orchidaceae	BSI (EC, NC, SC), LBG
**Paphiopedilum venustum* (Lindl.) Pfitz. ex Stein	Orchidaceae	BSI (EC, IBG, NC, SC), LBG
**Paphiopedilum villosum* (Lindl.) Stein	Orchidaceae	BSI (EC, NC, SC), FRI, LBG
**Peucedanum dehradunensis* Babu	Apiaceae	BSI (NC)
**Phaius luridus* Thw.	Orchidaceae	BSI (SC)
**Phaius tankervilleae* (L'Herit) Blume	Orchidaceae	BSI (EC, NC, SC, WC), LBG
**Phalaenopsis decumbens* (Griff.) Holtt.	Orchidaceae	BSI (SC)
Phoenix paludosa Roxb.	Arecaceae	BSI (IBG), SBG

Name of the species	Family	Growing in Botanic Gardens
Phoenix rupicola T. Anders.	Arecaceae	BSI (IBG), LB
Phoenix sylvestris (L.) Roxb.	Arecaceae	BSI (IBG, NC)
Platycerium alcicorne Desv.	Polypodiaceae	BSI (IBG, NC)
Podocarpus elongata L. Herit ex Pers.	Podocarpaceae	GBG
**Podocarpus neriifolius* D. Don	Podocarpaceae	BSI (EC, NC, IBG) LBG
**Psilotum nudum* (L.) Beauv.	Psilotaceae	BSI (IBG, NC, SC)
Psychotria andamanica Hook.f.	Rubiaceae	BSI (ANC)
Psychotria platyneura Kurz	Rubiaceae	BSI (ANC)
Pterocarpus dalbergioides Roxb.	Fabaceae	BSI (ANC)
Pteroceras muriculatus (Reichb.f. J.J. Sm.	Orchidaceae	BSI (ANC)
Pteroceras suaveolens Holtt.	Orchidaceae	BSI (NC)
Pterygota alata (Roxb.) R. Br. var. *irregularis*	Sterculiaceae	BSI (IBG)
**Rauvolfia serpentina* Benth. ex Kurz	Apocynaceae	BSI (CC, IBG, NC, WC), NBRI
**Renanthera imschootiana* Rolfe	Orchidaceae	BSI (EC)
Rosa clinophylla Thory	Rosaceae	NBRI
Santalum album L.	Santalaceae	BSI (IBG, WC), NBRI, LB
Saussurea costus Lipsch.	Asteraceae	BSI (NC)
Schima wallichii Choisy	Ternstroe-miaceae	BSI (SHC), LBG
**Seshagiria sahyadrica* Ansari & Hem.	Asclepiadaceae	BSI (WC)
Smitinandia micrantha (Lindl.) Holtt.	Orchidaceae	BSI (NC)
**Sophora mollis* (Royle) Baker	Fabaceae	BSI (NC)
Syzygium andamanicum (King) Bala.	Myrtaceae	BSI (ANC)
Taxus wallichiana Zucc.	Taxaceae	BSI (NC)
**Taeniophyllum khasianum* Joseph et Yog.	Orchidaceae	BSI (EC)
**Tetrastigma canarense* (Dalz.) Gamble	Vitaceae	BSI (WC)
Thunia alba Reichb.f.	Orchidaceae	BSI (NC)
Trachycarpus takil Becc.	Arecaceae	BSI (NC) GG
Uvaria andamanica King	Annonaceae	BSI (ANC)
Vanda cristata Lindl.	Orchidaceae	BSI (NC)
**Vanda coerulea* Griff.	Orchidaceae	BSI (EC), FRI
**Vanda parishii* Veitch. & Reichb.f.	Orchidaceae	BSI (EC)

Name of the species	Family	Growing in Botanic Gardens
Vanda roxburghii R. Br.	Orchidaceae	BSI (EC,IBG)
Vanilla andamanica Rolfe	Orchidaceae	BSI (ANC)
Vanilla planifolia Dyer	Orchidaceae	BSI (IBG), NBRI
**Vanilla wightiana* Lindl. ex Hook.f.	Orchidaceae	BSI (SC, WC), TBG
**Vernonia shevaroyensis* Gamble	Asteraceae	BSI (SC)
Victoria amazonica (Poepp.) Sow.	Euryalaceae	BSI (IBG), TBG
Victoria cruziana Orbign.	Euryalaceae	BSI (IBG)
Wagatea spicata Dalz.	Caesalpiniaceae	BSI (IBG)
**Wallichia densiflora* Mart.	Arecaceae	BSI (IBG, NC)
Zamia floridana DC.	Cycadaceae	NBRI
Zamia furfuracea Ait.	Cycadaceae	NBRI
Zamia latifolia Lodd.	Cycadaceae	BSI (IBG)
Zeuxine andamanica K. & P.	Orchidaceae	BSI (ANC)

*Suggested immediate conservation. BSI : Botanical Survey of India; AFS : Arunachal Field Station, Itanagar; ANC : Andaman & Nicobar Circle, Port Blair; CC : Central Circle, Allahabad; EC : Eastern Circle, Shillong; IBG : Indian Botanic Garden, Howrah; NC : Northern Circle, Dehra Dun and Pauri; SC : Southern Circle, Yercaud; SHC : Sikkim Himalayan Circle, Gangtok; WC : Western Circle, Pune; BG-ORD : Botanic Garden, Orchid Research and Development Centre, Tipi; FRI : Forest Research Institute and Colleges, Dehra Dun; GBG : Government Botanic Garden, Udhagmandalam; JNBG : Jawaharlal Nehru Botanic Garden, Rumtek; LB : Lalbagh Gardens, Bangalore; LBG : Lloyd Botanic Garden, Darjeeling; NBRI : National Botanical Research Institute, Lucknow; SBG : State Botanical Garden, Barang; TBG : Tropical Botanic Garden and Research Institute, Thiruvananthpuram.

Conclusion :

India has a fairly good number of Botanic Gardens and parks in relation to maintenance, and protection of the plant resources. Teaching of plant sciences in the universities and colleges is also presently oriented in such a way that requires establishment and maintenance of Botanic Gardens. These local gardens will also enable to conserve a large number of local floristic elements, many of which may be rare, threatened or endangered. An overview of the status of Botanic Gardens in the country reveals that there are several areas covering distinct phytogeographical regions which have no Botanic Gardens. This lacuna is suggested to be overcome by establishing a network of Botanic Gardens for conservation of natural vegetation by bringing large acreage of land under each of these Botanic Gardens. Assistance and subsistence requires to be extended to all concern for the conservation and preservation of the country's flora, the endemics in particular, and also the potential exotics as per proposed recommendations of the Botanic Gardens Conservation Secretariat of the International Union for Conservation of Nature and Natural Resources (IUCN).

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Plate 17. *Sophora mollis* (Royle) Baker (BSI, NC, Dehra Dun)

Plate 18. *Itea nutans* Royle (BSI, NC, Dehra Dun)

Plate 19. *Rauvolfia serpentina* (L.) Benth. ex Kurz
(BSI, NC, Dehra Dun)

Plate 20. *Eremostachys superba* Royle ex Benth. (BSI, NC, Dehra Dun)

Plate 21. Lady's slipper orchids (clockwise from top left) : *Paphiopedilum fairieanum* (Lindl.) Stein, *Paphiopedilum spicerianum* (Reichb. f.) Pfitz, *Paphiopedilum druryi* (Bedd.) Stein, *Paphiopedilum venustum* (Sims.) Pfitz, *Paphiopedilum insigne* (Wallich ex Lindl.) Pfitz., *Paphiopedilum villosum* (Lindl.) Stein (BSI, EC, Shillong; NC, Dehra Duṅ; SC, Coimbatore)

Plate 22. *Phaius tankervilleae* (Banks ex L'Herit) Blume
(BSI, NC, Dehra Dun)

Plate 23. *Taxus wallichiana* Zucc. (inset : a branch with Arils)
(BSI, NC, Dehra Dun)

Plate 24. *Trachycarpus takil* Becc. (BSI, NC, Dehra Dun)

Plate 25. *Wallichia densiflora* Mart. (BSI, NC, Dehra Dun)

Plate 26. *Psilotum nudum* (L.) P. Beauv. (BSI, NC, Dehra Dun)